LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
School of Engineering Science
Master's Degree Program in Chemical & Process Engineering

Muhammad Al Jubury

Improve the production capacity: A case study of Eurofins Viljavuuspalvelu Oy

Examiners: Professor Mika Sillanpää
Kalevi Koivunen

Supervisors: Ano Halonen
D.Sc. Eveliina Repo
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ABSTRACT

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Improve the production capacity: A case study of Eurofins Viljavuuspalvelu Oy
Master’s thesis
2016
81 pages, 20 figures, 22 tables and 3 appendices

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Keywords: Capacity, Bottleneck analysis, OEE, JIT production, Six Big Losses.

In any manufacturing system, there are many factors that are affecting and limiting the capacity of the entire system. This thesis addressed a study on how to improve the production capacity in a Finnish company (Viljavuuspalvelu Oy) through different methods like bottleneck analysis, Overall Equipment Effectiveness (OEE), and Just in Time production.
Four analyzing methods have been studied in order to detect the bottleneck machine in Viljavuuspalvelu Oy. The results shows that the bottleneck machine in the industrial area that constraint the production is the grinding machine while the bottleneck machine in the laboratory section is the photometry machine. In addition, the Overall Equipment Effectiveness (OEE) of the entire system of the studied case was calculated and it has been found that the OEE of the Viljavuuspalvelu Oy is 35.75%. Moreover, two methods on how to increase the OEE were studied and it was shown that either the total output of the company should be 1254 samples/shift in order to have an OEE around 85% which is considered as a world class or the Ideal run rate should be 1.45 pieces/minute. In addition, some realistic methods are applied based on the finding in this thesis to increase the OEE factor in the company and in one realistic method the % OEE has increase to 62.59%. Finally, an explanation on how to implement the Just in Time production in Viljavuuspalvelu Oy has been studied.

Acknowledgement

First and above all, I praise God, the almighty for providing me this opportunity and granting me the capability to proceed successfully. This thesis appears in its current form due to the assistance and guidance of several people. I would therefore like to offer my sincere thanks to all of them.

I would like to express my deepest gratitude to my advisor, Mr. Kalevi Koivunen, the manager of Eurofins Viljavuuspalvelu Oy for his continuous support, patience, motivation, and for giving me the opportunity to work in the company.

Besides my advisor, I would like to thank the rest of my thesis committee: Dr. Eveliina Repo, Mr. Kai Bastuck, Mr. Ano Halonen, and Professor Mika Sillanpää for their time, efforts, comments, encouragements and guidances during the thesis work.

I am extremely grateful to my parents for their love, prayers, caring and sacrifices for educating and preparing me for my future. I am also very much thankful to Dr. Raghda, my wife, for her love, supports, and for being always there cheering me up and stood by me through the good times and bad.

Last, but not least, I would like to thank my friends Rahul Ashok and Ezeanowi Nnaemeka for their supports, advices, and for being always by my side. Also I would like to express my deep thanks to my friend and class mate, Mohammadamin Esmaeili, who act like a problem solver for me and for helping me a lot in this work.

Abbreviation

EC: Electric conductivity

EDTA: Ethylene diamine tetra acetic acid

EOX: Extractable Organic Halogens

HPLC: High-performance liquid chromatography

ICP-AES: Inductively coupled plasma atomic emission spectroscopy

ICP-MS: Inductively coupled plasma mass spectrometry

JIT: Just in Time

LC-MS: Liquid chromatography–mass spectrometry

LVI-GC-MS: Large Volume Injection-Gas Chromatography-Mass Spectrometry

OEE: Overall Equipment Effectiveness

PAH: Polynuclear Aromatic Hydrocarbons

TMC: Theoretical Maximum Capacity

TPH: Total Petroleum Hydrocarbons

TPM: Total Preventive Maintenance

VT (viljavuustutkimus): Soil fertility analysis

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Introduction

A highly successful plant manager once said that one of the secrets to great manufacturing is to do simple things exceptionally well. In other words - great results can come from mastering a simple technique and applying it consistently. (Asefeso, 2014).

In order to remain competitive, many companies need to maintain their production capacity to meet their customers' need. So to make sure that the production is healthy and the expected capacity is met, some lean production methodologies such as bottleneck analysis to detect the constraint machine in the production chain, the Overall Equipment Effectiveness (OEE) to measure the effectiveness of a machine or process line, and/or the Just in Time production to keep the inventory levels low by only producing what is needed when its needed need to be applied in companies.

In general, the manufacturing industry consist of equipment and machinery that are combined together in order to convert the raw-materials and sub-assemblies into products which they are either final products or a products that are used in the next manufacturing process (Hansen, 2002).

This thesis studied the identification and management of the bottleneck machine as it is very crucial for any organization. The bottleneck analysis can help to find the weakest point in the production chain in order to increase the production capacity.

Moreover, the businesses are usually investing a significant amount of their capital to have a system that can produce a product uniformly at high rate with less waste. So every company should have a projections about the effectiveness of the proposed system and how well it will contribute to the bottom line (Hansen, 2002). Here the measuring of the Overall Equipment Effectiveness is becoming important.

Finally, this thesis discusses on how to implement the Just in Time production in the company. The JIT philosophy in the manufacturing context includes having the right items of the right quality and quantity in the right place and the right time (Javadian et al., 2013). In JIT manufacturing, the Pull parts through production is used based on customers' need instead of pushing parts through production based on projected or forecasting demand. The main goal of JIT is to reduce costs by saving money which is spent on the inventory items or products.

This thesis consist of two main parts, the literature review part which explain and define general things about the three main topics, Bottleneck analysis, Overall Equipment Effectiveness, and Just in Time production. It also includes some parts as a general information that are needed by the company later for further studies and improvements.

The second part includes the experimental section which is done in the Eurofins Viljavuuspalvelu Oy in Mikkeli/Finland. The Experimental part involves the Bottleneck analysis of the machines, the OEE of the whole company and some methods to increase the OEE in the company, and an idea to implement the JIT production in the company.

The main Objective of this thesis is to find the Bottleneck machine in the Viljavuuspalvelu Oy and to improve the production capacity by increasing the % OEE of the company. Also a bottleneck management was given for each analysis method. In addition, the OEE of this company was calculated in order to increase the production capacity and reach the nearest OEE of the world class by applying some methods. Finally, the Just in Time production's concepts was also studied in order to implement it by the company.

Literature review

In this part the general information that are used in order to obtain the right results for this thesis are explained. The literature review discusses the capacity in the first chapter as it is the main topic of this work and the goal is to increase the capacity of the company. The capacity planning based on long and short term has been explained. Moreover, some methods on how to increase the capacity has also been discussed.

Furthermore, the Overall Equipment Effectiveness is explained in chapter 2 as it is a method on how to increase the capacity in the company by calculating the percentage of OEE. In addition, the Total Effective Equipment Performance (TEEP) is explained in this part but it is not used in the experimental part as it is not part of the calculation at this time but it might be used later by the company.

The main chapter in this review is the analyzing of the Bottleneck machine which is demonstrated in chapter 3 by explaining its types and its analyzing methods.

Finally, the Just in Time production is expounded in chapter 4 in order to be implemented properly by the company by explaining its objectives, concepts, and the method of pull system which is the main goal of JIT.

1 Capacity

1.1 General overview

Capacity is defined as the measurements of the industrial capability of supplying the required goods and/or services to the customers in the exact quantity and time that agreed between the company and the customers. It is also known as the maximum rate of production. (Vonderembse and White, 1996).

In operations management, the capacity is defined as the highest level of value-added activity through a fixed time in which the system can accomplish over the normal operating states (Slack and Chambers, 2007).

Sometimes the capacity rates inside the industry varies from one machine to another. At some points the capacity of one machine reaches its peak and in others working below the planned capacity, these machines are known as constraints or bottleneck machines which will affect the whole production of the industry. For this reason, it is important in any company to make sure that they have enough capacity and pre-planned capacity decisions to cover the limited in some machines and meet the present and future demands of their customers (Slack and Chambers, 2007).

1.2 Capacity planning

It is crucial for companies to implement capacity planning in their operations management if they want to meet the goals of production and to be able to provide their customers the demands they need at the proper time.

The capacity planning might be the only factor in the system to be responsible of achieving the planned profit if it is applied well in the company. While if the company do not pay so much attention to capacity planning, a series of problems can be seen especially over the growth or the starting period (Sernola, 2011).

So, capacity planning is one type of measurement for the organizations to forecast how much products are needed at time manner, thus they can produce more products or new products depending on the market demands without any negative effects on the company by following the planned production. However, some factors can affect the capacity such as the number of employees and the ability of them, number of equipment and machines, defect orders, errors, wastes, suppliers, government regulations, and preventive maintenance (Referenceforbusiness.com, 2015).

Moreover, the planning capacity decisions can be divided into two main categories, the long term and short term capacity planning:

1.2.1 Long term capacity planning

The long term is a plan for more than one year and the decisions of it are set for increasing or reducing the capacity. Therefore, it is implemented for the reason of changing the forecasted demand (Sernola, 2011). In addition, the long term decisions are found to increase the capacity which includes investing capital in new machines and equipment, build additional plant space and other new facilities. The long term is important for the success of the business in the future time (Slack and Chambers, 2007).

1.2.2 Short term capacity planning

The short term is a plan for one month or even less and planning related to issues for daily or weekly scheduling such as work shifts and balancing resource capacities (Sernola, 2011). The objective of this term is to manage the unexpected shifts in demand in a sophisticated economical way. Moreover, the best and most famous way to increase the capacity with this term is by working overtime which is considered as flexible and cheap way for increasing the capacity. Other methods that help to increase the capacity in short term include, adding shifts, part time jobs, the method of using floating employees, hiring employees, the subcontracting method, and by improving the uses of resources (Referenceforbusiness.com, 2015).

The importance of capacity decisions for long and short term or for future and present time can be seen when a lot of money is invested in different projects and enterprises and maybe more many need to be maintained and changed in those facilities, thus the capacity decisions are needed to manage those issues and increase the profit not only by concentrating on reducing the production costs.

So for a better decisions, the enterprises and facilities should be flexible to allow the managers to:

a. Alter the production size to meet the customer requirements.
b. Use the product mix to produce various products with same machines to meet the changing in customer needs through the time.
c. Ease of changing in product and process technologies to increase the competence with other companies and increase the ability of maintenance (Vonderembse and White, 1996).

1.3 Methods for Increasing Capacity

Generally no equipment or machines will work at or near to its full capacity. However, there are some techniques to increase the capacity of the industries. The reason of increasing capacity is to meet the customer needs when they increase their demands or meet the expected demands of the customers in the future. Moreover, the capacity increasing can be a short or long term plan or immediate or future increases. The immediate capacity increasing can be achieved by using the current machines and equipment for longer time such as adding shifts or overtime, or by using outsources equipment. While the future capacity increase can be done by improving the efficiency of the current machines or by spending more money on buying new machines and equipment.

In addition, there are two categories of unused potential in the industry that can constrain the capacity and make a capacity loss, the first one called the equipment losses where some equipment are working at less than highest potential and it can be measured through the overall equipment effectiveness OEE, the second one is called the schedule losses where the equipment is not scheduled at all and it can be measured by Total Effective Equipment Performance TEEP (Vorne.com, 2015). The OEE and TEEP are explained in the next chapter.

2 Overall Equipment Effectiveness

In an ideal industry, machines and equipment can work at 100% of the time with full capacity giving 100 percent good quality, but as it was said earlier, this situation is difficult in real life. So the importance of OEE here will appear as it can calculate the losses in equipment and processes.

The OEE is a metric that integrates the manufacturing issues with the data points to give a clear information about the process (Vorne.com, 2015). In other words, the OEE gives a percentage of planned production time which is really productive.

The percentage indicators of the OEE results are as follows:

- OEE = 100% is perfect production.
- OEE = approximately 85% is excellent for discrete industrialists.
- OEE = approximately 60% is fairly good for discrete industrialists.
- OEE = around 40% is not good to the manufacturers if it is without a program of total productive maintenance or lean programs (Leanproduction.com, 2013).

There are three elements for overall equipment effectiveness, calculating and finding them are crucial for the calculation of OEE, these elements are:

- Availability rate: it is defined as a time at which the equipment are really running divided by the time that the equipment should run. If the result is low, then there are downtime losses. (Makigami.info, 2015)

$$\text{Availability rate} = \frac{(\text{Operating time} - \text{Downtime})}{\text{Total operating time}} \quad (1)$$

- Performance rate: Is the real amount of products produced during the running time of the equipment over the potential amount of products to be produced, given the designed speed of the machines. The low results give speed losses. (Makigami.info, 2015)

$$\text{Performance rate} = \frac{\text{Total output}}{\text{Potential output at rated speed}} \quad (2)$$

- Quality rate: is the number of good products divided by total number of products being produced. If the result is low, then there should be a defect loss in the system (Makigami.info, 2015).

$$\text{Quality rate} = \frac{\text{Good output}}{\text{Total output}} \quad (3)$$

When the elements of OEE are known, then the calculation of OEE can be done by the equation: (Makigami.info, 2015)

$$\text{OEE } \% = (\text{Availability rate} * \text{Performance rate} * \text{Quality rate}) \quad (4)$$

2.1 Total effective equipment performance (TEEP)

The TEEP is a metric that calculates the total equipment effectiveness proportional to calendar time (24/7 time or 365/year). The results of TEEP can be used to guess the potential capacity of the existent industry and also it can show how the equipment is utilized.

While the OEE ignore the planned downtime, the TEEP concentrate on the important activities which may include equipment shutdown, planned maintenance pauses, development of new products, meeting and training for crew needs, shift schedules, and strategies for manufacturing (Hansen, 2002).

The difference between OEE and TEEP is that the OEE measures the effectiveness based on scheduled hours and the TEEP measures the effectiveness versus the calendar hours (capstone metrics, 2011).

The TEEP can be calculated according to the following equation: (capstone metrics, 2011).

$$\mathrm{TEEP} = \mathrm{Loading} * \mathrm{OEE} \tag{5}$$

Loading is stand for the percentage of total calendar time which is truly scheduled for operation. The loading can be calculated from the following equation (capstone metrics, 2011):

$$Loading = Scheduled\ time * Calendar\ time \tag{6}$$

2.2 Increase the capacity by improving the manufacturing productivity

There are many ways that transact with equipment losses in order to increase the capacity and one of those methods is the six big losses where the TEEP and OEE goals is to reduce these losses which are the reason of losing the effectiveness of the equipment and thus decreasing the capacity of the industry (Oee.com, 2012).

The six big losses are related to the calculation of OEE and it can be divided into three major groups, the downtime which happened when there are low results in availability calculation, speed losses when there are low results in performance calculation, and defect losses happened when quality results are low (Makigami.info, 2015). See figure 9.

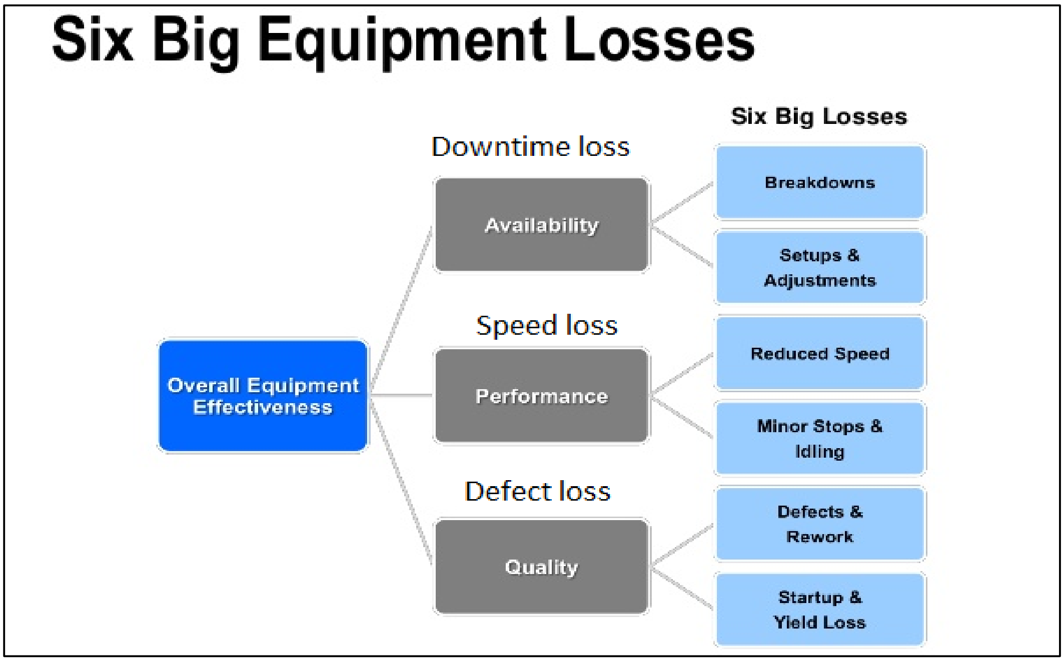

Figure 1. The six big losses (Slideshare.net, 2011).

The six big losses are:

1. Setups and Adjustments

It belongs to the downtime loss category and it affects the availability of OEE. It usually measures the time between the last good product produced before starting the setup time and the first good product produced after the setup time. It often includes the adjustment and warm up time in order to produce acceptable quality of products with the desired standards (Oee.com, 2012). The machines need a setup and adjustment because when there is a need in changing one broken part of the machine then the whole machine should be shut-down in order to replace the non-working parts and after that the machine needs to be steeped and adjusted again (Makigami.info, 2015).

2. Breakdowns

It also belongs to the downtime category and it affects the availability of OEE. The breakdowns indicate the time that the machine should work on it but for some reasons it has stopped working. The downtime includes two types, the equipment failure and other type of stops like setup time (Makigami.info, 2015).

Moreover, to improve the OEE, the downtime should be eliminated or reduced. The downtime is very critical because no OEE factors can be addressed with a downtime industry (Oee.com, 2012).

3. Reduced Speed

It is part of speed loss category and it affects the performance of OEE. The reduced speed operations show the difference between the actual speed and the designed speed of the machine. In other words, there are differences between what people expect from the machine's speed when it is designed and what the current speed in the current operation is. The goal here is to reduce the differences between the actual speed and the designed speed (Makigami.info, 2015).

4. Small Stops

The small stops may occur for only 5 minutes and they do not require a big maintenance work. Their impact may appear on the performance of OEE and thus the speed loss occurred (Leanproduction.com, 2013).

In addition, the small stops will make unstable speed in the system and affect the smoothly flow of the materials. The small stops can be called 'idling' considering as a small failure not a technical problem (Makigami.info, 2015), such as sensor and delivery blocked, minor adjustment, component jam, and cleaning of the machine (Leanproduction.com, 2013).

5. Production Rejects

It affects the quality of OEE and belongs to defect loss group. In normal production there are some items or products that do not meet the quality standards so it will be rejected even if the products can be reworked. The rejects can occur during the steady state production. The main goal here is to make zero defects in the production (Makigami.info, 2015).

6. Startup Reject

The rejects here are during the early production such as the warm-up or set up production and have an influence on the quality of OEE (Leanproduction.com, 2013).

The startup losses are occurred at the immediate time when the machines start to work and in some cases the first products do not meet some quality standards (Makigami.info, 2015).

2.3 Estimating Capacity

The most important thing in capacity estimation is to find out the yardstick to measure the capacity, for example tons/hour of steel in industry or beds can be used in hospitals as a yardstick to estimate the capacity. If we take the hospital as an example, we can figure out its capacity of receiving patients per year. Let's assume that there are 100 beds in the hospital that are available for 365 days/year, by multiplying number of beds and time period we can get 36500 patient-days/year.

Technically, the patients will not consume all beds all over the year, so by calculating the operation ratio which it is the capacity consumed divided by the capacity available we can get a percentage of how many beds will be consumed over a year.

$$Operating\ ratio = \frac{\text{capacity consumed}}{\text{apacity available}} * 100 \qquad (7)$$

If we assume the capacity consumed in previous example is 24000 patient-days so the operating ratio will be 65.8 %.

When the yardstick for capacity measurement is found the estimating capacity become easier by adopting the following steps:

- Determining the equipment's maximum rate/hour of the production
- Then find out the number of hours worked in a certain time period
- And finally multiply the previous steps.

$$\frac{Capacity}{period} = m\text{ax production rate/h} * \text{number of hours worked/time period} \qquad (8)$$

The production rate can be calculated according to the following equation:

$$\text{Production rate} = \frac{\text{Number of units produced}}{\text{Amount of time}} \qquad (9)$$

From equation (8) we can see that the capacity can be changed by altering both the number of hours worked per time period and by altering the production rate.

The number of hours worked per certain time is influenced by some factors such as working overtimes, different shifts, downtime and stopping time, preventive maintenance, and equipment failures (Vonderembse and White, 1996).

In addition, some management decisions can also affect the capacity. Those decisions are for example:

i. Adding people

If any operation is constrained by the amount of employees assigned then the production rate can be increased by adding people to manage the operation of the industry (Vonderembse and White, 1996). Also the capacity of service operations and manufacturing operations can be adjusted through adding or reducing employees. In addition, by using part time shifts, the employees can fill the places of unskilled labor demands and save more money for the business (Kachru, 2007).

The technique of adding people is to reduce the time required per shift and thus increase the capacity. For example: if a shift finish 25 products in 4 hours and that shift is working for 8 hours then the number of products that the shift will finish in their shift time will be 50 products/shift according to equation 10:

$$\text{Number of products per shift } = \frac{\text{Number of items}}{\text{time spent}} * \text{length of the shift} \qquad (10)$$

So by adding people the time to finish same products will be less, for example 3.5 hours and the shift can finish more products during the same period of time per shift, according to the following calculation:

$$\text{Capacity } = \text{ (25 products/3.5 hours) } * \text{ 8h/shift } = 57.14$$

So now we can calculate the percentage of capacity increase by using the next equation for the previous examples

$$\text{Capacity increase} = \frac{(\text{new capacity } - \text{ old capacity})}{\text{old capacity}} * 100 \qquad (11)$$

So the capacity increase is 14.28 % which is the increase in capacity by adding people to the industry (Vonderembse and White, 1996).

ii. Increase the motivation of workers

Another way to increase the production rate is by increasing the motivations of workers in a systems that have labor constraints. Managers can increase the productivities by giving more responsibilities to the workers and make them feel they are more important to the company. This technique will not cost the company extra money like investing in new machines or adding more people where the company have to pay them (Vonderembse and White, 1996).

iii. Increase the production rate of the machine

In some cases adding people or increase the motivation will not have a noticeable effect on capacity when the machine is a bottleneck because if the machine is working at full speed on the period time and the capacity is not on the required level as for example there are some idle time then it will affect the whole production rate of the system and adding people will not be a solution in this case. The solution here is either to buy a new machine with better properties or to increase the efficiency of the current machine.

Another way for increasing the machine's production rate is by increasing the preventive maintenance so the downtime of the machines can be eliminated or reduced and thus increasing the efficiency of the machine (Vonderembse and White, 1996).

iv. Improve the quality

The quality of products is important to increase the capacity and all managers should take more responsibility on this field. When quality is improved, less product will be rejected and the waste time to replace the rejected products will be reduced. Moreover, the image of the company will be affected negatively if the quality of products is poor (Vonderembse and White, 1996).

v. Increase the product yield

Another important step that the managers should take a decision on to increase the capacity is to calculate and improve the product yield. The product yield can be calculated by dividing the quantity of output over quantity of input.

It is important for any business to increase the quantity of output to increase both the sales and the effective capacity (Vonderembse and White, 1996).

2.4 The Product and Process Layout

2.4.1 The product layout and system capacity

The product layouts are considered as the best conductive to repetitive processing, and they use demands for the same or similar products. This kind of layout uses standardized processing operations to reach the goal of smooth and fast flow of large numbers of goods and customers throughout the system.

The product layout has advantages of high product rate with low unit and material handling cost. Also it has high utilization of work and machines. While on the other hand, it has boring and repetitive actions, the quality of product is poor because of small attention to the maintenance part, and it might also have some shutdowns (Mcu.edu.tw, 2015).

Therefore, the capacity of product layout can be illustrated as a series of pipes of different capacities. The pipe that has the smallest diameter or capacity will be responsible of and direct the whole system, see Figure 2.

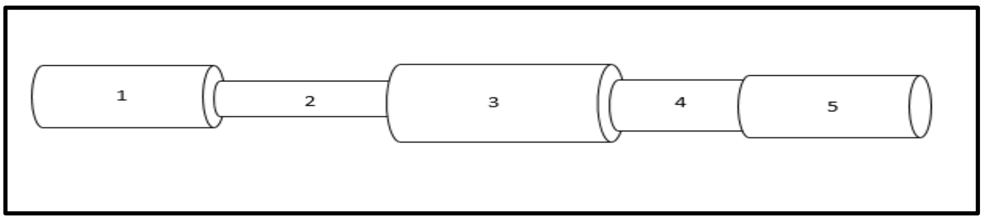

Figure 2. The Pipes represent the machine's capacities and the small diameter pipe will be a bottleneck and affect the system's capacity (Vonderembse and White, 1996).

The output of one pipe in the previous figure is the input of the next pipe and it is a series of in-and-output materials till the final products. In addition, the pipe number two has the smallest diameter which means it has the smallest capacity and it cannot process all materials that come from pipe or machine 1 and thus the system's capacity will be based and determined by pipe or machine 2 and this machine is a bottleneck (Vonderembse and White, 1996).

2.4.2 The process layout and system capacity

The process layout is considered as a multiple-product facility with a feature of low volume per product. Unlike the product layout, the products of it are different with each other and it uses different methods and procedures in the production (Vonderembse and White, 1996).

The advantages of process layout start from the ability of it to deal with different processing requirements, it has low rate of failure equipment and low maintenance cost.

The disadvantages of it include minimum equipment utilization, repeated routing and scheduling, the material handling is slow and inefficient, and the cost of material handling is high (Mcu.edu.tw, 2015).

The process layout is utilized with product that has different production requirements and different demands on the equipment. Also in this layout each product does not follow the same route over the system and the machines that produce same products are grouped together in the same department (Vonderembse and White, 1996).

2.5 Assembly lines

The assembly line is a manufacturing process where its interchangeable parts are combined with a product in a consecutive method to reach the final product. In many industries, the assembly lines are semi-automated systems where the product can move. The employees and equipment which are taking place in the production are constant along the line and the products are moving from start of manufacturing to the end of product (Inc.com, 2015).

In addition, assembly lines are usually used in mass production of products as they can reduce the labor costs by employing workers with a few-or-without skills by training them on some certain tasks instead of employing high skilled employees where they cost the company more money. By using the assembly line in manufacturing, the company can hire a worker to add certain part to the product such as adding a leg to a chair instead of hiring one person that do all the parts of building a chair (Radcliffe, 2014).

2.5.1 Objectives of assembly lines

Generally, there are two main objectives in laying out the assembly lines processes. One of them is to reduce the material handling costs by positioning the line for a continuous flow of assembled products such as reducing the distance travel between stations or reduce the material movements between stations.

The other objective is to balance the assembly line by assigned equal amount of work in each work station. If this objective is not applied then a workstation that has small amount of work which in other words will do its work faster will wait until the slow station completes its work which will be known as a bottleneck station. So the imbalanced line will reduce the capacity and increase the costs (Vonderembse and White, 1996).

Some factors are important related to assembly lines such as:

- The cycle time

It is known as the time required to produce a unit or the time needed by a machine to finish one task and repeat it which is measured in minutes/pieces or second/pieces (Vonderembse and White, 1996).

Every series job in the system should have a cycle time equal or less than the cycle time of the whole system (Netmba.com, 2010).

- The Idle time

The idle time is a phenomena that is happening when one workstation or a machine has no work to do as it is waiting for a work to come from the upstream machine (Netmba.com, 2010). The idle time is the time that the company is paying for without receiving an output or product. In general, the idle time of the system is the sum of all idle times of each machine. (Vonderembse and White, 1996).

3 Bottleneck

The bottleneck is phenomena which occurs in a machine and leads to affect the system output causing delaying or blocking in a certain machine and thereby affecting the whole process by slowing it down or stopping it (Koenig, 1994).

The bottleneck can happen in a certain machine when the input in that machine comes faster than the machine can handle and the output of this machine is becoming less. An example of the bottleneck is shown in Figure 3.

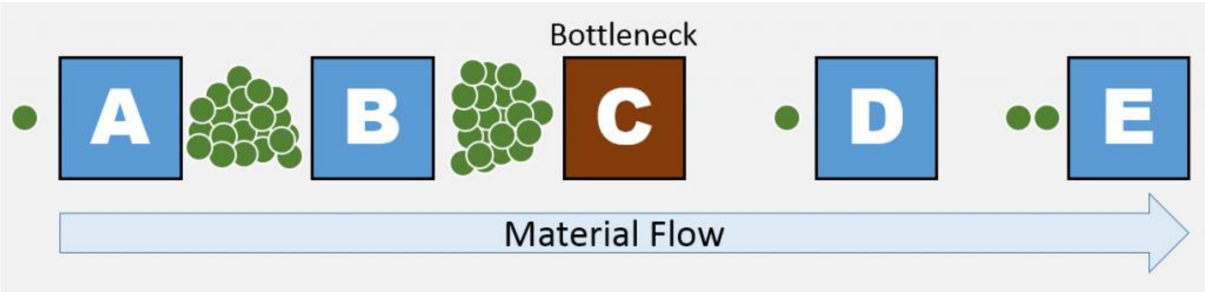

Figure 3. Example of the bottleneck in a line production (Roser, 2013).

The previous figure shows that the material are flowing from machine A to B normally, but the input to machine C is higher than its output and because of that the output of the whole industry will be less than what it should be. In this case the machine C is a bottleneck machine (Investopedia, 2006).

3.1 Types of Bottlenecks

Bottlenecks can be classified into two types: short term bottlenecks or momentary which can be defined as machines that prevent the system from performing well for a short period of time. The momentary type itself can be divided into three parts: the first one is called sole bottleneck machine and in this case the bottleneck is a single and separate in the process at any time. The second one is called shifting momentary bottleneck as the bottleneck is shifting between the machines. While the third part is called a multiple bottlenecks and this exist when the system has more than one bottleneck machine and those bottleneck machines are appeared simultaneously in the system.

The other type of bottleneck is called long term bottlenecks. This term is occurred in a system when the bottleneck machines are affecting the system for long period of time. Also the long term bottleneck machine is affecting the other machines in the system process (Tamilselvan, 2007).

3.2 Bottleneck analysis

Bottleneck is the major reason that affect the production outputs and causes slowing down in a system. For that reason the bottleneck should be detected and identified in the system, analyzed, and resolved (Timilsina, 2012).

Basically, when the bottleneck is appearing in a system, it will have the following characteristics (Koenig, 1994):

- Materials and samples will be in long queue in a machine waiting to be processed
- The output of the industry will be much less than what it was predicted in a certain period of time.
- Some of the machines will be working at their maximum capacities.
- Succeeding machines will be underutilized.

By finding the bottleneck correctly, the industry can minimize the production cost and thus increase the efficiency of the system (Timilsina, 2012).

The approach to determine the bottleneck is explained in the next diagram.

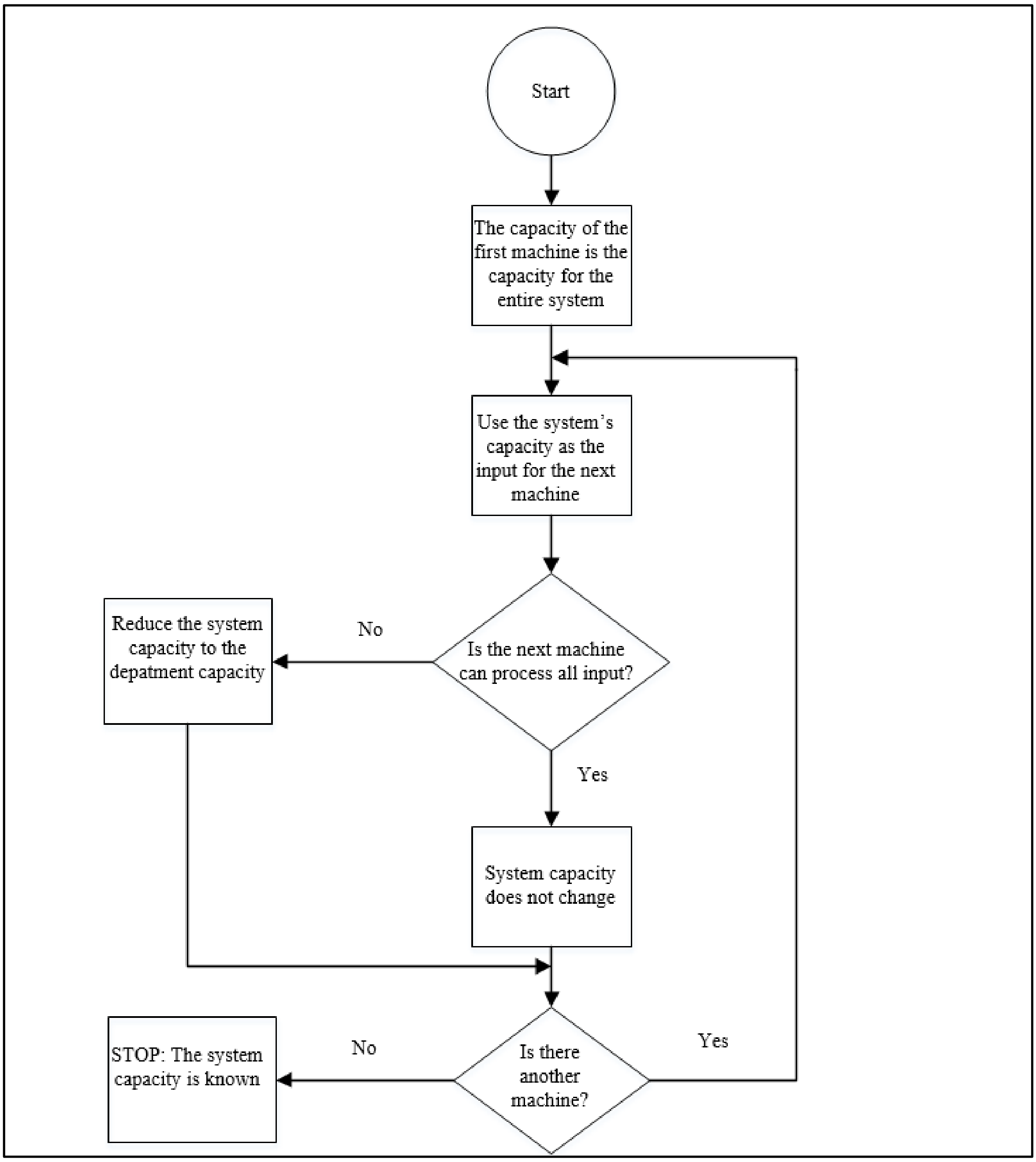

Figure 4. Approach to determine the bottleneck (Vonderembse and White, 1996).

The approach in the previous diagram is set to figure out the capacity of the first machine which is considered as the capacity of the whole system and it is also the input to the next machine. The next step is to find whether the next machine can process all the input from the previous machine or not. If it can, then the system capacity is not changed. If not, then the capacity is reduced to the capacity of the same machine. This method is continued until the end process is accomplished and the system capacity is known (Vonderembse and White, 1996).

There are numerous methods such as, Utilization method, queue length method or cycle time, Shifting Bottleneck Detection Method, active duration method, Theory of constraints, and five way Principle to find and identify the bottleneck in a system (Tamilselvan, 2007).
However, the problem in finding the bottleneck in any system is that the system is not static but alter over time. The reason for that is random events such as failure or temporary delaying in one machine and in that case the machine is considered as a first type bottleneck and it is just for a short period of time. Also, the system might have more than one bottleneck machine.
Another reason of variation or altering in a system is because of long term type of bottleneck and it is for a long period of time, as for example new products are inserted to the system or changing in the load of one machine. Also adding and replacing machines can cause a variation in a system (Roser et al., 2003).

3.3 Some methods to find and identify the bottleneck

Several bottleneck methods that are needed in this thesis are explained below.

3.3.1 Utilization method

In this method the percentage of active time of a machine is utilized (Roser et al., 2003). The machine with largest active percentage is considered as a bottleneck machine (Tamilselvan, 2007). Roser et al. (2003) gave example of this method by calculating the working and repairing percentage time of different machines and by adding them to give the active time. The machine with highest active percentage time is a bottleneck machine (Roser et al., 2003). The utilization method is not so efficient for the analysis of the first type of bottleneck or the short term type as the bottleneck is measured after the production run is completed (Tamilselvan, 2007).

3.3.2 The queue length method

The waiting time or the queue length is another method to identify the bottleneck in a system. Here the bottleneck is defined according to the queue length of the products in front of the machine. It is either determined by the longest queue or longest waiting time (Roser et al., 2003).

This method requires unlimited buffer capacity because the bottleneck identification of products is hard with limited queue capacity. Also to avoid on and on filled queues capacity of an industry the system have to override the supply in the long run (Roser et al., 2003).
To identify the bottleneck, the machine with largest continuous active time is a bottleneck machine (Tamilselvan, 2007).

3.3.3 Shifting Bottleneck Detection Method

This method is similar to the utilization method as it also measures whether the machine is active or not, but unlike the utilization method, it identifies the bottleneck in a system by measuring the active time without interruptions. Hence the meaning of 'Active' is the working time, breakdown periods, tool changes, etc. (Roser et al., 2003).
Sometimes the active periods are interrupted by the inactive periods. Here the machine should wait for the perfecting of the process by other machine such as a blocking or starving of a machine (Roser et al., 2003).
The idea of this method is at any given time, the longest active period of a machine will be considered as bottleneck machine and this machine will affect the whole system.
The shifting bottleneck is happening when the active period of one bottleneck interfere with the active period of the next bottleneck, while the sole bottleneck will not interfere with the next or previous bottleneck (Roser et al., 2003). An example to explain this case is shown in Figure 5.

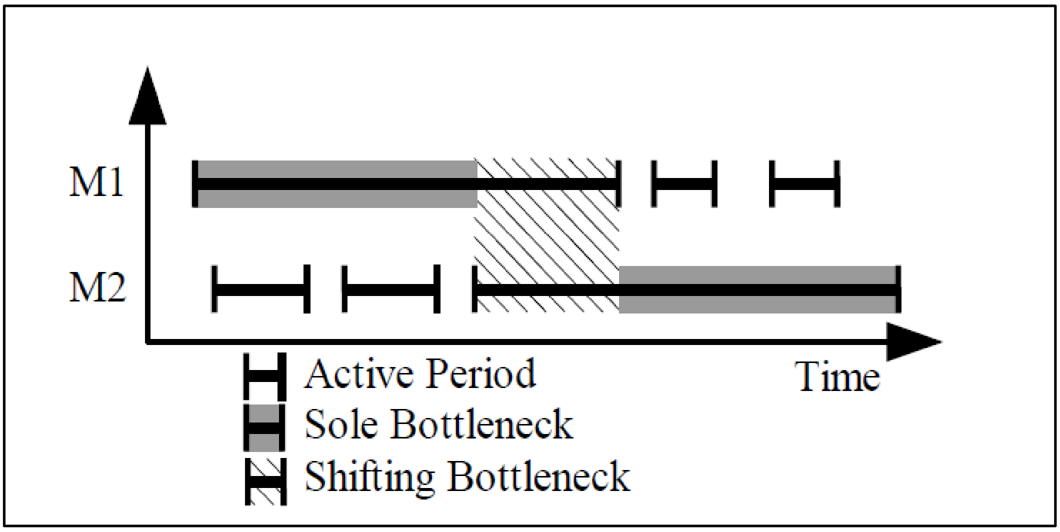

Figure 5. Bottleneck shifting (Roser et al., 2003).

Figure 5 shows two machines M1 and M2. The longest active period is shown in machine M1 which is the bottleneck machine. After that the bottleneck will be shifted from M1 to M2 where M2 is a sole bottleneck machine (Roser et al., 2003).

3.3.4 Theory of constraints TOC

TOC is a multifaceted management philosophy which appeared and was developed in the 1980s by Eliyahu M. Goldratt. The TOC is a management paradigm that allows us to think differently about policies, goals, procedures and objectives that we set for our business. (Mabin and Balderstone, 2000).

Generally, in every process there is at least one constraint and this constraint is considered a limiting factor in the process and it may lead to prevention of achieving the goals and profitability of whole business. It is often referred to the constraint as a bottleneck in manufacturing world.

The most effective way to improve the profitability is by identifying the constraint and try to focus on how to improve it. Thus, the Theory of constraints is used for the purpose of improving the throughput and the profit of the industry which is why it is important in any business (Leanproduction.com, 2013).

In a simple words, in any production industry there is a series of chains from inputs of raw materials to the output of products and the constraint or the bottleneck is the weakest point in that chains and the purpose of the TOC is to identify the weak chain or the bottleneck and make it stronger to the point where it will not be the limiting factor in the industry (Pegels and Watrous, 2005).

Dr. Eliyahu Goldratt sets tools through which the industry can achieve its goals. Those tools are:

- The Five Focusing Steps: it is mainly about identifying and eliminating the bottleneck
- The Thinking Processes: it is focusing on analyzing and resolving problems
- Throughput Accounting: it is a tool for the purpose of measuring performance and set decisions for guiding the management (Leanproduction.com, 2013).

3.3.4.1 The benefits of using TOC

By implementing the TOC in a successful way the company can get many benefits such as: increasing the throughput of the company; reduce the inventories which will eliminate the bottleneck and make less work-in-process; and reduce the lead time which lead to better sales and higher profits and makes good quality products which in turn lead to satisfy the customers and meet their needs (Mabin and Balderstone, 2000).

3.3.4.2 Tools of Theory of Constraints

The TOC is trying to give accurate and sustained focus on how to make the existing bottleneck better until there is no constraints that limits the throughput. Usually the bottleneck is moving to the next step after its being improved on one step.

The TOC strength appears by showing an ability to create a very robust focus to a single target or the profit and to eliminate the main obstruction or bottleneck to achieve that goal (Leanproduction.com, 2013).

The tools of TOC are:

- **The Five Focusing Steps**

In general, the five focusing steps are the main tools of TOC as their identify the bottleneck in the process, take the full advantage of it, and make the rest of the process subordinating to the flow which run out over the bottleneck. After the process flow becomes smoother, the bottleneck capacity is supposed to be improved and then the process is repeating the steps to ensure continuous improvement in the system process (Stefanova, 2014). The five focusing steps are shown in figure 6.

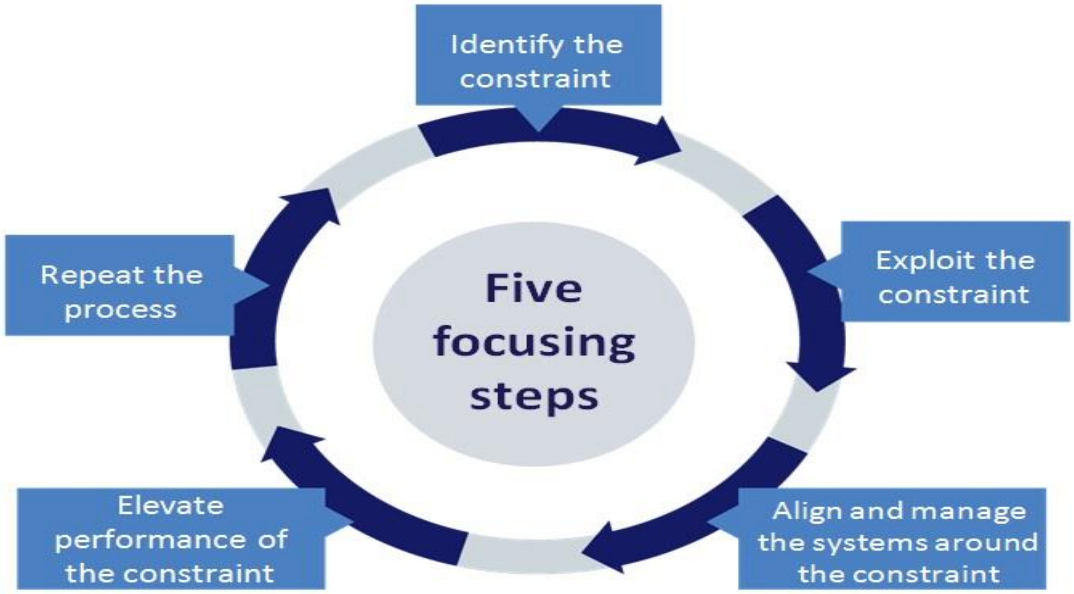

Figure 6. The five focusing steps of theory of constraints to identify and eliminate the bottleneck (Stefanova, 2014).

The objectives of each step are:

- Identify the Constraint: This is the main step and it starts by searching for the weakest link in the chain that limits the rate of the throughput
- Exploit the bottlenecks: using the maximum capacity of the bottleneck machine. This is done by removing the idle time such as removing the lunch breaks and reducing the cycle time of the machines (Stefanova, 2014).
- Align and manage the systems around the constraint: Check all other activities in the system to make sure that they are ranged with the bottleneck and support the requirements of it (Leanproduction.com, 2013).
- Elevate performance of the constraint: If the bottleneck is not moving then the thinking for more and different actions are required to eliminate the bottleneck.
- Repeat the process: The process is repeating itself until the bottleneck is found in order to find a new bottleneck in different stage (Leanproduction.com, 2013).

- **The Thinking Processes**

It is a set of important logical thinking and exchanging of information processes for identifying the wrong assumptions and connecting regional or short term optimum rules which limit the industry from superior protecting, exploiting or elevating the process bottleneck and for improving and validation the new complete system rules which makes better protection, exploitation and/or elevation of the bottleneck process (Goldrattresearchlabs.com, 2013).

Furthermore, The Thinking Processes are utilized for the purpose of answering the following questions, which are considered as fundamental and substantial to TOC:

- What must be changed?
- What should it be changed to?
- What actions will cause the change? (Leanproduction.com, 2013).

The thinking processes contain the following tools:

- Current Reality Tree: It is a diagram for documenting the present state.
- Evaporating Cloud Tree: It is a diagram that estimate the potential improvements. It is also useful for resolving struggle between different accesses to solve a problem. Moreover, this tool is used for progressing from the Current Reality Tree to the Future Reality Tree.
- Future Reality Tree: It is a diagram for documenting presenting the future state.
- Strategy and Tactics Tree: This tool is providing an action plan for improvement and achieving the future state (Leanproduction.com, 2013).

- **Throughput Accounting**

It is an accounting methodology that measures the situation and reasons of the financial performance of the whole system and control the impact of the local actions and/or thoughts that affect the performance of the system (Goldrattresearchlabs.com, 2013).

This tool is for the purpose of removing the harmful malformations that entered to the system from some practices like traditional accounting practices, and by removing those malformations so that the system can reach the goal of increasing the profit in the long term (Leanproduction.com, 2013).

This accounting is achieved through merging the insights on the effect of current and future actions that will take place on the bottleneck system with the quantitative effect in the throughput of the system, operating expenses and the investment (Goldrattresearchlabs.com, 2013).

Usually, the decisions of the industry is based on the influence on gaining over the next improvement:

- Will Throughput be increased?
- Will Investment be decreased?
- Will Operating Expenses be decreased?

In order to increase the profit, the TOC idea is to concentrate more on the throughput and make a fewer concentration on the investment and Operating Expenses or what is known as the cutting expenses (Leanproduction.com, 2013).

The Idea of TOC about increasing the profit is shown in Figure 7.

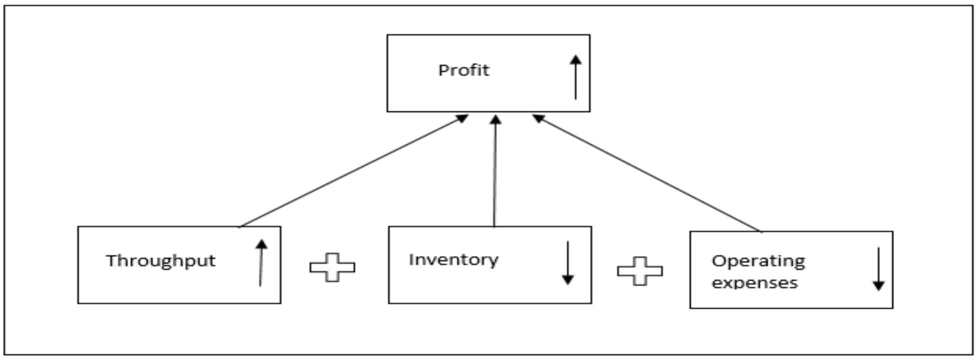

Figure 7. Relationships between Profit, Throughput, inventory and operating expenses (Vonderembse and White, 1996).

According to TOC, to reach the target of profit, the throughput should be increased and operating expenses and inventory should be decreased.

3.3.4.3 Drum-Buffer-Rope

It is one part of the TOC planning and scheduling operations solution, and the three elements (Drum, buffer rope) are important for TOC. The Drum-Buffer-Rope is defined as a production application of theory of constraints which synchronize the production to the constraint while decreasing the inventory and work in process (Leanproduction.com, 2013).

- The Drum

The drum is responsible for determining the rate of production and that rate agree with the master production schedule. As in TOC, the constraints are used to improve the schedule, and in that case the constraint is the drum and it will determine the rate of other operations and corresponding with its own (Vonderembse and White, 1996).

- The buffer

The buffer is founded mainly to protect the drum resources from interruptions and fluctuations that occurs in the system and make sure that the system will not be affected by the upstream of the system (Woeppel, 2008).

Buffers is the amount of time, generally measured in hours, and used to make sure that the stable operation of the process is reached by letting the work-in-process arriving and storing before the next step is using it. Moreover, the size of the buffer is based on the variation of the system and the more variation the more buffer is required.

The buffer is divided into two parts:

- ➢ Constraint Buffer: It is set directly before the constraint and it is used to protect the constraint and;
- ➢ Customer Buffer: it lays at the end of the process to protect the delivery schedule (Leanproduction.com, 2013).

- The Rope

The rope is a method that create a signal by the constraint and send it to the non-bottleneck processes to alarm the process about the slowing down, stopping or the flow of the material should be faster in the process to make sure that the throughput is well-maintained. This process is known as “Pull Scheduling” (Shmula, 2006).

4 Just In time production

4.1 Introduction

Just in time method is a philosophy more than a technique that was firstly used by Toyota (the Japanese cars manufacturer) in the early of 1950s for the purpose of reducing waste and improving the quality of products (Sernola, 2011).

After the Japanese company made a tangible successes by using this method, many companies applied it in their processes in order to make stockless production and to reach almost zero inventories which helps the company to invest and concentrate more on new equipment or developing the production lines (Vonderembse and White, 1996).

The idea of just in time in production is to make what is needed at the immediate time when it is needed, or in other words, the company produces based on the customers requirement not based on a forecast production. This mean the reducing in wastes, waiting time, excess inventory and unreasonable requirements which leads to maximize efficiency and improving the productivity in many parts of the company including engineering, marketing, quality control and also strengthen the relationship between suppliers and customers (Toyota-global.com, 2015).

4.1.1 The objective of JIT

JIT attempts to make the materials flow smoothly between the suppliers and the customers and trying to increase the time speed of the manufacturing process. The main objective of JIT is to change the manufacturing system step by step to reach the following achievements:

- To be more reactive with customers
- To increase the communication skills between its departments and suppliers
- To be more flexible for an unpredictable changes
- To improve the quality
- To decrease the production cost to a minimum level. (Mo Yeh, 2003)
- To reach zero concepts in queues, defects, inventories, breakdown, etc.
- To reduce the setup time as much as possible.

Once the JIT is implemented in a system, some indicators such as improvement in the inventory control system, quality system will be improved, can improve the maintenance system, improvement in the productivity and setup time can be achieved (Ikegwuonu, 2013).

4.1.2 Concepts of JIT

- Eliminating waste

  One of the main principles of JIT is the elimination of the wastes. There are several types of wastes which can appear in any production industries such as overproduction waste, waste of waiting time, waste caused by transportation, motion waste, processing waste, inventory waste and waste from product defects. In addition, those wastes can fill up the storages for unnecessary materials and will result extra maintenance costs and can cause some damages to materials and/or equipment. Moreover, elimination of wastes can help the industry in many aspects as for example eliminate idling work in plant, material wastage and resources wasting (Ríos-Mercado and Ríos-Solís, 2012).

- Flow manufacturing

  This concept is for providing the production a smooth and continuous flow of materials without interrupting or stopping in any part of the production. This principle is very important since the idea of JIT is to make what is needed at the time when it is needed, so any delaying or interrupting in any part of the system will affect the whole system resulting delay in the throughput (Ríos-Mercado and Ríos-Solís, 2012).

- The quality control

  The quality of products is really important in any system and it makes sure that the final products will reach to the customer with the highest requirements. Also it affects the flow work of the industry. For instance, if one part of the product is defective then it will not assemble with other parts of product and the company that use JIT production will face a problem like stopping the whole process in order to wait for another part and continuing the assembles of product.

  Inspecting and checking of products and equipment will result a continuous production process without delaying in deliveries of products to customers (Vonderembse and White, 1996).

- Continuous improvement

  However, it is difficult for the companies to reach the goal of eliminating all the wastes even if they have adopted JIT for many years. But in fact, the companies will continue improving by the time through reducing wastes, being able to produce smooth and continuous flow of materials and improve the efficiency (Vonderembse and White, 1996).

Moreover, one philosophy of JIT is to use same process to produce different products rather than producing same products over and over, so the JIT can be considered as unending series of short, controlled steps (Mo Yeh, 2003).

- Simplified Production process

  Simplifying the production is leading to the philosophy of JIT as the products and equipment should be designed in a way that makes it simple to manufacture, setup, and repair.

  If the setup time for one machine in the process takes long time then the company should implement the JIT and the solution can be achieved by buying more multipurpose machines that can change the non-working machine easily or by simplifying the setup time of the machine in some way. Actually, some companies that use JIT have reduced the setup time by one simple machine for each part rather than using one complex machine that do all the parts (Vonderembse and White, 1996).

- Total preventive maintenance

  Another problem can be seen in companies that use JIT system is the machines breakdown. To eliminate this problem, the machines should first be lubricated and maintained continuously and then the company should implement the total preventive maintenance (TPM). The TPM includes three major components:

1. Emphasis on the preventive maintenance itself. This is done through continuous checking of the state of each machine and maintain and inspect them frequently.
2. Set some time each day for the purpose of maintenance. To reduce the breakdowns of machines to minimum level, the companies should activate a shift inside their companies for the purpose of maintaining the machines each day.
3. Operator liability for maintenance. Trained operators can take the responsibility of maintaining the machines instead of assigning it to a maintenance department (Vonderembse and White, 1996).

4.2 The JIT pull system

In fact, many production systems are using push system in their processes. The push system can be defined as a material getting pushed to the process system based on a schedule (Vonderembse and White, 1996). So the company will produce the products based on the customer's requirement and based on that, the company forecast what to produce and in what amount (Ikegwuonu, 2013).

But the push system, like any other system, has its advantages and disadvantages. The main advantage of the push system is that it can deal well with the oscillating and Rocky demands but it requires a lot of inventory which itself has other problems like the inventory cost.
On the other hand, the JIT system is using the reverse technique of push system which is called the Pull System to move parts and materials. The pull system moves materials to the work stations when one work station sends a signal that there is a need for some materials in the downstream of the process (Vonderembse and White, 1996), see figure 8.

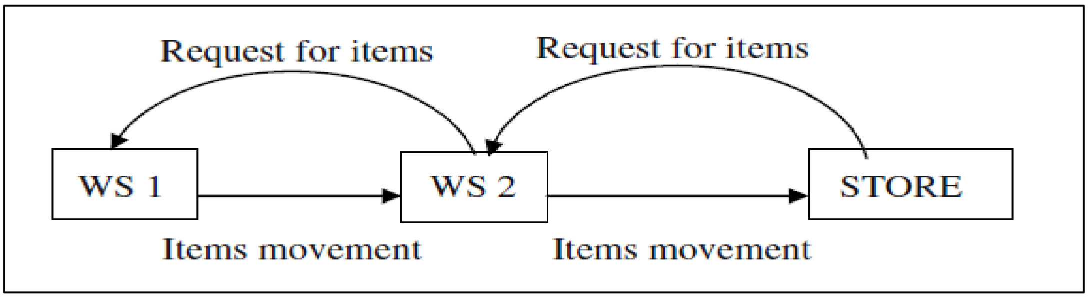

Figure 8. The pull system diagram showing the process of the work with two workstations and store (Sendil Kumar and Panneerselvam, 2006).

4.2.1 Methods to pull the materials

The inventory accumulation between the workstations will not be seen if the process is using the Pull system as the customers will be the last workstation and they will pull the products from the industry and the industry pull the materials from the suppliers (Mo Yeh, 2003). The next figure shows the differences between Push and JIT pull system.

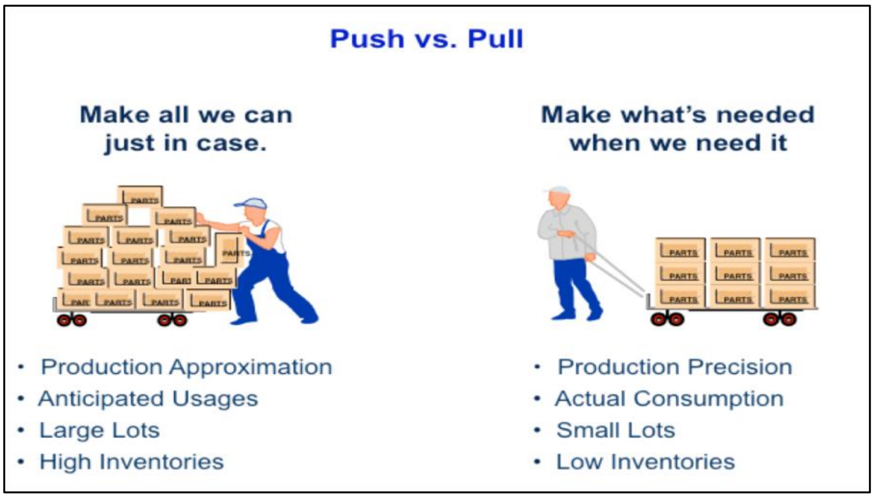

Figure 9. Comparing the pull and push systems. (Sibaja, 2014).

The pull system requires small inventories and produce what is needed when it is needed and it is based on the customers demand while push system is based on a predication and forecasting. Generally there are many methods that the pull systems is sending the signal and pull the material from the upstream workstation (Vonderembse and White, 1996). Those methods are:

- Level scheduling: it is known as heijunka in Japanese and it points out to the leveling production by volume and variety. This method helps to keep the constant flow of materials through the production. This method can deal with the changes in orders by good scheduling and planning.
- Small-lot production: The purpose of this method is to make small-lot production on steady basis so the constant flow can be achieved.
- Quick changeover technique: This method is used to reduce the machine's setup time. Also it can help to deal with the changing in environment in short period of time such as changes in production methods and demands (ReVelle, 2002).
- Kanban Systems: Is a method founded and developed by the Toyota car manufacturers based on cards. It refers to two words in Japanese (con-bon) which means a sign or marker and in manufacturing concepts it refers to a card that sends a signal for the purpose of needing more materials or parts at downstream station (Vonderembse and White, 1996).

The Kanban method is more than one stage scheduling and inventory control system. The Kanban cards are used in the system for controlling the inventory and production flow and they make the high production volume and high capacity utilization in any industry better by reducing production time and work in process (Sendil Kumar and Panneerselvam, 2006). As the idea JIT is to produce one unit at a time, it is sometimes difficult as the travel time between the supplier and the industry is long or there will be some imbalances between workstations. So the movement of containers of parts are needed and the Kanban is the best choice for movement. Generally, there are two types of Kanban cards, the Withdrawal (Conveyance) Kanban and the production Kanban (Vonderembse and White, 1996).

The Kanban is a tool that manage the JIT production and make the process more efficient, so there are some rules that should be applied in any manufacturing process to achieve the better production. Those rules are:

- The faulty products should not be sent to the next process.
- The customers or the next process will withdraw materials at the time and amount needed. To make sure that this step is not based on random choice or arbitrary, some rules should be

applied such as no Kanban means no withdrawal, withdrawn materials equals to submitted Kanban, and the Kanban should always go with the withdrawn materials

- The upstream produces the exact amount required by the downstream process
- Appropriate facilities and staff should be available in order to make an exact products in time and amount needed
- Kanban is able to reply to the need of fine-tuning and unexpected order cannot be handle by the Kanban system
- The system should be stable and rational otherwise the defective work will affect the system quality (Irwin, 1997).

4.3 Types of Kanban

I. Withdrawal (Conveyance) Kanban

It is an authorization to move a container of materials from on stage to another. The mechanism of this method is happening by filling the materials to the container from the previous process and move the container to the next one with the filled materials until all of the materials is being consumed. Then the empty container is going back to the previous stage to be filled again (Beyondlean.com, 2015). See Figure 10.

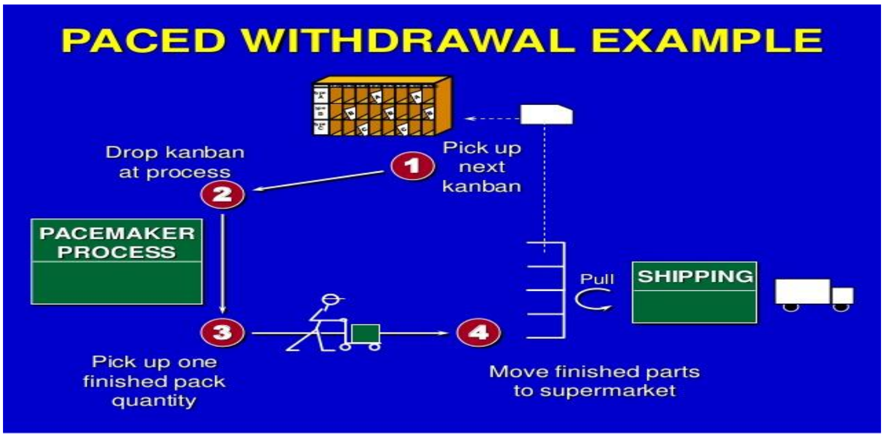

Figure 10. The circulation process of Withdrawal Kanban (Martinez, 2014).

To activate the withdrawal Kanban process, the following principles must be noted:

- The containers that filled with materials cannot be moved if the Kanban card is not attached.
- Only standard containers should be used.
- The standard containers should be filled with standard number of units (Vonderembse and White, 1996).

II. Production Kanban

Is utilized for the purpose of authorization of parts or subassemblies in the previous stages to make the lot size specified on the card and it sends signals in order to make more parts when needed (Beyondlean.com, 2015).

The production Kanban send a signal when the parts or materials is consumed and make a new production to replace the consumed parts

The mechanism of the Production Kanban is as follows:

- The Kanban card is placed on the product, or waiting to be located at the production site.
- When there is no Kanban in front of the machines, it means that there is no request for production
- When there are Kanban in front of the machines, it means there is order for the production so the wanted amount should be prepared.
- The Kanban is linked to the manufactured product once it's produced
- Finally when the product is pulled from the final stage of the production by customers for example, the production card is taken away and it goes back to the first process (Mdcegypt.com, 2014).The next figure shows the two types of Kanban cards.

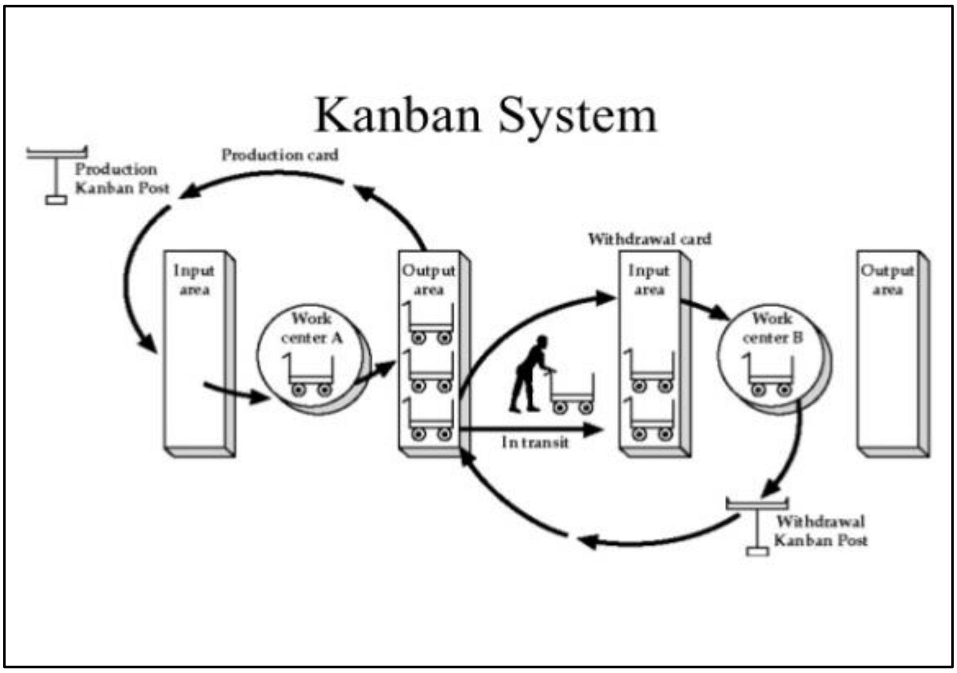

Figure 11. The schematic process of production and withdrawal Kanban cards (Patel, 2014).

Experimental Part

5 Introduction

The experimental part of this thesis was done in Eurofins Viljavuuspalvelu Oy in Mikkeli/Finland. The experimental part consist of three parts, identifying the bottleneck machine, Overall Equipment effectiveness and the Just in Time production.

The first part is focused on identifying the bottleneck machine in the company based on four different analyzing methods and a recommendation or a management on how to improve the capacity or how to eliminate and reduce the bottleneck machine was also given.

The Overall Equipment effectiveness (OEE) of the company was measured based on observation and calculation data and the idea on how to increase the %OEE of the company was also explained based on some calculations by Microsoft Excel 2013.

In addition, a realistic case was done to observe the effectiveness of the bottleneck machine on the industry.

Finally, the last part of the experiment is about the implementation of Just in Time production in the company and how the company can achieve it.

5.1 Eurofins Environmental testing laboratories

5.1.1 Eurofins Scientific

Eurofins is an international group of laboratories headquartered in Luxembourg. The company is providing testing and support services to pharmaceutical, food, environmental and consumer products industries and also to governments. Their services comprise testing of water, air, soil, waste and other products to assess their quality and impact on health and the environment. As a result of that the Eurofins is becoming the world's leading in laboratory analysis services and it operates in over 200 laboratories in 38 countries and their staff is around 20 000 employees and the company had about 1.4 billion € annual revenues in 2014 (Eurofins.com, 2015).

In addition, the Eurofins Group offers a portfolio of more than 100 000 reliable analytical methods for describing the safety, identity, purity, composition, authenticity and origin of products and biological substances. The Group draws on the latest developments in the field of biotechnology and analytical sciences through research and development, in-licensing and acquisitions.

Moreover, Eurofins is one of the global market leaders in agro science, genomics, discovery pharmacology, and laboratory services and it plays a key emerging in specialty clinical diagnostic testing in Europe and the USA (Eurofins.com, 2015).

5.1.2 Viljavuuspalvelu Oy in Mikkeli

Eurofins Viljavuuspalvelu Oy is a part of Eurofins Scientific Group and it was founded in 1952 in Mikkeli/Finland by Agriculture and Environmental laboratory sector. Their business cover the production from the beginning of the whole food chain as well as the environmental management and also providing supervision for analytical services (Viljavuuspalvelu.fi, 2015).

Eurofins Viljavuuspalvelu Oy operations are certified by (SFS-EN ISO 9001: 2008) in accordance with the quality management system and all the main assay methods for laboratory and the sensory soil type configuration are certified by the accredited ISO 17025 (Viljavuuspalvelu.fi, 2015).

In addition, the quality control, the national and international monitoring, and the comparative studies are connected together to ensure the reliability of results obtained by the soil testing (Viljavuuspalvelu.fi, 2015).

5.1.3 Soil Testing in Viljavuuspalvelu Oy

For soil investigation and soil remediation projects, the testing of environmentally relevant parameters on soil and groundwater is very important to the company. Eurofins performs testing on routine parameters like nutrition (Ca, K, P, N,S) heavy metals, physical soil parameter like porosity size and soil type, TPH, PAH, EOX, aromatics, VOCs and pesticides, as well as non-standard parameters like glycols and phthalates using a wide range of modern techniques including ICP-AES, ICP-MS, (LVI)-GC/MS, HPLC and LC-MS. The pre-treatment and analytical methods that they currently use are fully complied with national and international legislation standards (Viljavuuspalvelu.fi, 2015).

6 Case study: Eurofins Viljavuuspalvelu Oy

The soil testing in Viljavuuspalvelu industry in Mikkeli starts with ordering samples from Finnish farmers who are willing to test and analyze their soils. In the ordering department, the packed soil samples are opened and the information of it is checked and entered to the system. Then the system will print out the labels and that takes 20 seconds/sample. After that the labels are stick down on the testing boxes before entering the industrial department and that takes 12 seconds/sample.

The industrial part starts with drying the ordered soil samples in a six different drying machines. Each machine can handle up to 462 samples and the drying time is 55 hours/machine. After that the samples are moving automatically through a conveyer belt to the grinding machine where the samples are grinded and sieved. From the grinder, at least two containers are filled with the samples and one goes for measuring the pH and electric conductivity of the sample and the other container with same type of sample goes to the next unit. The next station is extraction unit with only one machine and this machine has 18 lines and each line can process up to 30 samples at the same time. The samples that are coming from the grinder are divided into two parts, one is VT (in Finnish is viljavuustutkimus, or soil fertility analysis) which all customers require. The VT type include testing of pH, EC, soil type, organic matter, P, K, Mg, Na, and S. The other part is called EDTA (ethylene diamine tetra acetic acid) which half of the customers of the Viljavuuspalvelu Company require with the main type (VT). The EDTA sample type includes trace analyzing of trace elements such as Cu, Zn, Mn and Fe.

Before entering the extraction machine, the samples are filled with water. Moreover, the samples in each line in the extraction machine has to be processed or treated for one hour.

After that the samples are moving automatically to the filtering unit which includes two machines, each machine can handle up to 60 samples for every 15 minutes. One machine is set for processing the VT type and the other one is for EDTA samples. As it said earlier, half of the customers require EDTA and in that case one filtering machine is in standby half of the shift time as there are less EDTA samples required by the customers compared to VT. The filtered samples are placed in a rack and each rack has 60 test tubes, which are moved manually to the laboratory section.

In the laboratory station there are two units, the ICP unit (inductively coupled plasma) which includes two machines and each machine can handle up to 60 test tubes of samples or one rack for every 50 minutes. One ICP machine are set for the basic elements (Ca, K, Mg, Na, S) and the other one is for trace elements (Cu, Zn, Mn, Fe). In addition, all customers require the basic elements and half of them require the trace elements testing. The other unit includes the photometry machine and the purpose of this machine is to check the availability of phosphorus in the soil.

In the laboratory, each machine can process one rack at the same time except the photometry which has two channels and can handle two racks at the same time. Each rack has a 60 test tubes which is equal to 60 samples.

The next diagram explain in detail the production assembly line for Wilma soil testing in Viljavuuspalvelu Company.

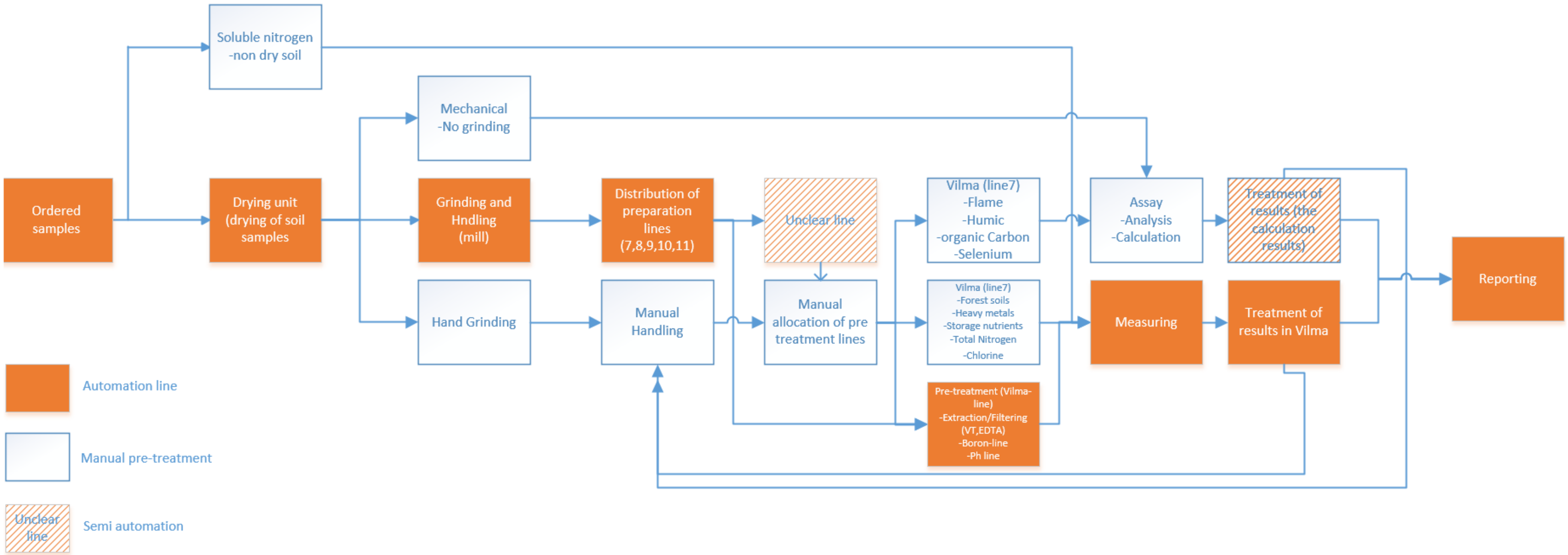

Figure 12. The production flow chart of Wilma soil in Viljavuuspalvelu Oy Mikkeli.

In the plant site, 90% of the samples are passing through the automation line, while the rest are going through the manual pretreatment. Generally, the ordering of the samples is an automation process and then samples go automatically to the drying units. After the drying, both manual and automation grinding occur. Then the samples are going to pretreatment zone before by passing through the measurement zone.

6.1 Ordering samples and Labeling

The first gate in the company starts with samples' ordering and registration department. This department is divided into two sections, the registration of the ordered samples section and the labeling section. In the sample registration section, the output capacity is based on the data given by the company and it is around 1350 samples/shift (shift length is eight hours), and the company use two operators in that section so the theoretical maximum capacity of the registration of the ordered samples is 2700 samples/shift and here the cycle time is about 20 second/sample.

For the labeling section there is one operator working on that section and the theoretical maximum capacity is 2250 samples/shift as the cycle time 12 second/pieces. For this department there was no observation or a real calculation as this thesis is focused on the industry and laboratory departments. Moreover, this department cannot be a bottleneck as the theoretical output capacity is high by comparing it to other units in table 1. So this unit will not be taken into account for any decision or further studying and calculations in this thesis.

6.2 Theoretical maximum capacity

The theoretical maximum capacity is the maximum output capability, without adjustments for preventive maintenance, unplanned downtime, shutdown, etc. (Demandsolutions.com, 2015). Table 1 shows the number of machines in each unit in Viljavuuspalvelu industry and the theoretical maximum capacity per 8 hours shift of each unit based on Table 14 in appendix I.

Table 1. Theoretical maximum capacity for each unit: Eurofins industry in Mikkeli/Finland.

Unit	Number of machines	Theoretical maximum capacity
Drying	6	403/shift 1210 samples/24 hours
Grinding	1	960 samples/shift
pH and Electric Conductivity	1	960 samples/shift
Extraction	1	4320 samples/shift
Filtering	2	2618 samples/shift
ICP	2	864 samples/shift
Photometry	1	768 samples/shift
Ordering and Registration	2 operators	2700 samples/shift
Labeling	1 operator	2250 samples/shift

In Viljavuuspalvelu Oy, the drying unit consists of 6 dryers with a total capacity of 403/shift and because the drying unit can work without operators for 24 hours/day so it is calculated per day (24 hours) and the capacity is 1210 samples/day as shown in Table 1, while the other units are measured per shift and the shift length is 8 hours. The filtering unit is composed of two machines one for VT samples and the other one for EDTA samples. Each filtering machine has a capacity of 1745 samples/shift, but in Viljavuuspalvelu half of their customers require EDTA testing, so the theoretical maximum output from filtering unit is 2618 samples/day (Full capacity of VT samples plus half capacity for EDTA samples).

The laboratory part includes two units, the ICP unit which includes two machines, one for the basic elements (Ca, K, Mg, Na, S) and the other one for trace elements (Cu, Zn, Mn, Fe) and the capacity for each machine is 576 samples /shift, and the total capacity is around 864 samples /shift as it is same like that of filtering unit (full capacity of basic elements analysis and half capacity for trace elements analysis).

The other unit in laboratory section includes the photometry machine which has two channels with a maximum capacity of 768 samples/shift.

Other units in Table 1 has only one machine. The calculation of the theoretical maximum capacity (TMC) is based on equation 12 and the average of Tables 2, 3, and 4.

$$TMC = \frac{shift/day * Hours/shift * 3600}{Cycle\ time\ in\ seconds} * pieces\ per\ cycle \qquad (12)$$

The maximum capacity of each unit in Eurofins Viljavuuspalvelu is shown in the next block diagram based on the results from Table 1.

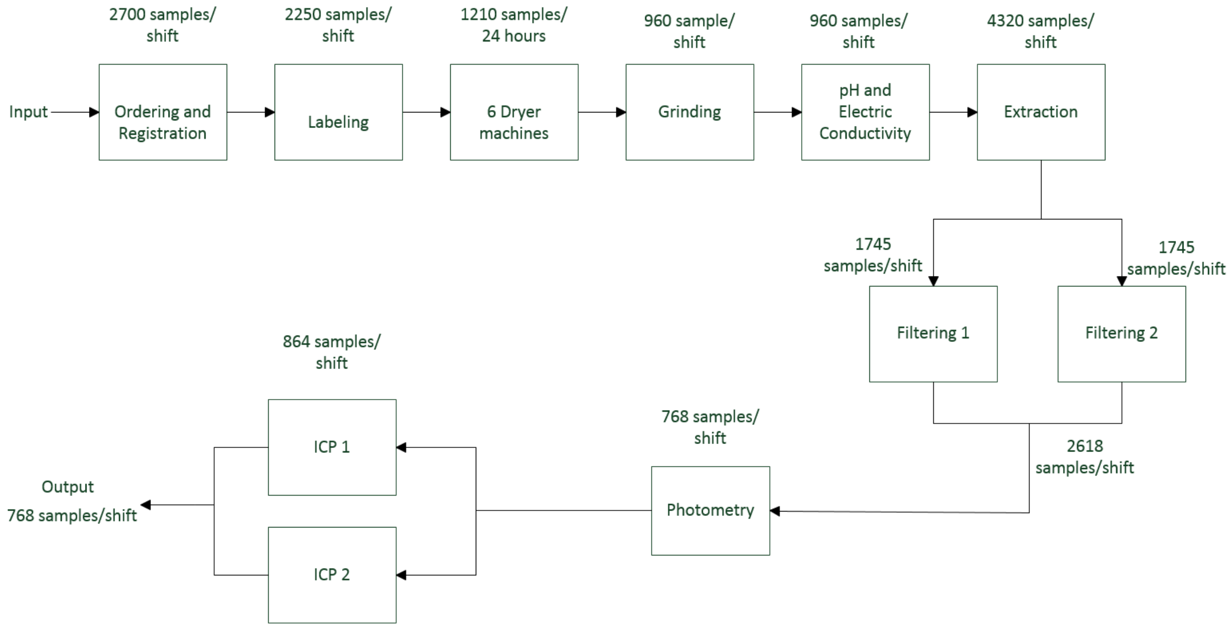

Figure 13 Block Diagram of maximum capacity in Viljavuuspalvelu Mikkeli.

It is shown in the previous diagram that the theoretical maximum output capacity of Eurofins Viljavuuspalvelu is 768 samples /shift because the photometry in the laboratory area has this amount as the maximum capacity and it is the last department before the products go to the customers.

7 Bottleneck analysis

The analyzing methods of the bottleneck machines were conducted based on the observation and data collection in Eurofins Viljavuuspalvelu in Mikkeli in 2015. The analyzing methods were carried out with four different methods. In general, the methods to detect the bottleneck are based on the tools of theory of constraint.

7.1 First analysis method

The first method that is used to detect the bottleneck is based on the maximum daily capacity of each machine which is calculated based on three different days of data collection in the industry during October 2015.

The comparison of maximum capacity and the performance of each machine is shown in Tables 2, 3, and 4.

Table 2. Data collection on 14.10.2015: Measurements of the capacities and machines performance in the Eurofins Viljavuuspalvelu, Mikkeli.

Process No	Process Name	Next Process	Shift/ day	Hours/ shift	Days/ week	Cycle Time (sec)	PCS/ Cycle	Daily Process Capacity	% Up Time	% Good	Process Capacity	Hours/ week	Maximum Daily Capacity
1	Drying	2	3	8	7	198000	2772	1210	0.98	0.9575	1135	165	1114
2	Grinding	2A	1	8	5	60	2	960	0.94	0.9575	864	40	864
2A	pH	3	1	8	5	60	2	960	0.96	0.9575	882	40	882
3	Extraction	4	1	8	5	3600	540	4320	0.9	0.9575	3723	40	3723
4	Filtering	5	1	8	5	990	90	2618	0.67	0.9575	1120	40	1680
5	ICP	6	1	8	5	3000	90	864	0.86	0.9575	711	40	711
6	Photometry	Customer	1	8	5	4500	120	768	0.93	0.9575	684	40	684

Table 3. Data collection on 20.10.2015: Measurements of the capacities and machines performance in the Eurofins Viljavuuspalvelu, Mikkeli.

Process No	Process Name	Next Process	Shift/ day	Hours/ shift	Days/ week	Cycle Time (sec)	PCS/ Cycle	Daily Process Capacity	% Up Time	% Good	Process Capacity	Hours/ week	Maximum Daily Capacity
1	Drying	2	3	8	7	198000	2772	1210	0.98	0.9575	1135	165	1114
2	Grinding	2A	1	8	5	60	2	960	0.93	0.9575	855	40	855
2A	pH	3	1	8	5	60	2	960	0.99	0.9575	910	40	910
3	Extraction	4	1	8	5	3600	540	4320	0.9	0.9575	3723	40	3723
4	Filtering	5	1	8	5	990	90	2618	0.56	0.9575	936	40	1404
5	ICP	6	1	8	5	3000	90	864	0.86	0.9575	711	40	711
6	Photometry	Customer	1	8	5	4500	120	768	0.93	0.9575	684	40	684

Table 4. Data collection on 27.10.2015: Measurements of the capacities and machines performance in the Eurofins Viljavuuspalvelu, Mikkeli.

Process No	Process Name	Next Process	Shift/ day	Hours/ shift	Days/ week	Cycle Time (sec)	PCS/ Cycle	Daily Process Capacity	% Up Time	% Good	Process Capacity	Hours/ week	Maximum Daily Capacity
1	Drying	2	3	8	7	198000	2772	1210	0.98	0.9575	1135	165	1114
2	Grinding	2A	1	8	5	60	2	960	0.96	0.9575	882	40	882
2A	pH	3	1	8	5	60	2	960	0.98	0.9575	901	40	901
3	Extraction	4	1	8	5	3600	540	4320	0.9	0.9575	3723	40	3723
4	Filtering	5	1	8	5	990	90	2618	0.47	0.9575	785	40	1178
5	ICP	6	1	8	5	3000	90	864	0.86	0.9575	711	40	711
6	Photometry	Customer	1	8	5	4500	120	768	0.60	0.9575	441	40	441

From the previous tables, the maximum daily capacity is per shift and the shift length is 8 hours except the drying unit which is per 24 hours. The cycle time and pieces per cycle of each machine has been shown based on the data collection from the industry. The daily process capacity is the maximum capacity that the machine can process without any breaks or stops and it is calculated based on equation 12. The percentage of up time is the time that the machine is working after reducing the idle time, stand by and setup time which are observed during the data collection from the industry. Also the percentage of up time is the percentage of production time vs. available time. The percentage of good products is 95.75% by assuming that the average rejected products is 4.25 % for each machine based on the annual report from the industry in 2014. So the previous tables are assuming that the company can achieve the maximum daily capacity based on the percentage of the up time and the percentage of good products (assuming that those percentages are same for the whole year). More calculations are shown in Appendix A.

From Tables 2, 3, and 4 it can be seen that the laboratory machines has the minimum amount of capacity and it is affecting the total output of the industry. In order to indicate the bottleneck, it is better to divide the manufacturing process into two parts, the industrial section and the laboratory section. The industrial part includes machines like drying, grinding, pH and electric conductivity, extraction, and filtration. While the laboratory area machines are ICP1, ICP2, and photometry. The next table shows the average of the maximum daily capacity based on Table 14 in Appendix A which is the average of Tables 2, 3, and 4 by taking into account that the shift length is 8 hours/day for each machine except the drying unit where its shift is set to be 165 hours/week as the cycle time of those machines is 55 hours.

Table 5. Average of the maximum daily capacity that the Company can achieve.

Section	Machines	Maximum daily capacity
Pre-industrial part	Ordering and Registration	2700 samples/shift
	Labeling	2250 Samples/shift
Industrial machines	Drying	1114 samples/24 hours shift
	Grinding	867 samples/shift
	pH and EC	898 samples/shift
	Extraction	3723 samples/shift
	Filtering	1421 samples/shift
Laboratory machines	ICP	711 samples/shift
	Photometry	603 samples/shift

From Table 5, the bottleneck machine in the industrial area is the grinding machine with a maximum capacity of 867 samples/shift. While in the laboratory area the bottleneck machine is the photometry machine with a maximum daily capacity of 603 samples/day.

The bottleneck is identified by considering the shift length, cycle time, pieces per cycle, the percentage of the up time after reducing the downtime time, the percentage of the good products by reducing the rejected from the total output products, and working hours per week for each machine.

7.1.1 Bottleneck management

During the data collection, it has been noticed that the grinding unit has the highest idle time between all machines, so it is good to maintain that unit and reduce the amount of stopping time. In addition, the grinding machine seems to be an old machine so it will be better to replace it with another one that has a better performance and higher capacity.

For the laboratory section, it is better to use the second machine ICP 2 (trace element machine) for the basic elements at the time when it does not have work to increase the total output capacity at that unit. Furthermore, it is good if the company has a second machine for the photometry in case of emergency when the main one does not work and hence the capacity will be maintained and kept at a high level.

Moreover, as there is big difference for the maximum daily capacity between the industrial and laboratory sections, it is important to add people and shifts in the laboratory area so maximum daily capacity can be symmetric between both sections.

In case of bottleneck shifting between machines, it is better to take the filtering unit into the consideration. So it will be good if some ideas are applied here. One idea is to make a buffering space for the samples between the extraction and filtering units so the next day the filtering unit will have always samples to process instead of waiting the output of the extraction machine as the cycle time of the extraction unit is high (one hour). Second idea is to set the second machine of filtering unit (EDTA) to handle same type of the first machine (VT) as only half of the customers require EDTA sample type, so in that case we can increase the capacity by half of what we have in the filtering unit. Another idea is to extend the shift length of the laboratory units in order to process all the samples that come from the industrial section and the balance between both units can be achieved.

7.2 Second analysis method

The second method for analyzing and finding the bottleneck in the system is to find the utilization or the active time of each machine. The active time is calculated by adding the working time of the machine with different types of stops that the machine has (idle, setup time, maintenance, etc.). The machine with the highest active time is a bottleneck machine.

Based on the data collection and a three hours observation in the industry, the active time of the machines is shown in Tables 6, 7, and 8. It is also important to notice that the ICP 2 machine for trace elements and filtering 2 for EDTA samples are machines that work based on customers' requirements and they will be in standby when there is no demand from the customers, so we exclude them because they will have very high number of standby and they will be bottleneck machines while in reality they will not affect the capacity of the industry.

Table 6. The active time of the machines (14.10.2015).

Parameters / Units	Drying	Grinding	pH	Extraction	Filtering 1	ICP 1 basic elements (Ca,K,Mg,Na,S)	Photometry
time of measurement/min	180.00	180.00	180.00	180.00	180.00	180.00	180.00
Measured capacity	462.00	302.00	302.00	480.00	360.00	240.00	420.00
Idle/min	0.00	10.00	7.00	6.83	0.00	0.00	0.00
Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00
standby	0.00	0.00	0.00	0.00	60.27	0.00	0.00
Setup-time	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Active time(Working + Stopping time)	180.00	190.00	187.00	186.83	240.27	180.00	180.00

Table 7. The active time of the machines (20.10.2015).

Parameters / Units	Drying	Grinding	PH	Extraction	Filtering 1	ICP 1 basic elements (Ca,K,Mg,Na,S)	Photometry
time of measurement/min	180.00	180.00	180.00	180.00	180.00	180.00	180.00
Measured capacity	462.00	247.00	247.00	450.00	346.00	180.00	360.00
Idle/min	0.00	13.00	2.33	6.83	0.00	0.00	0.00
Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Standby	0.00	0.00	0.00	0.00	78.60	0.00	0.00
Setup-time	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Active time(Working + Stopping time)	180.00	193.00	182.33	186.83	258.60	180.00	180.00

Table 8. The active time of the machines (27.10.2015).

Parameters / Units	Drying	Grinding	pH	Extraction	Filtering 1	ICP 1 basic elements (Ca,K,Mg,Na,S)	Photometry
time of measurement/min	180.00	180.00	180.00	180.00	180.00	180.00	180.00
Measured capacity	462.00	306.00	306.00	510.00	420.00	300.00	240.00
Idle/min	0.00	8.00	4.00	6.83	0.00	0.00	0.00
Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	120.00
Standby	0.00	0.00	0.00	0.00	96.00	0.00	0.00
Setup-time	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Active time(Working + Stopping time)	180.00	188.00	184.00	186.83	276.00	180.00	300.00

Tables 6 and 7, and 8 show that the filtering machine has the highest active time so it is the bottleneck machine and it constraint the capacity that goes to the downstream (laboratory).

Moreover, it can be seen that the filtering machine does not have much work as it has the highest standby time. The second highest machine that has the highest active time is the grinding unit. The grinding machine has a long idle time which effects on the performance of the machine. In Table 8, the active time of the photometry machine is 300 minutes due to machine required maintenance at that day of measurement, so it is the bottleneck machine in one observation day only from the laboratory section.

7.2.1 Bottleneck management

In order to increase the capacity, the working time of the filtering unit should be utilized by applying more work from the upstream machine (extraction), and add a buffer space so the filtering can process the samples even if the extraction machine is during its cycle time and in that case the filtering unit will start working immediately when the shift starts.

Also the grinding machine should be maintained from time to time in order to give a higher capacity and eliminate the idle time of that machine in case of bottleneck shifting.

In the laboratory area, the capacity of the machine is almost constant but in case of failure an extra photometry machine is needed. An example of this can be seen in Table 8 as the active time of the photometry is the highest due to maintenance time during that day of observation.

7.3 Third analysis method

The third analyzing method can be done through finding which machine has the longest queue in front of it by visiting the Eurofins Viljavuuspalvelu Company during the season where they have the highest production rate.

During the observation, I noticed that the grinding and the extraction machines have the longest queue of samples in front of them. This means that the grinding unit cannot process all the samples that are coming from the drying unit. Same thing goes with extraction unit as there are always a long queue in front of it during the observation in the industry. So in this analyzing method the grinding and extraction units are the bottleneck machines.

In the laboratory area no queue has been observed in front of any machine.

7.3.1 Bottleneck management

To fix this problem, the run rate of the grinder should be increased and this is done by either increasing the working time of this machine or by buying a new machine with a higher capacity. Another method is to reduce the amount of samples that are coming from the drying machines so here we can reduce the buffering space and the energy consumption but the capacity of the process will be decreased.

For the extraction unit, the length of the queue in front of it can be reduced by increasing the working time of the machine and assigning more work to it because during the observation time I noticed that only a maximum of eight lines out of 18 are filled with samples (each line can handle 30 samples).

To assigning more work to this machine more output can be achieved and here buffering space should be prepared after the extraction machine and before the filtering machine so that the filtering units can handle all output from the extraction machine even when the extraction is processing the samples during its cycle time.

7.4 Fourth analyzing method

This method is based on the technical issues that effects on the machines. Mainly this method is based on the feedback taken from the manager and employees of the company. So based on normal conditions, the extraction unit can handle up to 8 lines of samples out of 18 and this difference is rather high and affecting the whole production as the theoretical maximum capacity is 4320 samples/shift (see Table 1), while with this technical problem the maximum capacity can reach a maximum of 1920 samples/shift. So based on this method the extraction unit is the bottleneck machine.

7.4.1 Bottleneck management

The company should find a solution in order to utilize all lines in the extraction machine in order to increase the capacity as the maximum utilization of lines currently is 8 lines while the machine has 18 lines.

Moreover, in order to increase the overall capacity in the industry, the extraction should give more work to the next unit (filtering) and at this situation few work will be assigned to filtering and the output capacity of the company will not increase.

7.5 Further ideas and conclusion about bottleneck analysis

From the industrial section of the company it can be seen that the grinding machine is the bottleneck machine and it constraints the production of Eurofins Viljavuuspalvelu company based on the four analyzing methods that are used to identify the bottleneck machines. The grinding machine has been identified to be the first bottleneck machine in two methods and it comes as a second bottleneck machine in one method. In addition, the main problem with that machine is the amount of idle time. Also the pieces produced per cycle for that machine should be increased, so a frequent maintenance to that machine is highly recommended.

Moreover, in case of solving the problem of the grinding machine, the bottleneck might be shifted to another machine and in this case the filtering and extraction machines are nominated to be the second bottleneck machines as it has been seen two times in the previous analyzing methods.

Moreover, the main issue with filtering machine is that it has a lot of standby time which means few work has been assigned to this machine. While the main problem with the extraction machine is based on technical problems as 8 lines out of 18 in this machine can be utilized which means a significant drop in the maximum capacity. So in order to increase the work time for filtering, some consideration has to be taken into account in the extraction machine in order to increase the production. In addition, a buffering space would be a good idea to store some samples between the extraction and filtering machines so the filtering will have work when the shift will start and no need to wait the cycle time of the extraction machine. So by making extraction machine working at its full capacity by solving the technical problems more samples will be send to the filtering units and the standby time of the filtering machine will be decreased.

Furthermore, the other filtering machine (filtering 2 EDTA) should work with both samples, the VT and the EDTA in order to process all the work that comes from the extraction machine in case of that machine (the extraction) is working at its full capacity and here the total output capacity will increase.

In the laboratory section, the photometry machine has been seen twice as a bottleneck in the analyzing methods and it is a bottleneck machine in the laboratory section. Also if all the machines will work at their full capacity the photometry will constraint the production because it has the least theoretical output capacity.

Moreover, it is recommended to assign some work to the second machine of the ICP (ICP trace elements) and this machine should be able to treat the basic elements when there are no trace elements required from the customers. For the other unit, it is better to have another photometry machine to increase the output capacity and to be in a safe side in case of failure. Also people and shifts should be added to the laboratory section in order to handle all the samples that are coming from the industrial section, thus the plant balance can be achieved between the industrial and laboratory sections.

8 Analysis based on interviewing the employees

One of the best solutions to find what constrains the production is by interviewing the workers in the industry and ask their opinions about what might be the problem, what things should be changed, how to improve the production, etc.

The results which are presented in appendix III, Table 21, show that the environment in the industry is good while the process in the industry and people who are working in the Eurofins Viljavuuspalvelu are very good and nothing need to be changed up to these factors. The materials and equipment that are used in the industry are ranging between good and very good. However, the main reasons for the equipment's rating is high from the employers' point of view is that they do not want to replace the old equipment with the new ones as they are used to work with the old one and they are not willing to have a new equipment.

The main problem in the industry according to employers is the management, like management of the incoming materials and/or management of problems occurred during the work in the Viljavuuspalvelu and here a significant action should be taken in that part in order to improve the production in the Viljavuuspalvelu in Mikkeli/Finland.

Furthermore, another interviewing to employees has been made about each unit in the industry according to Table 22 in appendix III. The results show that all employees in the department of sampling and ordering are complaining about the delivery of samples by the customers and they said many of their samples are destroyed during the delivery, also they said the working area is small and they need a larger area for sampling and ordering. The best solution at the moment is to advice the customers on a certain procedure for delivering their samples in order to reach the company without any problems.

For the drying unit, the employees said that many samples are still wet after the drying process and this issue will slow down the process. In addition, some workers said that they need a method that shows how many samples are in each drying machine instead of guessing the number of samples. Moreover, the employees said that the drying time is long which will affect the production rate. The best option for this department is to arrange the samples inside the dryers in a proper way and try to utilize the whole space in the machine with samples as the drying time takes long time.

For the grinding machine, the employees think that it is an old machine and this is because it has usually many faults at the same time that cause a slowdown in the process. The recommendation idea is to have a regular maintenance to this machine and make basic renovation to it.

For the pH and electric conductivity department, the employees think that there is a problem with the sensors and barcodes. The sensors and barcodes need to be changed as they think that these issues are slowing down the completion of the samples.

For other departments and machines the employees think that there is no major problems that lead to affect the production rate and it seems they are not facing any problems.

9 OEE (Overall Equipment Effectiveness)

The equipment effectiveness of the Eurofins Viljavuuspalvelu is calculated by calculating the percentage of OEE of the company based on the factors in Table 9.

Table 9. Data for calculating the OEE.

Data of Production	data collection for Viljavuuspalvelu Oy
Shift length	8 hours or 480 minutes
Short Breaks	2 breaks each is 15 minutes so in total it is 30 minutes
Meal Break	1 break which is equal to 30 minutes
Down Time	The average downtime is 29.7 minutes/day (set uptime + breakdowns)
Ideal Run Rate	3.45 pieces / minute (based on the average of all machines)
Total output	The average output / shift is 542 samples based data from company
Reject products	the rejected percentage is 4.25 % which is equal to 24

The downtime in Table 9 is calculated based on the sum of the stops for each machine in each visiting day and the average of those stops is found to be 29.7 minutes/day. Moreover, the ideal run rate is the average rate based on the highest capacity in each machine which is shown in Table 1 divided by the shift length (8 hours except the drying which it is 24 hours) as it can be seen in Table 18. The average ideal run rate for all machines is found to be 3.45 pieces/minute.

9.1 The OEE factor for Eurofins Viljavuuspalvelu Oy

The percentage of OEE has been calculated for the Viljavuuspalvelu Company and it has been compared to the OEE of the world class as it is shown in Figure 14 and Table 10. The calculations of the OEE with the data collection tables are shown in Appendix II.

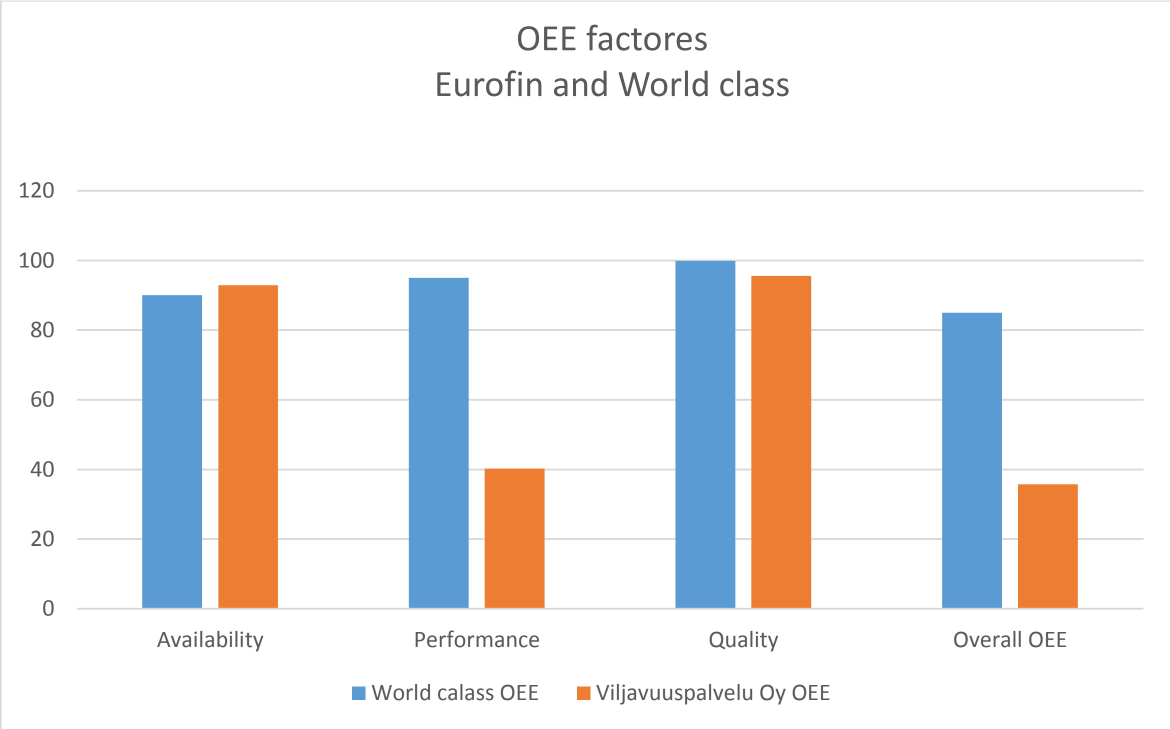

Figure 14. OEE factor for Eurofins and World class.

Table 10. Comparison of OEE factor between Eurofins and World class.

OEE factor	**World class %**	**%OEE Of Eurofins Viljavuuspalvelu**
Availability rate	90.00	92.93
Performance rate	95.00	40.25
Quality rate	99.90	97.57
OEE %	85.00	35.75

From the previous figure and table, the percentage of the OEE of the industry is 35.75% which is considered to be very low by comparing it with the OEE world class. However, the quality rate of the company and the availability rate are excellent but the performance rate is low compared to the performance rate of the world class and it affect the overall OEE %. The performance rate is very important as it is affected by the ideal run rate of the machines and the total output of the industry. In general, the OEE is not good if it is between 40-59%, while it is fairly good if it is between 60-84%.

9.2 Increase the percentage of OEE in Viljavuuspalvelu Oy

The OEE of the Eurofins should be increased from 35.75% to near 85% in order to have an OEE near to the world class. For that reason, two methods have been used in this thesis to increase the percentage of OEE in the Viljavuuspalvelu.

The first method is done by keeping all parameters constant and changing the total output. With this method the total output of the company should be around 1254 samples/shift in order to achieve OEE near to 85% which is excellent for discrete industrialists based on Figure 15 and Table 19 in Appendix II.

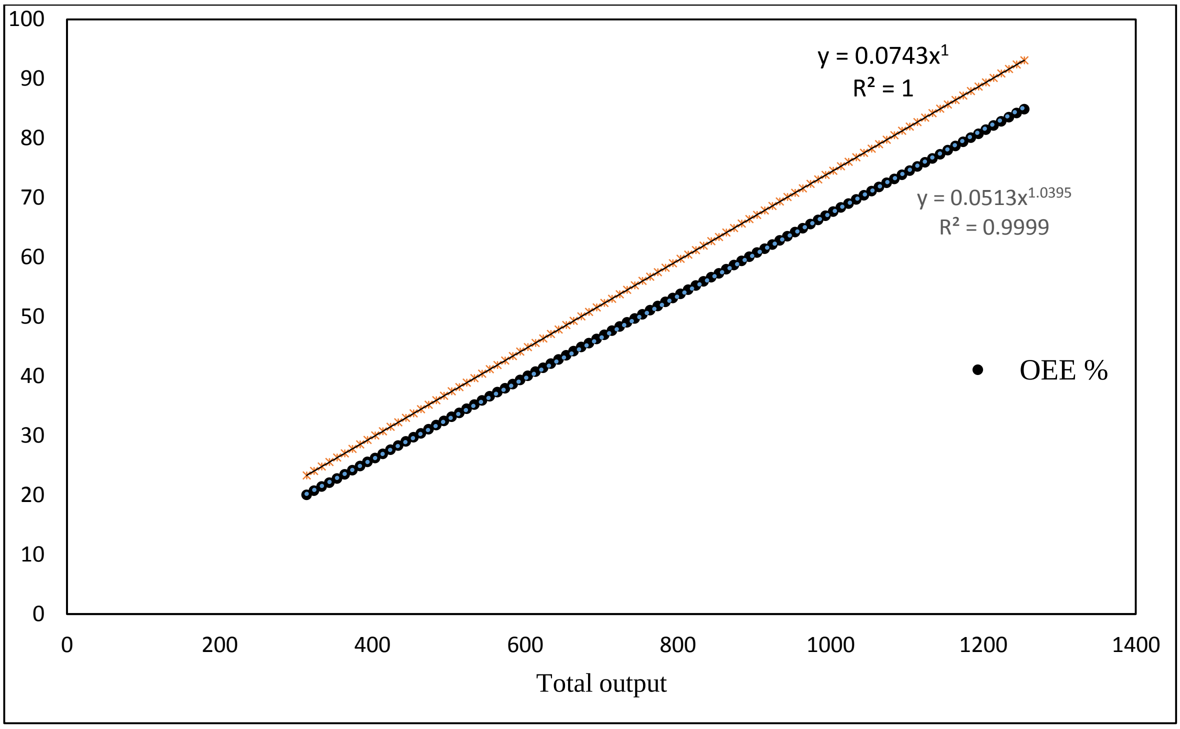

Figure 15. altering the total output in order to achieve an OEE with 85 %.

Another method to increase the industry's performance and total OEE is by keeping the total output and all other data in Table 9 constant and calculate the ideal run rate, the results shows that the average ideal run rate should be 1.45 pieces per minute as an average of all machines in order to get an OEE with a percentage of 85 based on Figure 16 and Table 20 in Appendix II.

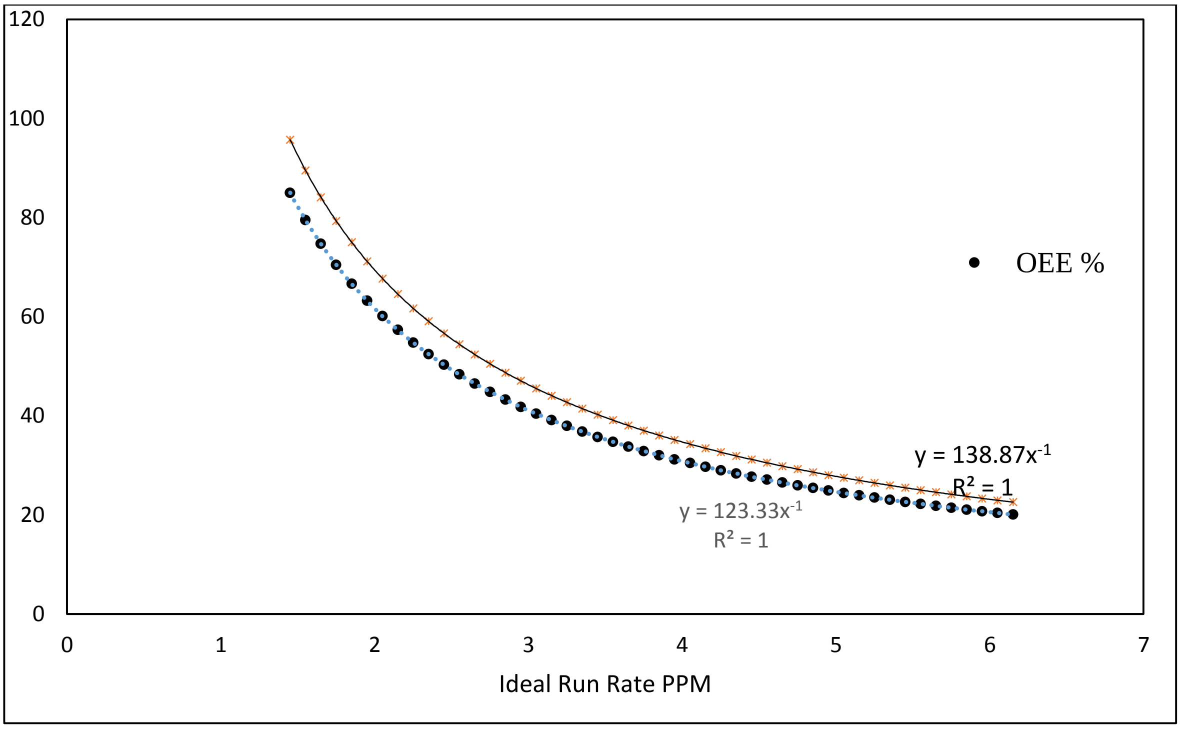

Figure 16. altering average ideal run rate (pieces/minute) of all machines in order to achieve an OEE with 85 %.

10 Realistic case

The realistic case was found to observe the effects of the bottleneck machine from the indusry and the laboratory sections after cahcanging some data. Some hypotheses will be applied to change the output of the ICP, phomtometry, and grinding machines. These hypotheses are based on the bottleneck management that are given after each bottleneck analysis.

In addition, this case will also use some assupmtions about chanhing some factores of OEE to see how the percentage of Viljavuuspalvelu OEE will be changed. These factors are for examples increasing the shift length or minimizing the the amount of rejected products.

10.1 First realistic method

This method is focused on increasing the working hours/shift for some machines. It also used the second ICP machine (ICP 2 trace element machine) for the basic elements at the time when it does not have work, and here the output of the ICP unit will be increased as the pieces/cycle form that unit is increased from 90 pieces/cylcle to 120 pieces/cycle. The machines that there working hours and their cycle time have increased are shown with a yellow mark in Table 11.

Table 11. Increase the maximum daily capacity by changing some factors.

Process Name	Shift/ day	Hours/shift	Days/ week	Cycle Time (sec)	PCS/Cycle	Daily Process Capacity	% Up Time	% Good	Process Capacity	Hours per week for this part	Maximum daily Capacity
Drying	3	8	7	198000	2772	1 210	0.98	0.96	1135	165	1114
Grinding	1	10	5	60	2	1 200	0.94	0.96	1084	50	1084
pH	1	10	5	60	2	1 200	0.9767	0.96	1122	50	1122
Extraction	1	8	5	3600	540	4 320	0.90	0.96	3723	40	3723
Filtering	1	8	5	990	90	2 618	0.5667	0.96	1421	40	1421
ICP1	1	9	5	3000	120	1 296	0.86	0.96	1067	45	1067
Photometry	1	14	5	4500	120	1 344	0.82	0.96	1055	70	1055

From table 11, the total output of the company can be increased to 1055 samples/day afer changing some factors. By applying these changes to the OEE calculation and increase the shifts length to be 9.57 hours based on the average on table 11 then the percentage OEE of the company will be increased from 35.75 to 55.33 %. See Figure 17.

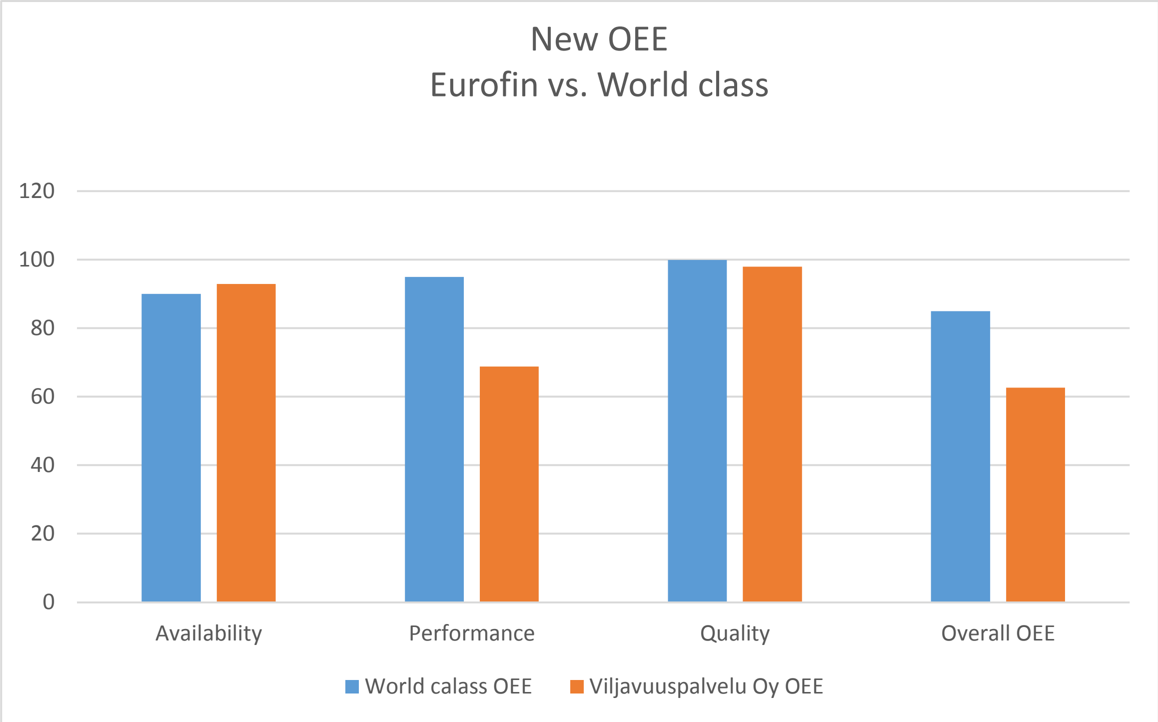

Figure 17 the new OEE of the company after changing the working hours of some machines and assign more work to the secone ICP machine.

10.2 Second realistic method

In this method the company is adviced to invest in a laboratory section only and buy a new photometry machine and in that case the total output of that unit will be 1206 samples/shift (output of photometry-1 plus output of fhotometry-2). For this method the second ICP machine will be used for basic elemnt when it doesn't have work, same like erlier. The changes are shown in yellow color in table 12.

Table 12. Investing a new photometry machine to increase the capacity.

Process Name	Shift/ day	Hours/shift	Days/ week	Cycle Time (sec)	PCS/Cycle	Theoretical maximum capacity/day	% Up Time	% Good	Process Capacity	Hours per week for this part	Maximum daily Capacity
Drying	3	8	7	198000	2772	1 210	0.98	0.96	1135	165	1114
Grinding	1	8	5	60	2	960	0.94	0.96	867	40	867
pH	1	8	5	60	2	960	0.98	0.96	898	40	898
Extraction	1	8	5	3600	540	4 320	0.9	0.96	3723	40	3723
Filtering	1	8	5	990	90	2 618	0.96	0.96	2400	40	2400
ICP	1	8	5	3000	120	1 152	0.86	0.96	949	40	949
Photometry-1	1	8	5	4500	120	768	0.82	0.96	603	40	603
Photometry-2	1	8	5	4500	120	768	0.82	0.96	603	40	603

By changing some data in table 12 the total OEE of the company will be 55.67% which is considered as fairly good as it is approximately equal to 60 % based on the global scale. See Figure 18.

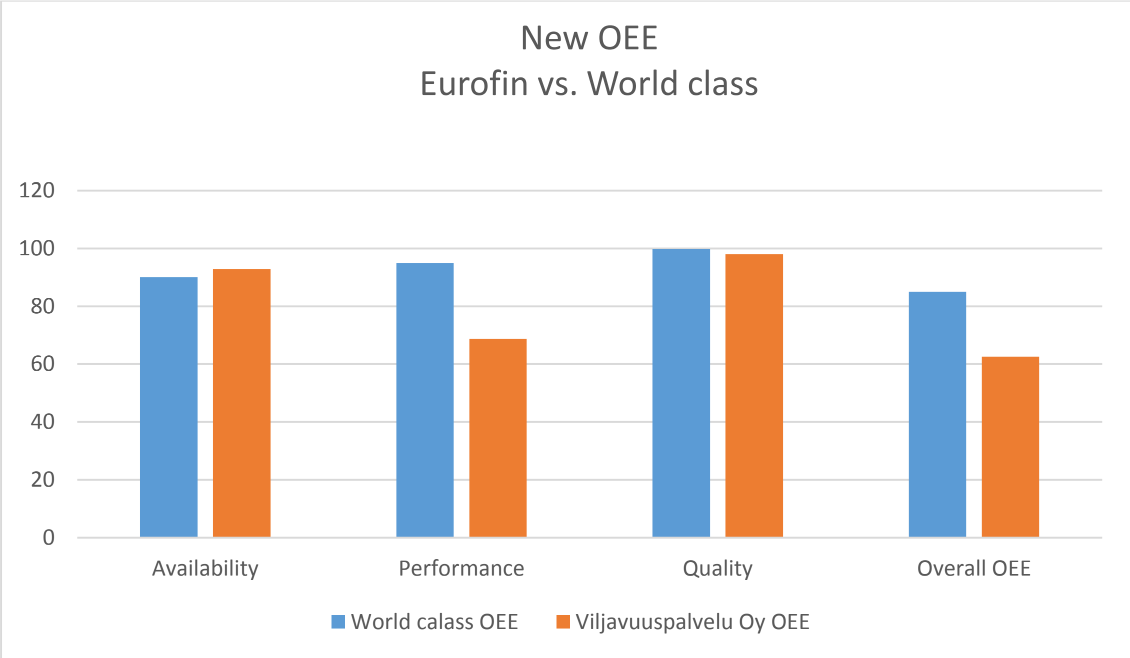

Figure 18. The new OEE of the company after investing a new photometry machine and use the ICP stand-by machine.

10.3 Third realistic method

In this method we assume that the total rejected samples will be improved and become 2% only while it was bfore 4.25%. Also two shifts will work in the laboratory section (each shift is 6 hours) to make a stable balance between the output of the indusry section and the laboatory section. Moroever, the shift length for grinding and pH unit are increased to 10 hours/shift. The changing data are shown in table 13.

Table 13. Improve the rejected products and change the number of shifts in the laboratory.

Process Name	Shift/day	Hours/shift	Days/ week	Cycle Time (sec)	PCS/Cycle	Daily Process Capacity	% Up Time	% Good	Process Capacity	Hours per week for this part	Daily Capacity for this part
Drying	3	8	7	198000	2772	1 210	0.98	0.98	1162	165	1141
Grinding	1	10	5	60	2	1 200	0.94	0.98	1109	50	1109
pH	1	10	5	60	2	1 200	0.98	0.98	1149	50	1149
Extraction	1	8	5	3600	540	4 320	0.90	0.98	3810	40	3810
Filtering	1	8	5	990	90	2 618	0.57	0.98	1454	40	1454
ICP	2	6	5	3000	90	1 296	0.86	0.98	1092	60	1092
Photometry	2	6	5	4500	120	1 152	0.82	0.98	926	60	926

After altering some data in table 13 the OEE factor of the comapeny will be 62.59% which is considered as fairly good for discrete industrialists according to the global scale. See Figure 19.

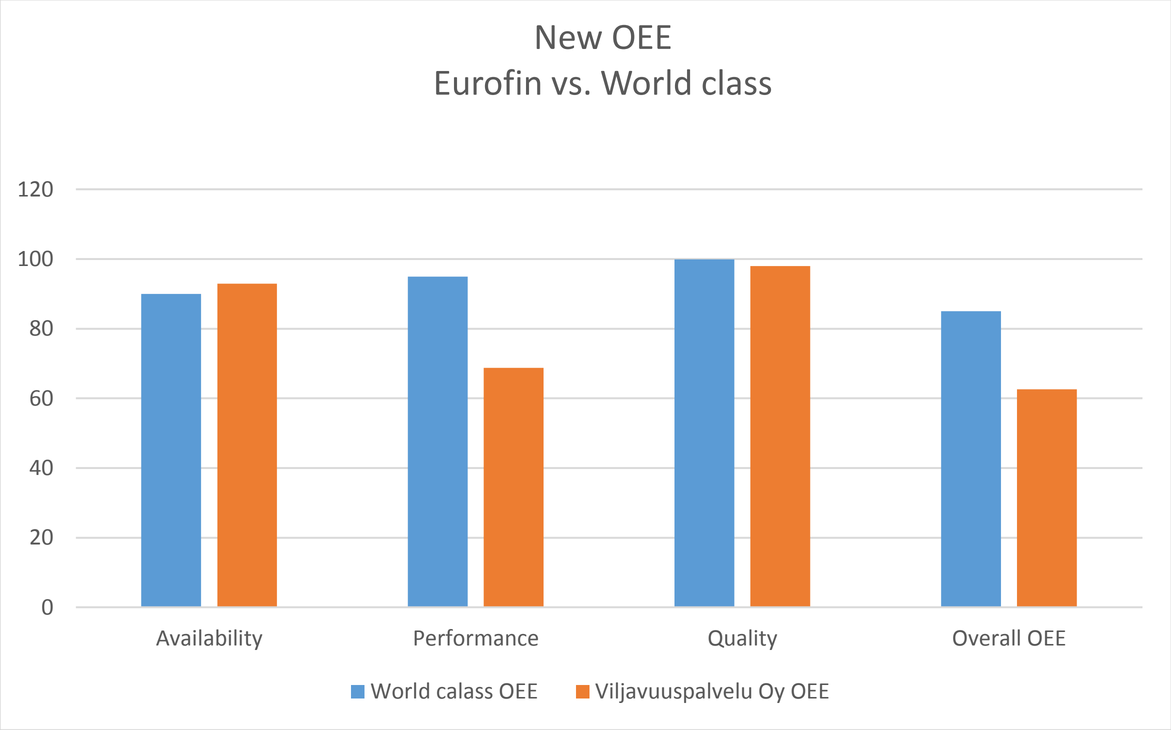

Figure 19. The new OEE of the company after improving the rejected products and increase the shift in the laboratory department.

11 The Just in Time production in Eurofins Viljavuuspalvelu

The Idea of Just in Time production is to make samples and products at the time when it is needed without using a forecasting production. In Eurofins Viljavuuspalvelu Company the production is based on the customers' samples, so there will be no production before the customers are sending their samples. Here the Idea of just in time production can be achieved without significant changes as the suppliers and the customer are the same, so the company will wait the soil samples from the customers and send it back to them after doing the required tests.

In order to obtain the objectives of JIT, the company should do the following achievements:

- It should interactive positively with the customers as the suppliers and the customers are the same.
- It should be ready for any changes, like changing in the weather (short or long winter), as it deals with Finnish farmers and the work is depending on the Finnish lands, so there will be very few samples when the land is covering with snow for long time.
- The production cost should be decreased by decreasing the buffer space between the units.
- Decrease the breakdown and setup times of the machines as this problem has been clearly seen in different machines like grinding.

11.1 Concepts of JIT in Eurofins Viljavuuspalvelu Company

In order to implement just in time production in the company, some concepts should be taken into account like eliminating the wastes. The meaning of waste here is for example reducing the overproduction of some machines like the drying units, and reducing the queue lines in front of some other machines like extraction and grinding.

Moreover, the flow manufacturing of products is very important as the production should be smooth and without any interrupts like idle time, setup time, and other breakdowns. So reducing of idle time of grinding machine, utilize the standby machines like the EDTA filtering and ICP trace elements are required to implement the JIT production in a proper way.

Another important concept in JIT is that the company need to apply some progresses like a continuous improvement of employees and equipment. The improvements can be for example changing the way of production or buying new equipment so the flow of products will be smooth from the beginning to the end of the production.

Finally, the Eurofins Viljavuuspalvelu Company should use the total preventive maintenance (TPM) frequently for the machines and equipment in order to reduce the breakdowns and minimize the emergency maintenance which will significantly affect the production in certain days. If the TPM is not applied in the company then the delaying in delivering samples to the customers will increase and hence more samples will wait in queues. A good idea for TPM is that the company include a shift responsible only for maintenance.

11.2 Pull System in Eurofins Viljavuuspalvelu Oy

In order to have a JIT production in the industry, the company should use the pull system of samples inside the company and among the suppliers, the company and the customers.
If the company is divided into three parts, the ordering part, the industrial part, and the laboratory part, then each part will send a signal to the previous one in order to send the samples to the downstream parts, while the company will send a signal to suppliers (customers) to send their samples, and the customers will send a signal to the company to pull back their products (testing results) from the company in the agreed date. The explanation of the pull system production can be seen in Figure 20.

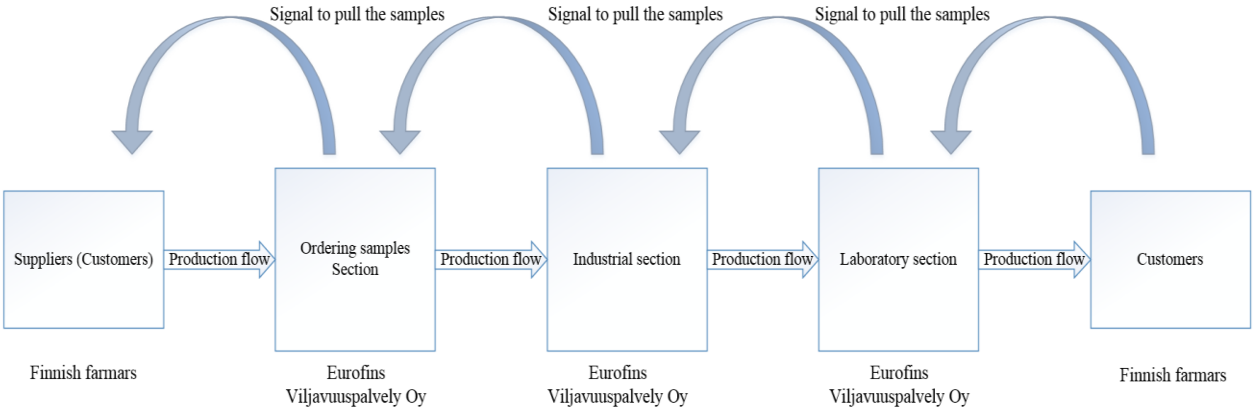

Figure 20. The pull system production in Eurofins Viljavuuspalvelu Oy.

By using the pull system, the company will not need to use the buffering spaces between the units and it will produce what is needed at the exact time when it is needed and thus the production cost will be decreased and the delivery date to the customers will be enhanced.

12 Conclusion

The main goal of this thesis was to increase the capacity in Viljavuuspalvelu Oy. Three different topics have been discussed, the indication of the Bottleneck machine, the Overall Equipment Effectiveness of the company, and the implementation of Just in Time production in order to increase the production capacity of the Eurofins Viljavuuspalvelu.
For the bottleneck part, the company has been divided into two sections, the industrial section and laboratory section because those sections differ from each other and the capacity of the laboratory machines is much smaller than that of the machines in the industrial section.

In the industrial section the bottleneck machine has been detected based on four different analyzing methods. In the industrial part the machine that constraint the production is found to be the grinding machine. In addition, as the company has a continuous flow of process and a shifting bottleneck between machines might happen as a result of multiple bottlenecks, then the nominated machines to be the second bottleneck machine after grinding are the extraction and filtering machines. The two machines have been nominated to be the constraint machines because both of them have been detected as a bottleneck machine at least twice in the previous analyzing methods.

For the laboratory section, the photometry machine has been found to be the bottleneck machine and it affects the production of the laboratory and the whole company as it is the last department before the tested samples are going to ICP and final destination (Customers).

In addition, a recommendation to reduce or eliminate the effect of the bottleneck and to increase the production have been explained after each analyzing method.

Furthermore, The Overall Equipment Effectiveness (OEE) of the whole company have been calculated and compared to the OEE world class. It has been found that the % OEE of Viljavuuspalvelu is low compared to the world class. So an idea on how to increase the percentage OEE of Eurofins Viljavuuspalvelu have been studied by showing the effects of total output and ideal run rate on the total OEE of the company.

Moreover, a realistic case has been applied to see the effects of changing some data in the company and observe the effects of the bottleneck machine from the industry and the laboratory sections so the managers in the company will have a clearer idea about the real problems inside their company and thus the best action can be decided easily by them.

The final part of the experiment discussed on how to implement a Just in Time production in the company based on regular checking onsite of the company by the writer of this thesis. Also the pull system of materials has been discussed as it is the main idea of JIT production. Furthermore, the total preventive maintenance have been found to be very important in the company to enhance the idea of JIT production inside the company.

Finally, an interviewing to the employees have been made and their opinion on how to improve the production has been expressed and the main problem in the industry according to employers is the management, like management of the incoming materials and/or management of problems that might occurred in the company. Also in the department of sampling and ordering the employees think that the working area is small and many samples which are delivered by the customers are destroyed during the delivery process.

In the Industrial area, the employees think that the samples are sometimes wet even after drying them in the oven for long time. Moreover, according to the employee’s opinion, the grinding machine is old and it has a lot of faults and idle time, while they think that sensors and barcodes need to be changed in the pH and Electric conductivity unit.

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Appendices

Appendix I

$$\% \, Up \, time = 100\% - \left(\frac{all \, kind \, of \, stops'}{time \, per \, shift} * 100\%\right) \quad (13)$$

’ All kind of stops based on data collection

$$Process \, Capacity = TMC * \% \, of \, Up \, time * \% \, of \, Good \, products \quad (14)$$

$$Max \, Daily \, Capacity = \frac{Process \, Capacity * \, Hours/week \, for \, this \, machine}{(Shifts/day * Hours/shift * Days/week)} \quad (15)$$

Table 14. The average daily capacity based on the data collection

Process No	Process Name	Next Process	Shift/ day	Hours/ shift	Days/ week	Cycle Time (sec)	PCS/ Cycle	Daily Process Capacity	% Up Time	% Good	Process Capacity	Hours/ week	Maximum Daily Capacity
1	Drying	2	3	8	7	198000	2772	1210	0.98	0.9575	1135	165	1114
2	Grinding	2A	1	8	5	60	2	960	0.94	0.9575	867	40	867
2A	pH	3	1	8	5	60	2	960	0.98	0.9575	898	40	898
3	Extraction	4	1	8	5	3600	540	4320	0.90	0.9575	3723	40	3723
4	Filtering	5	1	8	5	990	90	2618	0.57	0.9575	947	40	1421
5	ICP	6	1	8	5	3000	90	864	0.86	0.9575	711	40	711
6	Photometry	Customer	1	8	5	4500	120	768	0.82	0.9575	603	40	603

Appendix II

$$Ideal\ run\ rate = \frac{Average\ TMC\ of\ all\ machines}{The\ length\ of\ the\ sift} \quad (16)$$

$$Availability\ rate = \frac{Operting\ time}{Planned\ production\ time} \quad (17)$$

$$Planned\ Production = The\ length\ of\ the\ shift - Total\ breaks \quad (18)$$

$$Operating\ time = Planned\ prodction\ time - Down\ time \quad (19)$$

$$Good\ output = Total\ output - Rejected\ products \quad (20)$$

Table 15. Data collection and the sum of the down time

14.10.2015	Drying	Grinding	pH	Extraction	Filtering 1	ICP1	Photometry
Time of Measurement/min	180	180	180	180	180	180	360
Measured capacity	0	302	302	480	360	240	360
Idle/min	0	10	7	0	0	0	0
maintenance	0	0	0	0	0	0	0
Stand-by/min	0	0	0	0	60.27	0	0
Loading, unloading and setup/min	6.43	0	0	18.501	0	25	25
Down time / min	6.43	10	7	18.501	60.27	25	25
Sum of average of down time	21.743						

Table 16. Data collection and the sum of the down time

20.10.2015	Drying	Grinding	pH	Extraction	Filtering 1	ICP1	Photometry
Time of Measurement/min	180	180	180	180	180	180	360
Measured capacity	0	247	247	450	346	180	360
Idle/min	0	13	2.33	0	0	0	0
maintenance	0	0	0	0	0	0	0
Stand-by/min	0	0	0	0	78.6	0	0
Loading, unloading and setup/min	6.43	0	0	18.501	0	25	25
Down time / min	6.43	13	2.33	18.501	78.6	25	25
Sum of average of down time	24.123						

Table 17. Data collection and the sum of the down time

27.10.2015	Drying	Grinding	pH	Extraction	Filtering 1	ICP1	Photometry
Time of Measurement/min	180	180	180	180	180	180	360
Measured capacity	0	306	306	510	420	300	240
Idle/min	0	8	4	0	0	0	0
maintenance	0	0	0	0	0	0	120
Stand-by/min	0	0	0	0	96	0	0
Loading, unloading, setup/min	6.43	0	0	18.501	0	25	25
Down time / min	6.43	8	4	18.501	96	25	145
Sum of average of down time	43.276						

Table 18. Ideal run rate for each machine in Viljavuuspalvelu Oy

Unit	Equation	Ideal run rate
Drying	1210 samples/(24h*60min)	0.84
Grinding	960 samples/(8h*60min)	2.00
Extraction	4320 samples/(8h*60min)	9.00
Filtering	2617 samples/(8h*60min)	5.45
ICP	864 samples/(8h*60min)	1.80
Photo	768 samples/(8h*60min)	1.60
Average		3.45

Table 19. Achieving 85 % OEE by changing the total output on Eurofins industry

Total output	OEE %	Performance rate%	Total output	OEE %	Performance rate%
313.80	20.00	23.30	793.80	53.13	58.95
323.80	20.69	24.05	803.80	53.82	59.69
333.80	21.38	24.79	813.80	54.51	60.44
343.80	22.07	25.53	823.80	55.20	61.18
353.80	22.76	26.27	833.80	55.89	61.92
363.80	23.45	27.02	843.80	56.58	62.66
373.80	24.14	27.76	853.80	57.27	63.41
383.80	24.83	28.50	863.80	57.96	64.15
393.80	25.52	29.25	873.80	58.65	64.89
403.80	26.21	29.99	883.80	59.34	65.64
413.80	26.90	30.73	893.80	60.03	66.38
423.80	27.59	31.47	903.80	60.72	67.12
433.80	28.28	32.22	913.80	61.41	67.86
443.80	28.97	32.96	923.80	62.10	68.61
453.80	29.66	33.70	933.80	62.79	69.35
463.80	30.35	34.44	943.80	63.48	70.09
473.80	31.04	35.19	953.80	64.17	70.83
483.80	31.73	35.93	963.80	64.86	71.58
493.80	32.42	36.67	973.80	65.55	72.32
503.80	33.11	37.41	983.80	66.24	73.06
513.80	33.80	38.16	993.80	66.93	73.80
523.80	34.49	38.90	1003.80	67.62	74.55
533.80	35.18	39.64	1013.80	68.31	75.29
543.80	35.87	40.39	1023.80	69.00	76.03
553.80	36.56	41.13	1033.80	69.69	76.77
563.80	37.25	41.87	1043.80	70.38	77.52
573.80	37.94	42.61	1053.80	71.07	78.26
583.80	38.63	43.36	1063.80	71.76	79.00
593.80	39.32	44.10	1073.80	72.45	79.75
603.80	40.01	44.84	1083.80	73.14	80.49
613.80	40.70	45.58	1093.80	73.83	81.23
623.80	41.39	46.33	1103.80	74.52	81.97
633.80	42.08	47.07	1113.80	75.21	82.72
643.80	42.77	47.81	1123.80	75.90	83.46
653.80	43.46	48.55	1133.80	76.59	84.20
663.80	44.15	49.30	1143.80	77.28	84.94
673.80	44.84	50.04	1153.80	77.97	85.69
683.80	45.53	50.78	1163.80	78.66	86.43
693.80	46.22	51.52	1173.80	79.35	87.17
703.80	46.92	52.27	1183.80	80.04	87.91
713.80	47.61	53.01	1193.80	80.73	88.66
723.80	48.30	53.75	1203.80	81.42	89.40
733.80	48.99	54.50	1213.80	82.11	90.14
743.80	49.68	55.24	1223.80	82.80	90.89
753.80	50.37	55.98	1233.80	83.49	91.63
763.80	51.06	56.72	1243.80	84.18	92.37
773.80	51.75	57.47	1253.80	84.87	93.11
783.80	52.44	58.21			

Table 20. Achieving 85 % OEE by changing the ideal run rate of the machines

Ideal Run Rate PPM	OEE %	Performance rate%	Ideal Run Rate PPM	OEE %	Performance rate%
1.45	85.00	95.71	3.85	32.03	36.06
1.55	79.52	89.53	3.95	31.22	35.15
1.65	74.70	84.11	4.05	30.45	34.28
1.75	70.44	79.31	4.15	29.71	33.45
1.85	66.63	75.02	4.25	29.01	32.67
1.95	63.22	71.18	4.35	28.35	31.92
2.05	60.13	67.71	4.45	27.71	31.20
2.15	57.34	64.56	4.55	27.10	30.51
2.25	54.79	61.69	4.65	26.52	29.86
2.35	52.46	59.07	4.75	25.96	29.23
2.45	50.32	56.66	4.85	25.42	28.63
2.55	48.35	54.44	4.95	24.91	28.05
2.65	46.52	52.38	5.05	24.42	27.49
2.75	44.83	50.48	5.15	23.94	26.96
2.85	43.26	48.71	5.25	23.49	26.45
2.95	41.79	47.06	5.35	23.05	25.95
3.05	40.42	45.52	5.45	22.63	25.48
3.15	39.14	44.07	5.55	22.22	25.02
3.25	37.94	42.72	5.65	21.83	24.57
3.35	36.81	41.44	5.75	21.45	24.15
3.45	35.74	40.24	5.85	21.08	23.73
3.55	34.73	39.11	5.95	20.72	23.34
3.65	33.78	38.04	6.05	20.38	22.95
3.75	32.88	37.02	6.15	20.05	22.58

Appendix III

Table 21. Rating of the particulars in the industry by employers

Particulars	Ratings
Materials	3.50
Equipment	3.33
Process	4.00
Management	2.00
Environment	3.00
People	4.00

Grade it from 1 to 5

1= Poor management

2= Needs to change Guide line for ratings.

3= Good

4= Very good

5= Excellent

Table 22. Employees' opinion about machines and equipment and their effects in Eurofins

Process type	What is the Problem	How many times the problem has been seen	Effects of the problem	Recommendation for future
Raw materials and ordering samples				
Drying				
Grinding				
pH				
Electric conductivity				
Extraction				
Filtering				
ICP				
Photometry				