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# On the reporting of production performance in a global operation

Rapportering av produktionsprestanda i ett globalt produktionssystem

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# Abstract

As companies compete on the global market with an increasing amount of competitors trying to win market shares the need for an increasingly effective production becomes apparent. By utilizing the correct indicators the company can identify and improve their weaknesses to becoming more effective.

The project is performed at five of Alfa Laval's production sites, 1, 2, 3, 4 and 5. The study is also done for two different divisions A and B. For each of the sites a production line will be studied as well as a couple of products produced by those production lines. The sites will be studied with regards to their production performance and the performance measurement system used. The production performance and the performance measurement system will be analyzed using empirical data, interviews and questionnaires.

Using the empirical data it was established that the production lines have a fairly low availability. It was also possible to conclude that there are some discrepancies in the reporting of data regarding the performance. The five largest downtimes for each site was established to be responsible for a majority of the total downtime giving the company five targets to prioritize when trying to increase the availability.

The company's work with their performance measurement system is standardized when observing the higher levels but is not standardized when observing the lower levels. It was found that although the company measure OEE it was not used as a tool for improvement. There is also has a lack of documentation regarding the definitions and goals of the indicators used.

Keywords: <OEE, Performance Measurement System, production performance>

# Sammanfattning

Då företag konkurrerar på den globala marknaden mot ett ökande antal konkurrenter som försöker vinna marknadsandelar ökar vikten av en effektiv produktion. Genom att använda sig av korrekt indikatorer kan företaget identifiera och förbättra sina svagheter och på så sätt skapa en mer effektiv produktion.

Examensarbetet är genomför vid fem av Alfa Lavals produktionssiter, 1, 2, 3, 4 och 5. Dessa är dessutom indelade i två olika avdelningar.. För de olika siterna kommer en produktionslina att studeras och kopplat till dessa produktionslinor kommer ett par produkter att studeras. Siterna kommer att studeras avseende deras produktionsprestanda samt företagets prestationsmätningssystem. Detta kommer att analyseras med hjälp av empirisk data, intervjuer och enkäter.

Med hjälp av empirisk data kunde det konstateras att linjernas tillgänglighet är låg. Det var även möjligt att fastställa att det finns felaktigheter i data rörande anläggningsutnyttjandet. Det kunde också konstateras att de fem största stilleståndsorsakerna är ansvariga för en majoritet av det totala stilleståndet beroende på vilken produktionssite som studeras. Detta ger företaget fem områden att fokusera på vid förbättrande av tillgängligheten.

Företagets arbete med deras prestationsmätningssystem är standardiserat för de högre nivåerna inom företaget men är inte standardiserat för de lägre nivåerna. Det upptäcktes också att även om företaget mäter OEE så används det inte som ett förbättringsverktyg. Dokumentationen av de indikatorerna som företaget använder sig är upptäcktes även vara bristfällig.

Nyckelord: <TAK, prestationsmätningssystem, produktionsprestanda>

# Foreword

This is the report of a master thesis that was conducted during 20 weeks from January to May of 2016. The master thesis was done at Alfa Laval in Lund and will also be a part of a larger project called SuREBPMS. This thesis will mark the end of my education to become an engineer with a Master of Science in mechanical engineering and a specialization in product realization at the Faculty of Engineering at Lund University.

I would like to first and foremost give thanks to the employees of Alfa Laval who has taken the time to help me gather information and gain an understanding of the company. A special thanks to both Per Gabrielson and Anna Wenemark who have been of tremendous help and have guided me in this project.

I would also like to thank my advisor at the Faculty of Engineering, Carin Andersson, who has guided me and been of help when exploring ideas and solutions.

A thank you to the project group in SuREBPMS as well who left me inspired after each meeting.

I would also like to thank the students Endrit Smajli and Henrik Olsson who did a project in parallel to mine during the eight first weeks. Your work and results have been of help when analyzing Alfa Laval.

Lund May 26, 2016

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# Nomenclature

ALPS – Alfa Laval Production System

KPI – Key Performance Indicator

MES – Manufacturing Execution System. The system Alfa Laval uses to gather production data

OEE – Overall Equipment Efficiency

PMS – Performance Measurement System

Qlikview – A software used by Alfa Laval in order to visualize data.

Reason Group Description – The main category a downtime reason is divided into.

Reason Description – A lower category a downtime reason is divided into.

# 1 Introduction

## 1.1 Company description

Alfa Laval is a global manufacturer of equipment for fluids handling, separation and heat exchange. It is an old company which started in the year of 1883 in Lund Sweden. Alfa Laval is represented in nearly 100 countries and have 42 major production units worldwide (22 in Europe, 10 in Asia, 8 in the US and 2 in Latin America). Being a global company with production around the world means they have a lot of employees, over 18000. Alfa Laval's expertise is to produce products that are involved in treating water, reducing carbon emissions and minimizing water and energy consumption as well as heating, cooling and separating and transporting food. These areas also line up well with their vision of creating better everyday conditions for people. Alfa Laval currently holds over 2000 patents and are known for their innovations. They launch around 35 to 40 new products every year.

This master thesis project will focus on the production of heat exchangers. To be even more specific the divisions A and B. Heat exchangers are used to transfer heat between two or multiple fluids with differing temperatures. For division A the heat exchanger is constructed using multiple thin plates. These plates have specific patterns which determine which way the fluids will travel. The main idea is to get an area for heat exchanging that is as large as possible in order to make the heat exchanger efficient. The plates are placed within a frame and rubber packaging is applied between the plates in order to seal the product tight. Then the frames are pressed together in order to form the product. The fluids are then pumped through the heat exchanger through different entrances. The fluids travels between the different plates without coming into contact with each other and exchange heat energy making the colder fluid warmer and the warmer fluid gets colder. Division B is similar but has the difference of being brazed instead of using the rubber packaging as a sealing solution. Since they are brazed one set of plates can not be exchanged after it is produced, so if a problem with the plates arise after it has been produced the product needs to be exchanged. During the master thesis project five sites have been studied; 1, 2, 3, 4 and 5. The sites 1, 2 and 3 make up division A and sites 4 and 5 make up division B.

The plates to these products are produced in production lines and the layout is mostly the same for all of the lines, presented in Figure 1.

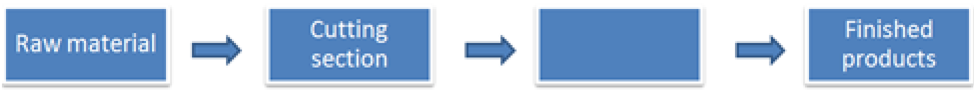



Figure 1 – Layout of a production line.

As can be seen in the figure the production start with raw material being loaded in to the production line. This material is then transported in some way to a section where it can be cut into the right shape and size. After the material has obtained the correct form it is transported in to a part of the production line which gives the material the right patterns to transport the fluid when in use. After that is done the product is transferred to a new section with finished products where it can be inspected and stacked in order to be transported to the next part of the production process. The transfers between the different parts can be handled quite differently depending on which site you study. The production lines studied in site 1, 4 and 5 uses conveyor belts to transfer the material between the different sections of the production. Site 2 uses robots for the transfer and site 3 uses manual labor as a means of transferring the material and products.

## 1.2 Background

At Alfa Laval a large amount of production data is acquired from their production lines globally, but they are experiencing deficiencies in how the data is reported at different global sites. Also the picture of how the information is collected is not complete. Today, there are procedures for working with systematic improvements, but a clearer connection to Key Performance Indicators (KPIs) and performance would provide better decision support in this work. The aim is to conduct an analysis of how the reporting of existing indicators is performed, and to identify which KPIs should be reported in order to conduct proactive and systematic improvement work regarding production lines globally.

The work during the project has been divided in to two different sections depending on the divisions that will be investigated, A and B. During the first eight weeks another project will be done in parallel to this project. During that time this master thesis project will focus mainly on the division A and the other project will focus on division B. The other project will be performed by the students Endrit Smajli and Henrik Olsson of the engineering department of  Lund University. The project they will conduct will be of a similar nature as this master thesis. Their results will therefore be used at a later stage in the project in order to analyze both of the divisions.

The master thesis project will also be a part of a bigger project called Sustainable Resource Efficient Business Performance Measurement System or SuREBPMS for short which in turn is a part of the project Produktion2030. Produktion2030 is a strategic innovation program for sustainable production in Sweden and the goals of SuREBPMS within this program is to:

- Integrate the sustainability dimension in BPMS and improvement work.
- Develop Key Performance Indicators and principles for proactive management instead of reactive reporting.
- Increase the visualization of performance between different levels in the company.
- Include the follow-up and improvement of other processes (production development, purchasing and R&D) in the BPMS.

This master thesis project will be used by the group members of SuREBPMS as a present state analysis of the company and the work they do regarding performance measuring. This will then be used as a basis to create suggestions of how they can improve their work process.

## 1.3 Purpose and goals

The purpose of the project is to analyze the current reporting and use of production KPIs, in order to analyze the need for changes in the set of KPIs and to identify potential improvements in the data acquisition routines. The aim is to establish a more consistent follow-up that may contribute to more preventive activities/actions.

## 1.4 Problem definition and demarcations

In the master thesis project, the following problem areas will be addressed:

- Identification of root causes behind the current production performance, by analysis of collected data from the production.
- Analyze variations in the reporting of data and definition of parameters for different global sites in comparison with the Lund site, with the purpose of suggesting corporate standards for definition and acquisition.
- Analyze if the right information is stored for the KPIs currently used and propose improvements for how to improve the use of KPIs in improvement work.
- Identify the need for new KPIs to capture the right / most important root causes to be addressed in improvement work.

## 1.5 Limitations

The areas within Alfa Laval that will be studied are the divisions A and B, which are heat exchangers. Division A is made up of the sites 1, 2 and 3. Division B is made up of the sites 4 and 5. The study will be done at both a production line level and also at a product level, where a few products from each site will be studied.

## 1.6 Structure of the thesis

The thesis will consist of the following chapters.

1. An introductory chapter that explains the need for the project as well as describing the company.
2. A methodology chapter explaining how the information gathering and analysis of the data and KPIs was conducted.
3. A theory chapter explaining the main concepts that the project revolves around such as Performance Measurement Systems, KPIs and OEE.
4. A chapter containing a present state analysis of the company on both a production line level and a product level. Presented here is how the

company reports and use their data and the production performance of the company.

5. A chapter presenting the findings of the project, such as root causes behind the production performance, variations in the company's data and how that data is used.
6. A chapter for discussing the findings of the project. Discussed here are the company's performance measurement system and its components, the downtime causes and the reporting of them, how the company can utilize their gathered data to give a more detailed view of the production performance and the standardization or lack thereof in the company.
7. A chapter containing suggestions for the company in regards to solving current problems or for improving their performance measurement system. Included is a suggestion for a way to better visualize the OEE and have the information be more directed to the different stakeholders. It is also suggested that the company investigate the discrepancies found in the data. Lastly a system to document and store detailed information regarding their KPIs/PIs is suggested.

# 2 Methodology

The methods used in this project will consist of information gathering both from the company and from scholarly sources and an analysis of the gathered data.

This master thesis project I aligned to a student project during the first half of the project period. During this period the major part of the information gathering and analysis is performed. The author was responsible for information gathering concerning division A, while E. Smajli and H. Olsson (2016) was responsible for division B. Information and results from Smajli & Olsson (2016) is used in the presentation and analysis of this master thesis.

## 2.1 Information gathering

### 2.1.1 Empirical data

The information needed in order to analyze Alfa Laval's work regarding a Business Performance Measurement System will be gathered from empirical data or through questionnaires and interviews made with personnel of different levels in the company. Information regarding division B will be provided by the project by Smajli & Olsson (2016). The empirical data that will be used during the project will consist of data from their MES-system, Qlikview and Jeeves. The data that is provided will mainly be from the year of 2015, with the exception of site 2 which will consist of data from both 2014 and 2015.

The system that Alfa Laval uses in order to log and gather information about the production is called MES. The data is registered in MES by the operators of the production lines when a downtime occurs. The MES also register the production rates of the production automatically without the need of input from the operators. The information needed from the system will be the production data from the year of 2015, January through December. The data will be supplied in the form of excel sheets in order to easily analyze it. The excel sheets will contain production data regarding the downtimes and the production rates. The analysis performed during the project will be made from this raw production data. By utilizing excel functions such as the "Filter" the data can be structured and divided into manageable portions.

The information that will be used from the software Jeeves during this project will be about the sales prices and the cycle times that should be used in the production for the different products.

The software Qlikview is used by Alfa Laval to visualize the production data gathered in MES and compare it to some of the data that Jeeves contains. During this project Qlikview will be used in order to gather data concerning the OEE-values calculated by Alfa Laval, information regarding the downtime causes and used as a comparison to the values that will be calculated using the raw production data. This comparison will be done to see if the data that is used by the company is correct.

### 2.1.2 Interviews and questionnaires

Interviews will be conducted throughout the entire project period by interviewing the different stakeholders in the organization that are of use in the project. Figure 2 show a hierarchical view of the personnel that will be interviewed in this project.

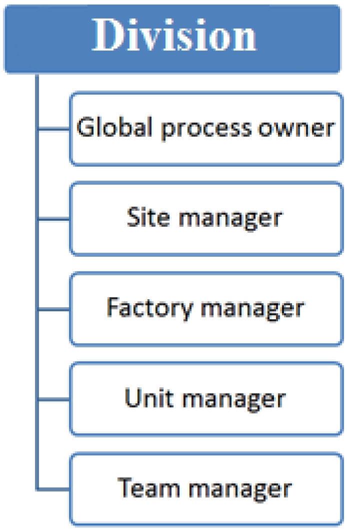



**Figure 2 - A hierarchical view of the personnel interviewed in this project.**

Weekly meetings will be scheduled with relevant personnel from the different sites in order to gather information about the production and improvement work, but also in order to monitor the project progression in relation to the expected outcomes. The personnel that will attend these meetings will be a team manager and a unit manager from site 1 and during the first 8 weeks of the project meetings will be held with a lean six sigma project manager from site 4 as well. Team managers are the closest boss to the operators and unit managers are the boss of the team managers.

Monthly meetings will be held with the steering committees for the project in order to keep them updated on the project and to assure that the resources needed for the project will be available. There are two different steering committees, one for division A and one for division B. In addition to these weekly and monthly meetings the different sites will also be contacted for updates and interviews when needed.

Questionnaires will also be sent out to representatives from the different sites in order to gather information. The different questions that was sent out can be found in appendix 1 and 2.

The operators are the ones closest to the production and the everyday work and problems that occur. The operators in site 1 will be interviewed in order to gather information and fill in the gaps that the empirical study does not show.

Other categories of employees that will be contacted in order to gather information are the following.

- *Factory manager* – Manager of the unit managers. They are responsible for a specific section of the plant, in this case the factory manager is responsible for the production of the plates used in the heat exchangers. One factory manager is a part of the steering committee for division A.
- *Site manager* – The site managers are the managers in charge of the entire site and is the manager of the factory managers. Site managers will be present in both of the steering committees.
- *Global process owner* – The global process owners are in charge of a specific division and the processes used in the production of them around the world.
- *Qlikview specialists* – An employee working exclusively with maintaining and updating the Qlikview software.
- *MES specialists* – An employee in charge of the work with MES will provide the production data and information regarding the program.
- *Controllers* – Personnel working with the financial data at different levels in the company.

## 2.2 Analysis of the data

The analysis will be at both a production line level and a product level during the master thesis project. The analysis at a production line level will contribute to understanding the overall state of the production and the product level will provide further information regarding the production of specific products that Alfa Laval wishes to study further.

The analysis of the gathered data will be done in different steps and by use of either tables or charts. In order to manage the massive amount of data it will be sorted into different categories. The separate downtime instances for the production lines will be sorted using the filter function in excel and by then combining the downtime for the separate instances the total number of instances and time each downtime cause contribute to is known. The same will be done at a product level for the different sites as well. This is done in order to identify the root causes behind the current production performance.

The information that has been gathered concerning the production performance will also be used in order to calculate the Overall Equipment Efficiency, Time Before Failures and Time Before Running. This will be done to analyze if the right information is used by the company when calculating these measurements. This information will then be compared to the data stored in Qlikview to see if there are any differences. The definition of parameters will also be compared to see if there are any differences between the sites.

## 2.3 Analysis of the KPIs

In order to know what the KPIs measure and how they aggregate between the levels they will be mapped by the author with the help of employees at Alfa Laval. The mapping will contain the KPIs used by production lines and the departments in charge of the production lines. This map can then be used to see if there are any areas that are lacking this aggregation. The mapping and the use of interviews and questionnaires will be analyzed in order to see if there is a need for new KPIs and if so which kind of KPIs that are needed.

# 3 Theory

The following theories have either been used by Alfa Laval in order to evaluate their production or by the author in order to analyze the pros and cons of their work or in order to improve certain areas of Key Performance Indicators (KPIs).

## 3.1 Performance Measurement System (PMS)

Organizations are required to perform and to communicate their achievements to key stakeholder (Micheli & Mari, 2014). In order to track and communicate an organizations performance a measurement system can be used. There are a many different reasons for a company to measure performance and according to Neely (1998) these fall under four categories.

- In order to check the position/status of the company
- In order to communicate the position/status
- To confirm the company's priorities
- And to compel progress

In short it can be said that the system is implemented to achieve organizational goals (Franco-Santos et al., 2007). In order to be of use for the company in achieving those goals the underlying metrics for the performance measurement system need to quantify the efficiency and/or the effectiveness of an action (Neely et al., 1995). There are a lot of measurements needed to be done in order to collect the data necessary for the PMS. This can be done manually for individual projects, but the PMSs requiring regular reporting are best automated (Bourne et al., 2000). The metrics are often called KPIs or PIs (Performance Indicators) within companies and the collection of these measures is what builds the performance measurement system, as shown in Figure 3.

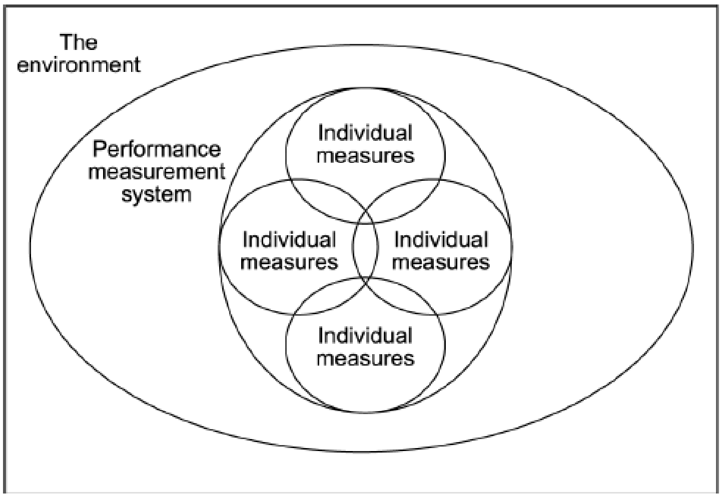



**Figure 3 – A framework for performance measurement system design (Neely et al., 1995).**

The KPIs/PIs can also be divided into different areas depending on what they measure (Keegan, Eiler & Jones, 1989) as shown in Figure 4 – The performance measurement matrix (Keegan et al., 1989)

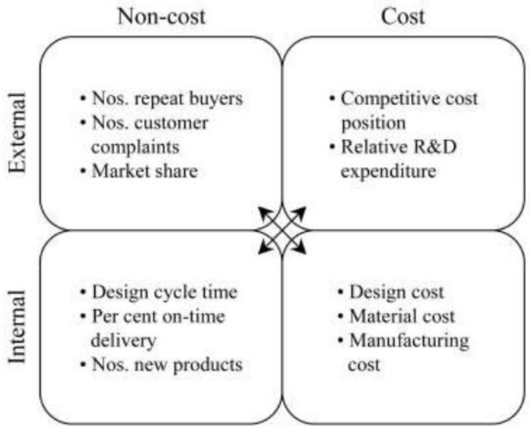



**Figure 4 – The performance measurement matrix (Keegan et al., 1989).**

A framework for implementing a performance measurement system is suggested by Kaplan and Norton (1992) called the balanced scorecard. The scorecard is based upon four perspectives which should represent the company's vision and strategy using both financial and non-financial measures:

- Financial perspective
- Customer perspective
- Internal business perspective
- Learning and growth perspective

This framework stresses the importance of translating the organization's strategy into a set of objectives for each of the perspectives. The performance measures used are also specified in order for a specific objective to be attained. This approach allows the organization to align the business performance with its strategy, enabling it to be successful in the market place (Khan & Shah, 2011). A fully functional and well implemented performance measurement system can be of great use to the company, but it is not always easy to implement. Bourne et al., (2000) identified three obstacles when implementing a PMS within a company.

1. Resistance to measurement, occurring during design and use phases.
2. Computer systems issues, occurring during implementation of the measures.
3. Top management commitment being distracted, occurring between the design and implementation phases.

A useful tool to utilize in order to check the position of the company is benchmarking. Alarcon et al. (1998), state that " performance measurement and benchmarking is the cornerstone of challenging any industry to become world class. A strategic benchmarking initiative has most to contribute towards their change culture, process, improvement of performance and productivity. Benchmarking enables an organisation to identify its performance gaps and opportunities, and develop continuous improvement programs for all stages of their process”.

# 3.2 KPIs

Key Performance Indicators, or KPIs, are used by companies in order to get a reading of how it is performing and can be used to analyze how the company should move forward. By the use of simulation of prospective scenarios the KPIs can be used in order to describe the possible outcomes which the company then can use to decide what areas to prioritize and what actions to take in order to improve the selected areas. However it is not an easy process to select which set of KPIs a company should implement and follow, often leading to repetitive KPIs. Various scholars have stressed the need for a concise list of core KPIs which are quantifiable and measurable (Lavy et al., 2014). But the reliability of the KPIs is only as good as the data that is gathered. Should the wrong data be gathered it can lead to incorrect assumptions being made and a prioritization leading in the wrong direction. In order to get reliable input from the processes it is important that the operators are motivated to do a good job in producing accurate information. As claimed by Maslow (1970), human beings have reasons for the things that they do and our behavior is actually purposive. Ahmed, Siantonas, Siantonas (2008) refers to McLagan (1989) who states that everything may be more productive if your people are sufficiently motivated, trained, informed, managed, utilized and empowered.

## 3.2.1 Leading and lagging KPIs

A way of categorizing different KPIs is by dividing them into those that can be used in a proactive way and those that is used in a reactive way. Leading KPIs tracks performance before a problem arises. They can therefore be used to predict the outcome of a process, should the process be continued to run in the same direction. These are therefore able to aid the proactive work a company is doing. They are often hard to measure but easy to influence and can be used to show how the company can improve. A lagging KPI shows the success or failure of an instance that has already happened. Since they show the result of something that has already happened they generate reactive measures. They are often easy to measure but hard to improve or influence. They themselves do not give a clear path forward in order to improve the company but instead are measures of how the company is performing.

In order to illustrate the meaning of leading and lagging KPIs Ricky Smith uses an example of driving a car. Should the car veer off towards the side of the lane it could be noticed by the tires hitting the small bumps on the side of the road. This can be seen as a leading indicator since it tells you that following this trajectory the car will steer off the side of the road, this indicator gives you time to take a proactive action to correct the course and avoid a crash. Should these indicators not exist the car could crash into the ditch. The condition of the car after the crash can be seen as a lagging KPI since it tells you what happened in the past. In order to fix this a reactive action is taken to call a tow truck.

# 3.3 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness measures how effective the company is in using its equipment. The use of OEE is spread throughout the manufacturing industry, and the OEE definition can be considered to be standardized globally. The different factors of the standard definition however has a varied interpretation (Andersson & Bellgran, 2011). Since such a variation exist the comparison of OEE between different companies is uncertain.

It is often used in connection with businesses working with Lean Production (Ståhl, 2015). According to Peterson (2000) the main application area of OEE is automatic and semi-automatic processes mainly due to the cycle time parameter. Another application aspect noted by Garza-Reyes et al., (2010) is that the OEE is normally used in high volume processes where capacity utilization is a high priority and disruptions are expensive, implying high capacity cost.

The definition that Alfa Laval uses is based on the original take on OEE by Nakajima (1988), which is presented in appendix 4. According to Nakajimas model the use of the equipment can be divided into different time sequences which are dependent on different time losses, as shown in **Fel! Hittar inte referenskälla.**Figure 5. For a full representation of Nakajimas definition see appendix 3.

The loading time is all the available time when an operator is present for the equipment during the entire year. Subtracting the time losses that occurs because of downtimes gives how much time the machine is in operation, the “Operating time”. Subtracting the time losses which accumulates when the machine is not running at full speed gives the “Net operating time”. Finally, accounting for the time it takes to produce defective products gives the time actually spent on creating value for the company “Valuable operating time”. OEE is then calculated by using the time shares dependent on these three losses; showing a value (percentage) of how well the equipment is utilized.

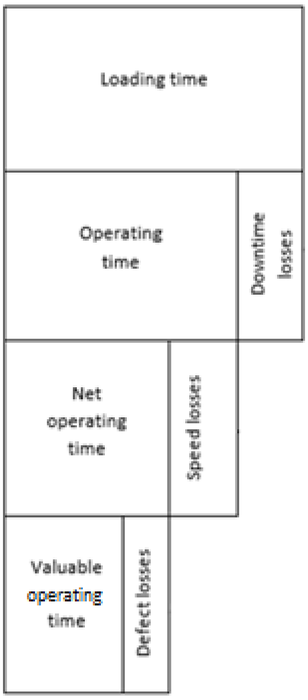



**Figure 5 - Nakajimas definition and sectioning of available time.**

These three time shares are named availability, performance efficiency and rate of quality products and their definitions are presented in the list below

$$Availability = \frac{Loading\ time - downtime\ losses}{Loading\ time} \times 100$$

$$Performance\ efficiency = \frac{Theoretical\ cycle\ time \times processed\ amount}{Operating\ time} \times 100$$

$$Rate\ of\ quality\ products = \frac{Processed\ amount - defect\ amount}{Processed\ amount} \times 100$$

$$OEE = Availability \times Performance\ efficiency \times Rate\ of\ quality\ products$$

According to Nakajima (1988) the ideal conditions for manufacturing are:

- Availability greater than 90 %.
- Performance efficiency greater than 95 %.
- Rate of quality products greater than 99 %.

These target values leads to an OEE of 85 % or higher which is the goal to achieve when aiming for world class manufacturing according to Nakajima (1988). What can be counted as an acceptable level for the OEE has however been the subject of discussion among scholars. According to Kotze (1993) an OEE level greater than 50% is a more realistic target, Ericsson (1997) claims that anywhere between 30 % to 80% can be an acceptable  OEE performance and Ljungberg (1998) claim that it should be between 60 % to 75 %.

# 4 Present state analysis

The data that has been collected is analyzed in order to get a clear picture of how the company works, in regards to the scope of the master thesis. The aim of the present state analysis is to detect any differences that exist between the different sites and between the raw data and the analysis and visualization made by the software Qlikview. There are five different sites included in this study, 1, 2 and 3 being the sites that is a part of division A and 4 and 5 are a part of division B.

## 4.1 Reporting of data

The reporting of data is done in many different stages at Alfa Laval. It is partly done by the personnel and partly by different software creating an information flow in the company. In Figure the flow of the data in Alfa Laval is visualized.

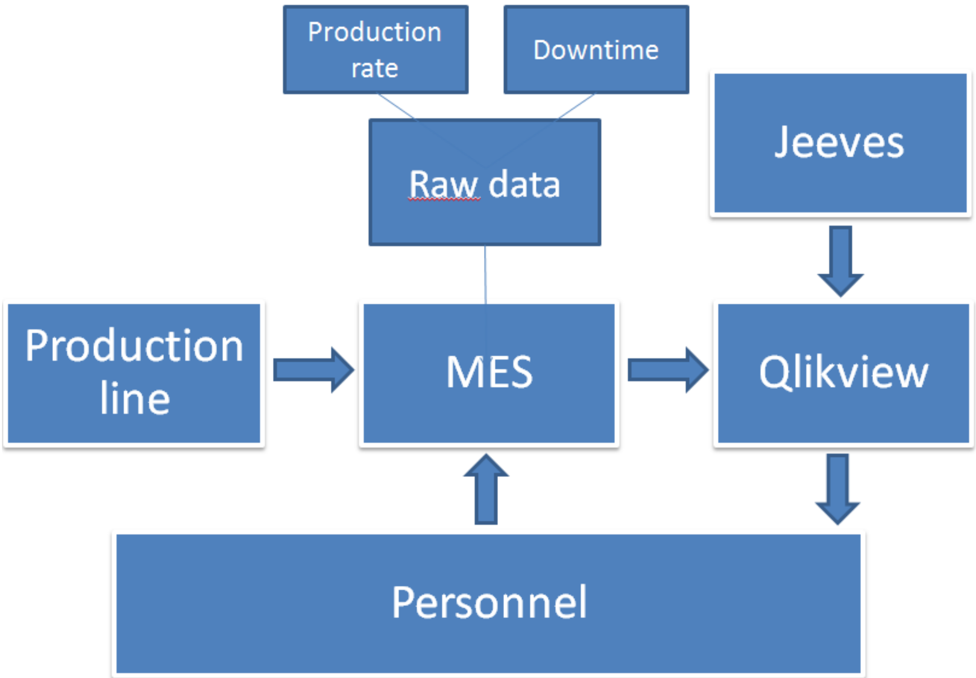



Figure 6 - Flowchart of the information of production data in Alfa Laval.

As can be seen in Figure the MES software is used by Alfa Laval and contain information regarding both downtimes in the machine and production rates. This data comes from either the machines in the production line or the operators feeding it into the system. This information is then compiled by Qlikview and visualized in order to make the data easy to understand and access for the personnel and shows the production performance.

In order to track the downtimes in the production MES is used to divide the downtimes into different categories depending on the reasons behind the stop. This is done manually by the operators when a stop occurs, with the exception of the failure code used for short stops (Stopped) which gets entered automatically into MES.

The different sites have a lot of different downtime reasons to select from when reporting a stop, they therefore use a main category and a subcategory when reporting stops. These categories are decided on a local level and are not standardized by the company. The main category is called "Reason Group Description" and the subcategory is called "Reason Description". Table 1 shows some of the main and subcategories used.

**Table 1 – An example of the categorization of downtimes used by Alfa Laval.**

| **Reason Group Description** | **Reason Description** |
|---|---|
| Reason Nr 20 | |
| | Reason Nr 21 |
| | Reason Nr 22 |
| | Reason Nr 23 |
| Reason Nr 30 | |
| | Reason Nr 31 |
| | Reason Nr 32 |
| | Reason Nr 33 |

By utilizing different levels of categories the operators can more easily find the correct description of the downtime and register it in the system and providing information about the root cause of each downtime. This categorization is important to have in order for the operators to quickly enter the correct downtime. It is also useful if someone wishes to study the total downtime caused by for instance personnel instead of looking at the downtimes caused by personnel during education or breaks. Table 2 presents the amount of codes used within each category for the different sites studied.

**Table 2 - The number of Reason Group Descriptions and Reason Descriptions at each site.**

| | Number of Reason Group Description | Number of Reason Descriptions |
|---|---|---|
| Site 1 | 21 | 86 |
| Site 2 | 15 | 46 |
| Site 3 | 7 | 23 |
| Site 4 | 26 | 85 |
| Site 5 | Unknown | Unknown |

For more detailed information regarding the “Reason Group Descriptions” and “Reason Descriptions” used by the different sites of Alfa Laval see appendix 5-8.

All of the sites utilize the MES-system today, although site 5 started using it after the project start which has led to lesser empirical data from that site. Since site 5 did not use the MES-system in 2015 the analysis of that site in particular is lacking compared to the other sites.

The reason why a stop occurs is registered every time it happens giving the company a good view of the root causes. However this is only true if the correct reason gets registered for the stop. As it is, the wrong reason sometimes gets registered giving a false impression of the distribution of downtimes. This is partly due to human error since it could be an honest mistake that the wrong reason gets registered. It can also happen because the operator feels stressed that the MES reporting system works too slow when dividing a long downtime in to different parts. Their main duty according to themselves is to produce units and they report the issues as a supplementary duty meaning if they feel that the reporting is taking too much time and slowing down the production it will be not be prioritized from time to time. Since the wrong reasons behind the downtimes sometimes get registered it is not one hundred percent reliable.

Qlikview compiles the information that MES provides and visualizes it in different ways so that it can be used by the personnel, such as operators, their managers and planners, in order to analyze the production performance. As an example it provide information on both a line level and a product level regarding the OEE-values, the downtimes and the causes behind them, how often the downtimes occur and much more. At the moment Qlikview is not used by site 2 due to server issues so the data that was available for this master thesis was limited to only part of 2015 and not the whole year.

The sites and teams working with the production lines is provided with daily, weekly and monthly reports generated by Qlikview. The PIs/KPIs that the reports contain can be found in appendix 9.

Alfa Laval produces a lot of data concerning the production, it is however heavily focused on downtime as compared to production rate. Each downtime get a reason registered to it to explain why it occurred. The same is not done for production rates when they are slower or faster than they should be. This in turn leads to a higher understanding of the downtimes than of the production rates. Information stored about quality issues are also limited. The reason for this as explained by employees of Alfa Laval is that the company find it hard to track the quality issues to their original source since it may not be discovered until after the product has been assembled.

## 4.2 Definition of parameters

Alfa Laval has a department that works with developing their performance measurement system called Alfa Laval Production Systems or ALPS. The company utilize three different kind of scorecards:

- ALPS scorecard.
- Operations scorecard.
- Performance scorecard.

The operations scorecard, as seen in Figure 7, contains KPIs concerning the results of the different operative units in Alfa Laval whereas the ALPS scorecard, as seen in Figure 8, focuses on the processes used by the teams.

**Operations Total**

| Scorecard area | Measure | 2014-03 | 2014-04 | 2014-05 | Target | Unit measure | Trend L3M |
|---|---|---|---|---|---|---|---|
| Result | Cost Flex Gap | | | | | | |
| | OP F&E | | | | | | |
| | IDS | | | | | | |
| People | ESI | | | | | | |
| | LTI | | | | | | |
| Process | DOTp | | | | | | |
| | # of claims | | | | | | |
| | CAHR | | | | | | |
| | CO2 transport | | | | | | |
| | DPMO | | | | | | |
| Innovation | Suppliers DOT | | | | | | |
| | Suppliers Quality | | | | | | |
| | PPV External | | | | | | |
| Customer | DOTi | | | | | | |
| | OFLT | | | | | | |

Figure 7 - An empty operations scorecard.

**AL Operations Factory X - ALPS Scorecard**

| | |
|---|---|
| Reported Year: | 2016 |
| Reported Month: | 9 |
| Factory/Site: | Factory X |
| Factory Manager: | Name |
| ALPS Driver: | Name |
| Operations Staff: | 100 |

Fill in the 'Basic data' first so that the relevant cells get updated here!


| Actual vs Target | Actual vs Installation Target | Measurement | Unit | Installation Target | 2015 12 | Year Month | 2016 1 | 2016 2 | 2016 3 | 2016 4 | 2016 5 | 2016 6 | 2016 7 | 2016 8 | 2016 9 | 2016 10 | 2016 11 | 2016 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Near misses and unsafe observations - number of resolved | # | 24 | 14 | Target | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 20 | 20 | 20 | 24 | 24 |
| | | | | | 10 | Actual | 12 | 14 | 14 | 18 | 16 | 20 | 20 | 24 | 22 | | | |
| | | Performance Meeting - average Audit Dialogue score | Points (8-40) | 24 | 20 | Target | 22 | 22 | 22 | 23 | 23 | 23 | 24 | 24 | 24 | 25 | 25 | 25 |
| | | | | | 15 | Actual | 13 | 12 | 18 | 15 | 16 | 17 | 19 | 20 | 24 | | | |
| | | Improvement Meeting - average Audit Dialogue score | Points (8-40) | 24 | 14 | Target | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | | | | | 15 | Actual | 13 | 12 | 18 | 16 | 15 | 17 | 19 | 20 | 19 | | | |
| | | 5S - average Audit score | Points (0-100) | 50 | 50 | Target | 55 | 55 | 55 | 57 | 57 | 57 | 60 | 60 | 60 | 62 | 62 | 62 |
| | | | | | 51 | Actual | 52 | 51 | 53 | 54 | 55 | 56 | 53 | 56 | 58 | | | |
| | N/A | SOP Audit Dialogue Improvement - number of completed | # | N/A | 15 | Target | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| | | | | | 17 | Actual | 19 | 18 | 21 | 20 | 21 | 20 | 20 | 22 | 22 | | | |
| | | PRP - number of solved | # | 36 | 25 | Target | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 36 | 36 | 36 |
| | | | | | 22 | Actual | 30 | 27 | 29 | 35 | 36 | 27 | 18 | 26 | 31 | | | |
| | | GB projects - number of delivered L12M | # | 10 | 5 | Target | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 10 | 10 | 10 |
| | | | | | 6 | Actual | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 9 | | | |
| | | BB projects - number of delivered L12M | # | 1 | 1 | Target | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| | | | | | 1 | Actual | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | | | |
| | N/A | *IM - Number of Audit Dialogues* | Days | N/A | 12 | Target | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| | | | | | 8 | Actual | 8 | 9 | 8 | 10 | 11 | 12 | 11 | 12 | 13 | | | |

Figure 8 - An example of the ALPS scorecard.

The goal with ALPS is to achieve a stable and predictable output for Alfa Lavals' customers. This will be achieved by driving performance forward and by reaching the targets set for the four main areas, safety, quality, delivery and cost.

ALPS and its' scorecard are well implemented at Alfa Laval and much material is available for the employees with regards to how they should implement and work with the ALPS scorecard. The operations scorecard is a global scorecard and is mainly worked with outside of the ALPS team. Compared to the ALPS scorecard there is less information available to the employees with regards to how to use it effectively. The operations scorecard gets broken down by factory and their unit managers in to the KPIs/PIs used at a production line level on the performance scorecard. This is done in order to assure that the KPIs/PIs used at a production line level is of importance to the scorecard as well.

The ALPS team does work with the operations scorecard and the performance scorecards at the production line level in the company in the form of audits, which is being done at least twice a month. At these audits the work with the scorecards get evaluated to see if the right measures are being made and if the team responsible for the scorecard are pushing themselves to improve the results measured by the scorecard.

The 15 parameters in the Operations scorecard are standardized within the company and the definitions are available for the employees. The parameters used in the performance scorecard on the production line level within the company is not standardized and the choice which parameters they will contain is up to the factory managers and the people under him or her. Since it is up to the factory managers and their team to choose the parameters on the production line level they are not standardized throughout the company. It is possible that some of the parameters are the same for the different production lines, however this could not be confirmed during this master thesis project because the results of the questionnaires were not detailed enough. Should there be some KPIs that are the same for the different sites performance scoreboards it is not governed by top management. The parameter areas safety, quality, deliveries and cost are however required to be a part of the performance scorecard. And at least one parameter need to be measured in each of those areas by the production line.

One definition that differs however is the one for "Not scheduled time" which is the time that the line is scheduled to not be running. The reason why "Not Scheduled Time" is not a part of the OEE is that if the machine is scheduled not to run the OEE shouldn't be affected, which otherwise would lower the OEE.

The definitions of "Not Scheduled Time" for the sites 1, 2 and 4 revolve around instances where the production is stopped because of holidays, if there are no orders to produce or if they are testing out a new tool/process/product. Smajli & Olsson (2016) found that site 5 uses the lunch and breaks as "Not Scheduled Time". Site 3 uses meetings, breaks and 5S as "Not Scheduled Time". The reason why could be that the production line that is loaded manually and if there is a lack of personnel this production line can not run. However the definition in both site 3 and 5 excludes holidays and the instances that site 1, 2 and 4 bases their definition of. Even if there is a standard definition within the company the standardization is not fully implemented globally.

The definition of the duration of a short stop also differs depending on the site, these are presented in the Table 3 below.

Table 3 - The time definition for short stops at the different sites.

| | |
|---|---|
| Site 1 | 5 minutes |
| Site 2 | 5 minutes |
| Site 3 | 5 minutes |
| Site 4 | 3 minutes |

The sites decide for themselves how they wish to define the short stops and the time limit can be lowered in order to investigate the reasons behind some of the short stops. As can be seen in Table 3 site 3 define short stops to be less than or equal to 5 minutes, but during the investigated period the definition was lowered to two minutes during roughly two months, November and December. This was done in order find root causes behind the short stops.

## 4.3 Downtime & Runtime of the production lines

In order for the company to produce any products and conduct their business the machines need to be running. If the machines are standing still the company is losing money every second since there is no value being created. The production lines that has been investigated at Alfa Laval during this project all suffer from a fairly low share of runtime.

All of the sites except site 5 excludes the "Not Scheduled Time" from the runtime but since the information that has been available from site 5 does not contain information regarding the "Not Scheduled Time", this can not be done for that site.

The reason why the "Not Scheduled Time" has been excluded for the sites where this is possible is because it according to definition (Nakajima, 1988) should not have an impact on the OEE value which is calculated with this data. Because of the difference in definition of runtime and downtime, the value of comparing site 5 with the other sites is limited.

Since the runtime ratio is fairly low for all of the sites Alfa Laval has a good opportunity for improvement if the identified root causes with a major impact on downtimes can be corrected. Alfa Laval works with this by tracking the downtime causes and sending daily reports, which contents are presented in appendix 9, to the different departments in order for them to gain knowledge of the production performance so they know which areas they should focus on improving. These reports however are not read by everyone and some of the operators which had worked at Alfa Laval for a long time did not even know they existed. The downtime causes behind the low runtime is also presented in Qlikview if an employee want more detailed information. In order to improve the production issues are raised to the operators so they know what to focus on and if a large problem is found the company starts a project in order to work on finding a solution.

## 4.4 Downtime causes

In order to analyze the importance and the occurrence of different downtimes the downtime causes has been broken down in to different categories. They are also analyzed at both a production line level and a product level. The five largest downtime causes for each production line and for the products that has been studied are analyzed below. The reason for doing the analysis at both a production line level and for a product level is to see if the time distribution between downtime causes are product or site specific.

### 4.4.1 Production line level

The largest downtime causes, by Alfa Laval called "Reason Descriptions" for each site is presented in Table 4 below as a percentage of the total downtime. The data regarding the downtimes of site 4 was compiled by Smajli and Olsson (2016).

**Table 4 - The top five downtime causes at the different sites.**

| Site 4 | |
|---|---|
| Nr 1 | xx% |
| Nr 2 | xx% |
| Nr 3 | xx% |
| Nr 4 | xx% |
| Nr 5 | xx% |
| **Total** | **xx%** |

| Site 1 | |
|---|---|
| Nr 1 | xx% |
| Nr 2 | xx% |
| Nr 3 | xx% |
| Nr 6 | xx% |
| Nr 7 | xx% |
| **Total** | **xx%** |

| Site 2 | |
|---|---|
| Nr 1 | xx% |
| Nr 2 | xx% |
| Nr 8 | xx% |
| Nr 9 | xx% |
| Nr 10 | xx% |
| **Total** | **xx%** |

| Site 3 | |
|---|---|
| Nr 1 | xx% |
| Nr 2 | xx% |
| Nr 3 | xx% |
| Nr 11 | xx% |
| Nr 12 | xx% |
| **Total** | **xx%** |

These five different downtime causes amount to a large amount of the total downtime for each site. This in turn can be utilized by Alfa Laval in order to know which areas to focus on for future improvement work. A more detailed view of the downtime causes for the different sites can be seen in appendix 10, 11 and 12.

Reason Nr 2 can be found among the top five downtime causes for all of the different sites making it of high interest at both a global level as well as a local level if the company aims at lowering its' downtimes. Another downtime cause that is a commonality between the sites are cause Nr 1. Finally downtime concerning reason Nr 3 can be found in the top five downtime causes for all of the sites except site 2. Figure 9 shows the magnitude of the downtime cause "Nr 1" contributes in relation to the total downtime for each site.

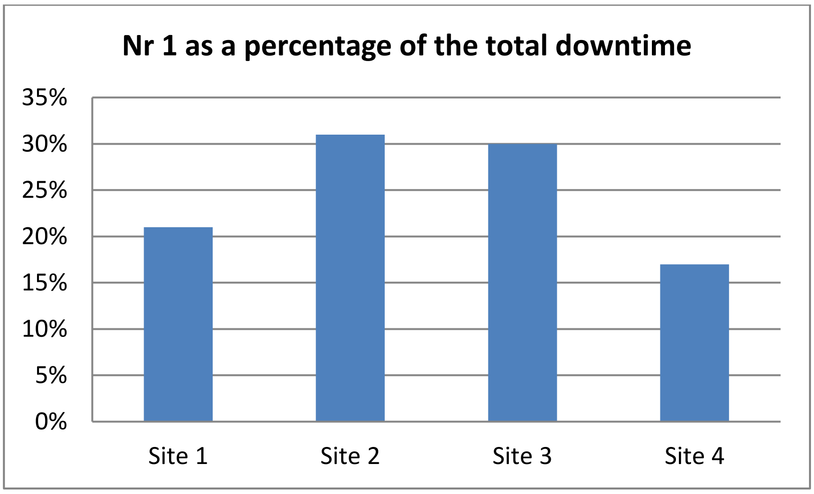



**Figure 9 – Reason Nr 1 seen as a percentage of the total downtime for each site.**

As can be seen in both Table 4 and Figure 9 cause Nr 1 range from 17 % to 31 % of the total downtime depending on the site but it is the number one cause of downtime for each site.

## 4.4.2 Product level for division A

Studying individual products and not only the entire production lines, as done above, makes it possible to see if and how the production performance for the products differ from each other. It is also possible to see if some products are more prone to generate stops, and it is also possible to see the specific stops that the product in question is generating. The different products that were chosen for the different sites were the product 1 for all of the sites within division A, product 2 in site 1, product 3 in site 2 and product 4 in site 3. These products were chosen because the personnel that were interviewed from each site said they wanted these products to be analyzed further. Product 1 were chosen from each site in order to be able to do a comparison.

What was found for all of the sites were that downtime cause Nr 1 is prevalent in all of the products that has been studied during the master thesis. Another common downtime cause is reason Nr 2. Every product except product 3 produced by Site 2 has reason Nr 2 as a part of the top five downtime causes.

When comparing the products it can be seen that the downtime causes are largely site dependent instead of being product dependent. There are some exceptions to this dependency as not all of the top five downtime causes are shared between the specific products studied and the production line level for each site, but four out five downtime causes are shared. Although many downtime causes are shared between the products at a site the placement in the top five downtime causes may differ between them.

### 4.4.3 Product level for product division B

The products that were chosen to be analyzed further from site 4 were products 5, 6, 7 and 8. The data regarding these products were compiled by Smajli & Olsson (2016) during their project. What can be seen from this data is that reason Nr 1 is the biggest downtime cause for all of the products except one, product 7, where it is ranked second. Almost all of the top five downtime causes are shared between the products, showing that the downtime causes are to a large extent not product driven but site dependent. However, the ranking for the different causes differ somewhat between the products showing that even though there are similarities the importance of what to improve can be different between the products.

### 4.4.4 Comparison between the products in division A and B

A similarity between both divisions is that both reason Nr 1 and setup times are some of the largest downtime causes.

One post that stands out from Site 4 which is not found amongst the products in division A is reason Nr 18. This is a downtime that does not show a root cause, it is simply stating that a downtime occurred. Since the root cause is unknown for these stops they are hard to improve.

### 4.4.5 Downtime caused by reason Nr 1

As presented in Table 5 the portion of downtime that is taken up by reason Nr 1 is significant for all of Alfa Laval's sites.

**Table 5 - The influence of reason Nr 1 for the different sites.**

| | Reason Nr 1 as a percentage of the total downtime | Percentage of the total amount of occurrences that are because of reason Nr 1 |
|---|---|---|
| Site 1 | 21 % | 79 % |
| Site 2 | 31 % | 56 % |

| | | |
|---|---|---|
| Site 3 | 30 % | 90 % |
| Site 4 | 17 % | 67 % |
| Site 5 | Unknown | Unknown |

Reason Nr 1 I very loosely defined and does not in itself contain a specific root cause. This makes it very difficult to track the root causes behind these stops. Since the root cause does not get registered the only people that can make an educated guess as to the common root causes behind the stops are the operators. But even they can at most make an educated guess. Since the stops constitute such a large amount of the downtime as they do, it would be important to identify the root causes behind them.

## 4.5 Time between failures and Time between runtimes

By compiling the production data, information regarding the time between failures and runtimes can be gathered as well. The distribution of downtimes and runtimes can be used by the personnel working closely with the production line in order to gain more detailed information of the statistical probability that a stop will occur within a specified timeframe. The downtimes distribution in can provide information on the average duration of a stop.

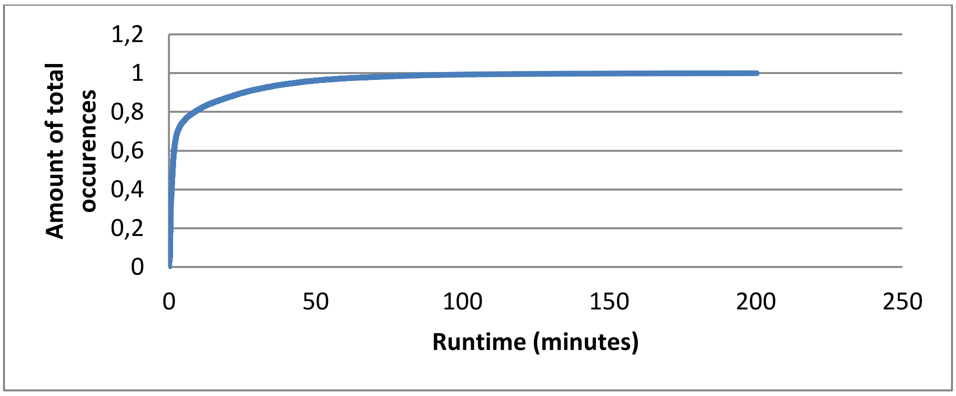



**Figure 10 - Distribution of Time Between Failures for site 1 during 2015.**

Figure  above shows the share of number of stops in relation to runtime. As can be seen in the figure 80% of the stops occur within a runtime of just under 9 minutes. This statistical knowledge is not measured or tracked by Alfa Laval at the moment. The same analysis has been done for the sites 2, 3 and 4 which is presented in Figure 6, Figure 72 and Figure 83.

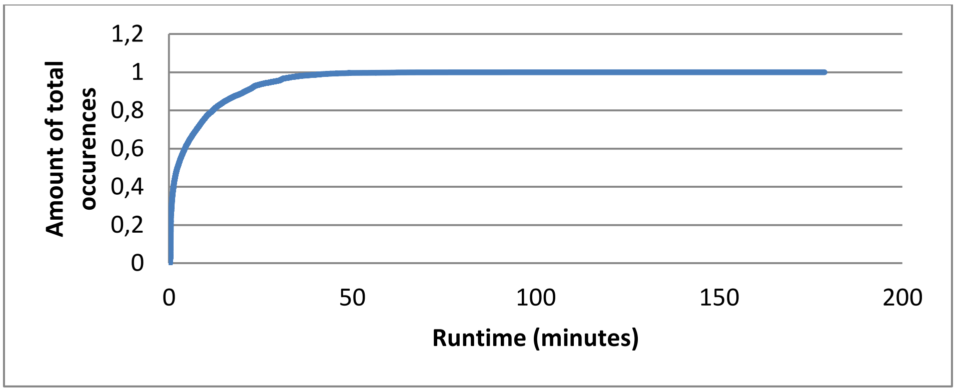



**Figure 6 - Distribution of Time Between Failures for site 2 during 2014-2015.**

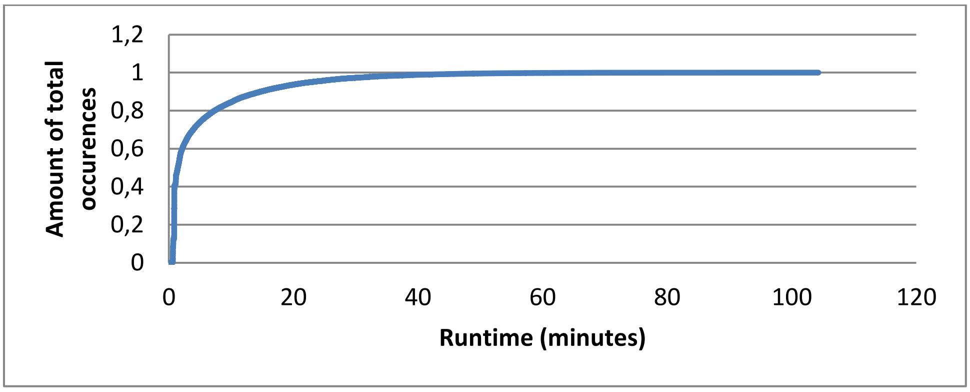



**Figure 72 - Distribution of Time Between Failures for site 3 during 2015.**

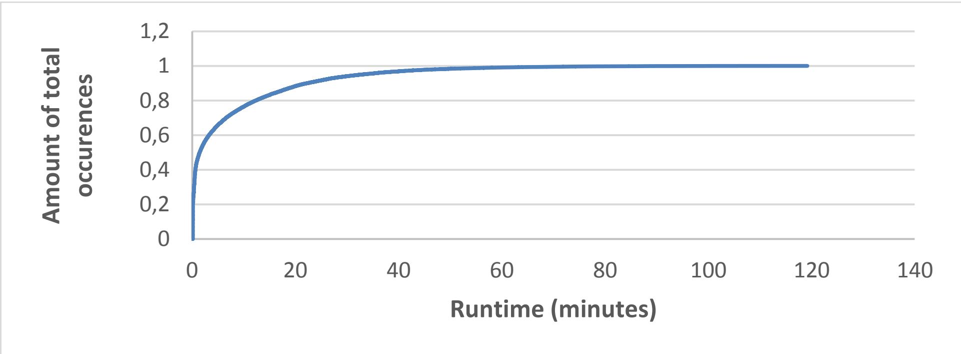



**Figure 83 - Distribution of Time Between Failures for site 4 during 2015.**

As can be seen in Figure 0-13 above the Time Between Failures is usually fairly short. By having a risk of failure that is higher than 80% within 15 minutes of running the machine it is highly likely that the production lines will have a stop during the breaks. However what should be pointed out when viewing this data is that some of the stops that occurs are only a couple of seconds long. This is not long enough for an operator to acknowledge the problem and start the machine again. This points to a misalignment in the line, meaning the transfer band could be working a second too slow with regard to another part of the production line and therefore making it wait a second or two before being able to produce the next plate. This is however only a probable cause to why these stops occur. In order to know why these stops happen an investigation is required.

In order to see how long time a stop usually lasts the same distribution charts were made for the Time Between Runtimes, shown in Figure 104, Figure 115, Figure 116 and Figure 127.

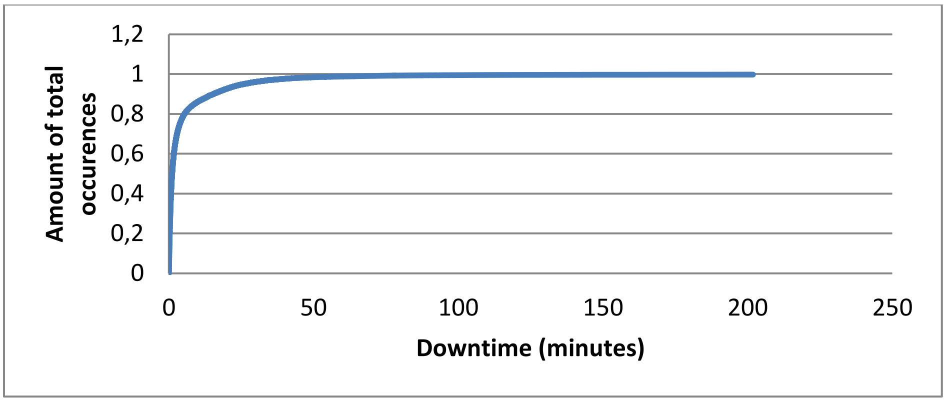



Figure 94 - Distribution of Time Between Runtimes for site 1 during 2015.

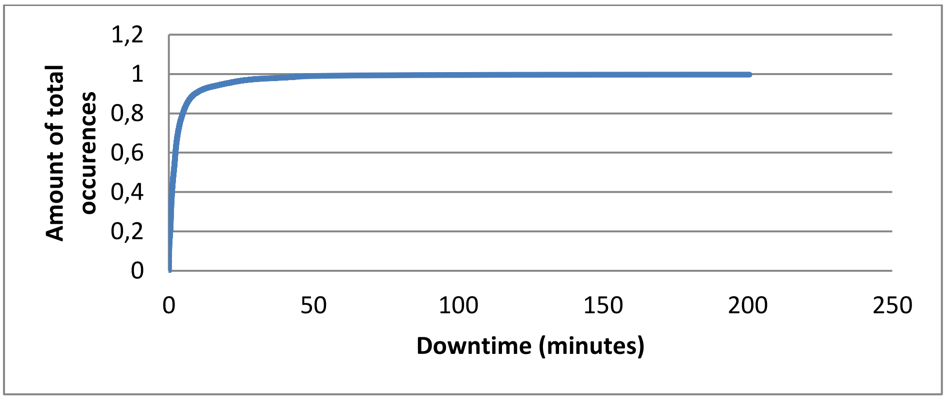



Figure 105 - Distribution of Time Between Runtimes for site 2 during 2014-2015.

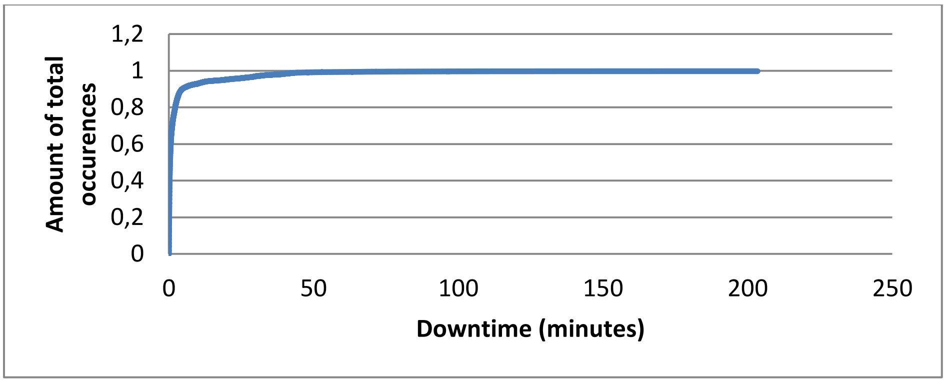



**Figure 116 - Distribution of Time Between Runtimes for site 3 during 2015.**

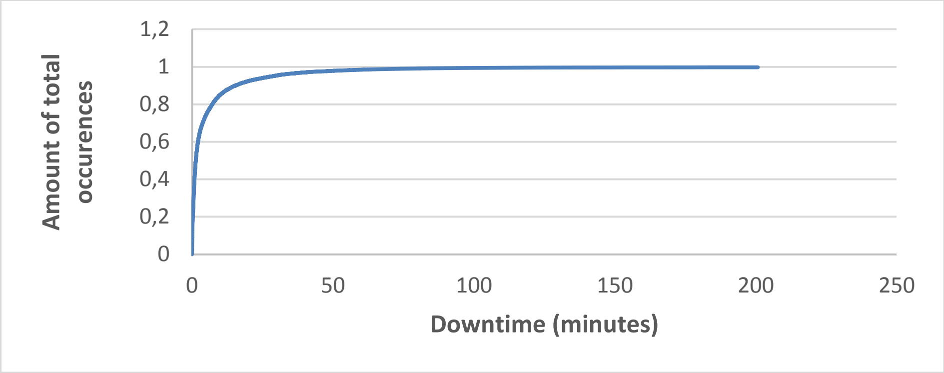



**Figure 127 - Distribution of Time Between Runtimes for site 4 during 2015.**

As can be seen from the charts most of the downtimes are fairly short before resuming production once again, 80 % of the stops that occur gets resolved within six minutes for the sites in site 1, 2 , 3 and in 7,2 minutes in site 4. Site 3 solves 80 % of the stops that occur within 2,17 minutes which is the shortest time for any of the sites studied. This however could be because the production line is manually operated in site 3 as opposed to the other sites which are either robotic or automated to a high degree. Finding solutions to a failure in a more complex production line often takes a longer time than a simpler one. This could be because the more complex lines consist of more parts whereas a manually loaded production line has far less parts that can produce a failure. These statistics, regarding the distribution of Time Between Runtimes are not tracked by Alfa Laval at the moment.

# 4.6 Discrepancies in the data

During the project some discrepancies have been found in the data pertaining to the speed losses as seen in Table 6. In the table it can be seen that for a certain interval in time when the runtime for the machine is zero, there are still a number of units produced.

Table 6 - Products being registered as being produced in zero seconds.

| IntervalSeconds | GoodUnits | BadUnits | TotalUnits | runtime | Idle | AvailabilityLosses |
|---|---|---|---|---|---|---|
| 1970 | 46 | 0 | 46 | 0 | 0 | 1970 |
| 0 | 13 | 0 | 13 | 0 | 0 | 0 |
| 943 | 10 | 0 | 10 | 0 | 0 | 943 |
| 3599 | 8 | 0 | 8 | 0 | 0 | 3599 |
| 721 | 8 | 0 | 8 | 0 | 0 | 721 |
| 624 | 7 | 0 | 7 | 0 | 0 | 624 |

This is of course an impossibility since it is not possible to produce something while the machine is not running. Another discrepancy that was found during the project is that the production rate far exceeds the ideal cycle time a number of times, as can be seen in Figure 18 and appendix 13.

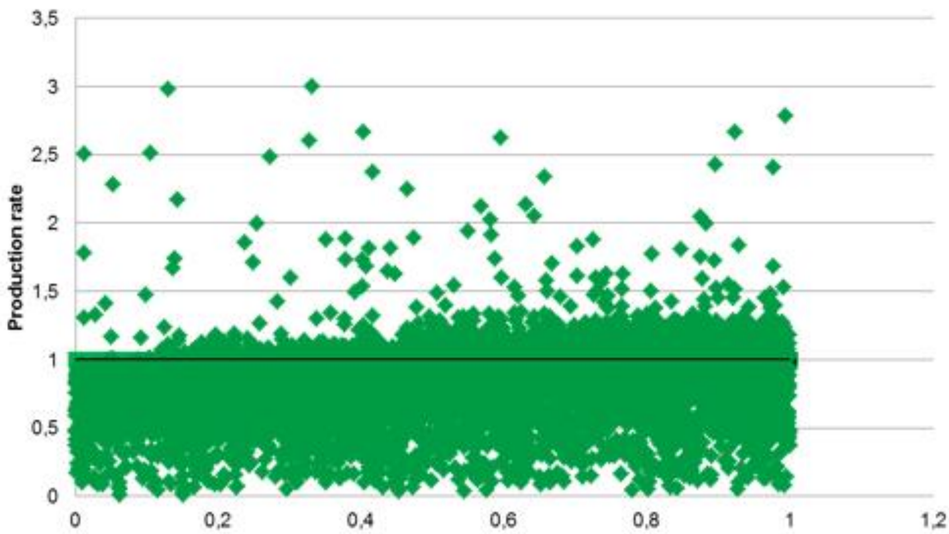



Figure 18 - Example of how the distribution of production rates differ according to the production data for site 1 during 2015.

As can be seen there are a couple of different discrepancies. Products being produced in zero seconds is obviously impossible yet it has been found in the data in all of the sites that has been investigated. This is obviously impossible and can not happen in reality. Therefore it can be concluded that there is something wrong with the data that has been analyzed.

The second discrepancy is that the production rate sometimes is higher than the theoretical rate. As explained by Nakajima (1988) the ideal production rate should be based on the equipment capacity as designed. Therefore it should by definition not be possible to have a production rate that is higher than 100%. The production rates for all of the different sites studied in the master thesis contain rates higher than 100%, on a rather high number of occurrences. This would indicate that the cycle time stored in the system is higher than the equipment is capable of producing at.

These discrepancies affect  the performance which in turn affect the OEE, the range of how the discrepancies affect the OEE is not studied in this master thesis. If this is of interest to Alfa Laval another project would be needed in order to map them.

# 4.7 OEE

Alfa Laval uses an alternative version of the OEE definition they have defined themselves, which can be seen in appendix 4. The biggest differences between their and Nakajimas version is the definition of speed losses and the use of rate of quality products. Speed losses in Alfa Laval's version is based on pure performance losses. Nakajimas version also contain minor stoppages which Alfa Laval places in the category "Downtime losses".

The rate of quality products is called quality at Alfa Laval and at present it is not utilized during the calculation of the OEE, with the reasoning that they are very near 100% in quality. So in their OEE calculations the quality is always 100% which means it has no impact on the OEE.

During the project work it was found that the target values for the OEE had not been changed for any of the years stored in Qlikview. In site 3 they had even gotten a higher OEE value the previous year than the target value was set at for the following year, meaning the target goal was to do worse than they had the previous year.

OEE is calculated and visualized with the software Qlikview, based on the data gathered by the MES. It was not clarified how the raw data was assembled in order to calculate OEE, therefore the Alfa Laval definition was used together with the raw data from MES to calculate the OEE and to compare with the results from Qlikview. Today OEE is measured at all of the sites and the people working close to the production have the option of getting daily, weekly and monthly reports regarding the OEE. It is also possible for them to see the OEE at both a production line level and a product level in Qlikview if they so choose. The OEE was studied at both a production line and a product level in order to gain a deeper understanding of the production of the different sites. Since there have been problems with the use of Qlikview in site 2 no data could be gathered from Qlikview from that site. And since the "Not scheduled time" could not be separated from the rest of the production data from site 5 the OEE has not been calculated from that site.

## 4.7.1 OEE at a production line level

The OEE values for the different sites that have been calculated using the raw data provided for the master thesis project. The calculations were done using the entire amount of data provided, excluding only two instances that were also excluded in the data used by Qlikview. The OEE calculations for site 4 were taken from the results obtained by Smajli & Olsson (2016).

The values obtained for the OEE is far from the world class level as defined by Nakajima (1988) in TPM, which according to him is an OEE value of 85 % or higher. If Alfa Laval is aiming at a word class level in regards to the OEE then they have a long way to go. What can be noted is that the speed losses for site 3 is actually a negative number, making it a speed gain. This indicates that the theoretical cycle times used in site 3 are set too slow since they are actually producing units faster than what is theoretically possible according to their definition. In Qlikview the OEE for site 3 is also higher than the availability even though the performance is reported to be 100 %. Another important point to make regarding site 3 is that the loading time and running time differ from the values used in Qlikview. This is the reason why the OEE values obtained for site 3 differ so much compared to the one presented in Qlikview.

When comparing the calculations done during this project with the values obtained from Qlikview all of the sites except site 1 had a higher OEE value in Qlikview than was calculated, site 1 instead having a higher calculated value. The availability values obtained corresponds with the value in Qlikview for site 1 but differs for the rest of the sites. The performance values that were calculated correspond fairly well with the values in Qlikview for all of the sites although there are some differences.

### 4.7.2 OEE for division A at a product level

In order to understand the problems that the production faces the OEE was analyzed at a product level as well. By doing this differences and similarities can be seen between the products and between the sites.

The calculations showed that the availability is lower at a product level when compared to the production line level for the sites 2 and 3, but higher for site 1. The opposite is found for the performance, i.e. that the performance is higher for the site in site 1 at a product level than at a production line level and it is lower for the sites 2 and 3. For site 1 this results in a product that has a lower than average OEE for all products and for the sites 2 and 3 product 1 has a higher than average OEE for all products when compared to the production lines. When comparing performance between the calculations and Qlikview it is seen that they differ for all of the sites, just as it did on a production line level. Since Qlikview only presents their values as integers it is not possible to say if the availability values corresponds for site 1 or not. The calculated value for availability however does not correspond with Qlikview.

Product 2 has a near perfect performance according to the data that was supplied. The availability is also higher than at the production line level which results in a much higher OEE. The OEE value presented in Qlikview for the product is however a bit strange since it should be a different value based on the availability and performance. Product 3 in site 2 has an OEE that is pretty close to the average at the production line, slightly lower availability and slightly higher performance. Product 4 in site 3 has a higher availability and slightly lower performance than the production line average, resulting in a higher OEE.

### 4.7.3 OEE for division B at a product level

The OEE was calculated for four different products produced in site 4. The products were chosen by employees from site 4 to be studied in Smajli and Olssons (2016) project and the production data used to do the calculations is from 2015. The products chosen are product 5, 6, 7 and 8. The actual calculations were however done during this master thesis project.

From the calculations it can be said that the availability is practically the same as in Qlikview. There is however a difference when comparing the performance. For product 5 the difference is large and for product 6 the difference is small. Qlikview only uses integers so it is not possible to say if products 7 and 8 has any differences at all. The only product to have an OEE value that is above the average production line level is product 8. Product 6 have a higher performance value than the production line average but the availability value is lower. Products 5 and 7 have both a lower availability and performance than the average production line level.

## 4.8 PIs and KPIs

The difference between Performance Indicators (PIs) and Key Performance Indicators (KPIs) according to employees within Alfa Laval is that KPIs are used in the higher levels of the company, for instance in the Operations scorecard, while the PIs are used in the lower levels of the company, for instance in the performance scorecard. A compilation of the PIs and KPIs used by the production in site 1 can be found in appendix 14. In addition to those the different production lines receive reports daily with information regarding the OEE and the top five downtime causes among others, the contents of the report can be seen in appendix 8. The information that those reports contain is the same for all of the sites, though the data is specific for the production lines.

The KPIs are developed using a top-down strategy meaning that the KPIs are defined at the top level. These KPIs are then what makes up the operation scorecard. The operation scorecard is used globally and at both site level and factory level. The factory managers and their unit managers then break down the KPIs and their goals from the scorecard to the KPIs/PIs used at a production line level. During the work with mapping the KPIs it was found that the links between the production line levels KPIs/PIs and the scorecards KPIs can be hard to understand, or in some cases does not exist. There is a file containing limited information regarding the 15 KPIs used in the scorecard, but a complete compilation of the KPIs and PIs and information regarding them do not exist. The department of Alfa Laval Production System (ALPS) has decided that the categories of safety, quality, delivery and cost must be presented at all levels and every work cell has to have at least one KPI within each of those categories. ALPS also audits the performance boards containing these PIs in order to see that the work with the PIs is progressing.

For site 1information was gathered in order to map the KPIs/PIs used at the production line level. Questionnaires were sent out to the sites in order to gather information and do a mapping for the other sites as well. Unfortunately due to the answers not being specific enough this was not possible to do. As can be seen in appendix 14, half of the KPIs/PIs at a production line level belong to the cost category. At the factory level the KPIs pertaining to costs only stand for a quarter of the amount of KPIs. Seen in Table 7 is Alfa Laval's prioritization of the importance of the areas of KPIs, going from the top to the bottom in falling importance.

**Table 7 - Alfa Laval's prioritization of the importance of KPIs.**

| Importance to Alfa Laval | Area of KPI |
|---|---|
| 1 | Safety |
| 2 | Quality |
| 3 | Delivery |
| 4 | Cost |

It can be noted that the importance of the areas do not correspond to a higher amount of KPIs for neither the production line level or at the factory level, which can be seen in appendix 14. The operation scorecard is used at both a factory and a site level with very small differences between the levels. The only difference is that the factory level contains information if something deviates or something special has happened in regards to the four areas presented in Table 7. This high similarity leads to easily aggregated KPIs between the two levels. The production line level and factory level are not as similar as the factory and site levels making the aggregation of KPIs harder to see in this case. In order to see what connections exist and how the KPIs aggregate from the bottom level and up the KPIs were studied and the connections were mapped. By studying the parameters included in the definition of each KPI in the scorecard and then study the same for the PIs at a production line level the connections were found. These connections can be seen in appendix 15. The mapping of these connections were made by the author so it is possible that Alfa Laval has found other connections missed here. The PIs labeled efficiency and productivity used in the performance scorecard is defined with the help of the total time and the direct time making these heavily connected to each other. The only difference between the two is that the efficiency measures how well the time directly used when working with the production lines is utilized and productivity measures how well the time is utilized when looking at all the available production time.

# 5 Findings

The findings of this project of aim to answer the problem definitions the project were faced with answering.

## 5.1 Root causes behind the current production performance

Alfa Laval has a problem with regards to their runtime/downtime ratio. The production lines studied during the project were only running a low amount of time when excluding the "Not scheduled time" from the data. This low level of availability directly limits the OEE value. In order for Alfa Laval to achieve a higher OEE they have to focus on minimizing the downtimes.

The company track the downtimes and their root causes fairly well. For the different sites there exist many different downtime causes from which to choose. As presented in table 2 the amount of "Reason Descriptions" vary between 23 and 86 depending on which site you look at. Even though they track many of the downtimes and their root causes there are some categories within the "Reason Descriptions" for downtimes which do not lead back to the root cause as to why it happened. Two such as the categories are the "Reason Descriptions" "Nr 99" and "Nr 1". The "Reason Description" for Nr 1 is the largest downtime category with unknown root causes. It is in fact the single largest reason for downtime for the sites investigated in this master thesis independent of the root causes being unknown or not.

Another of the most common downtime causes are reason Nr 2. Every site studied have some form of stop related to reason Nr 2 in the top five downtime causes. Downtimes related to reason Nr 3 is also present in the top five downtime causes for all of the sites studied with the exception of site 2.

The top five downtime causes for each site make up between the majority of the total amount of downtime the sites have, meaning that the rest 18-84 downtime causes make up a minority of the total downtime.

## 5.2 Variations in data

For the time periods studied during the master thesis there were some differences between the sites when reporting the production data. The main difference was that site 5 did not utilize the MES system in order to track the downtimes as the other sites did. At this stage the use of MES in site 5 is initiated. Another difference that was found was that the same definition for "Not scheduled time" were not used at all of the sites. So there seems to be a lack of standardization between the sites studied. Since site 3 uses a manual loading of the production line some of the differences found should be there, but not using holidays and the reason description "Nr 88" as a part of the definition of "Not scheduled time" can not be explained by this.

The “Reason Descriptions” are decided locally at each site but they get help with the implementation from the head office. Since they are decided locally there are no standardization of them but many are similar since they are used to describe the work with production lines. How the education of the operators is done regarding the use of the “Reason Descriptions” is up to each unit manager and team manager this lack of standardization leads to varying quality regarding the education of the operators.

The KPIs used in the operations scorecard are standardized globally by the company but the PIs in the performance scorecard are not. These are decided locally by the different factory, unit and team managers. The standardized parts of the performance scorecard is that it must contain at least one PI in each of the categories of safety, quality, delivery and cost. The prioritization of these areas are also standardized in the order they were written with safety being the most important one.

There are not much information that is easily accessible regarding the KPIs and PIs used by the company, making it hard to understand why that particular KPI/PI structure was chosen. Even if there were definitions available it was impossible to understand some of them without deep prior knowledge. Some employees expressed that they thought it was hard to understand why some KPIs are used and how the KPIs/PIs are connected to each other. This shows that there is a lack of knowledge within Alfa Laval with regards to their work with their performance measurement system.

## 5.3 Usage of data

In order to measure and use the KPIs within Alfa Laval a lot of information is gathered and stored. There is even data stored that can be used in order to visualize the KPIs within Alfa Laval better than today. However, the operators might have registered the wrong downtime, and some of the downtime, at least 17-31 % depending on the site, has unknown root causes. Because of this the data can not be said to be one hundred percent reliable when tracking the KPIs. This unknown segment is also a problem for the company since this makes some of the KPIs less useful than they can be.

The reliability of the data stored is also a problem regarding the performance. During the master thesis project it was found that the production rate varied greatly at all of the sites, and some instances of products being produced in zero seconds occurred as well. Since this data is used to calculate the OEE the value shown might not be correct. There were also some differences between the values stored in Qlikview and what was calculated using the raw data from MES during this project. The reason behind these differences could not be identified during the time of the project but these differences further accentuates the need to investigate if the data is reliable.

During this project the Time Between Failures (TBF) and Time Between Runtimes (TBR) were tracked, see chapter 4.5. This is not done by Alfa Laval at the moment but is fully possible to do by using the data provided by the MES and visualizing it in Qlikview. What was shown when analyzing the data in this way was that for all of the sites the risk of having a failure within 15 minutes of starting the machine is over 80 %, with site 3 exceeding the 80 % risk of failure fastest (under 9 minutes). The TBR is lower for the sites with 80 % of the stops being solved within 6 minutes for the sites within division A and 7.2 minutes for site 4. Site 3 solves the stops the fastest on average and 80% of the stops are solved within 2,2 minutes.

# 6 Discussion

The discussion section aim to bring focus on a couple of areas that could be of high interest to Alfa Laval when trying to improve their production performance and PMS.

## 6.1 KPIs

One of the challenges Alfa Laval faces is how to make the work force feel motivated to work with the KPIs that are available. The operators have during interviews expressed that they would like more information regarding the production line they work at. Sometime they get praise for getting a high OEE value during a week where they themselves feel like they have not worked so hard since they only needed to do setup for a few orders and then let the machine do the work. Other weeks they get scolded for a low OEE value when they have worked very hard with many setups and changes between orders. Since they feel like the OEE value does not reflect the reality of the production and the work they do it is hard for them to feel motivated and understand the need to work with it. To encourage the workers Alfa Laval would benefit from either finding a better corresponding KPI that can be used or by visualizing the OEE value in a way that enables the workers to see how they can affect it. In the section suggestions an alternative way of visualizing the OEE that could have great potential of achieving a higher motivation for the departments to actually work with it.

The interviews that has been conducted and the responses from the questionnaires give the impression that many employees find it hard to understand how the KPIs/PIs used at a production line level aggregates to the operation scorecard/ how these are connected. During the master thesis project it has also been challenging to find someone who can explain why the KPIs and PIs that are used today were chosen. This indicates that knowledge of the KPI structure is not spread fully throughout the company.

When the KPIs/PIs were studied by the author with the help of employees of Alfa Laval some of the KPIs in the operations scorecard were found to not have any connections to the production line level, however, the need for those KPIs to be connected is not certain. It all depends on how the company has set up their departments and on which department the responsibility for those specific KPIs falls. Should the responsibility to keep track of the $CO_2$ emissions be at a factory level it is not necessary for the production line to track these separately. Should the KPIs be handled at a lower level it may even increase the work load for the employees. It is important to have a discussion of the value of breaking down or placing the tracking of the KPIs to a lower level in order to make sure that the company actually gains something from doing so.

Another important discussion to have is how useful the KPIs at the production level are for the operators. The questions of why they are measured, how they are measured, and for whom they are measured need to be answered before implementing new or changing the existing KPIs/PIs. In the end they need to be useful at the level that they are presented at, making them tools for improvement for the employees.

# 6.2 OEE

OEE is measured by Alfa Laval at their different sites but it is not used to drive the production improvement forward. In site 3 they had even gotten a higher OEE value the previous year than the target value was set at for the following year, meaning the target goal was to do worse than they had the previous year. Having a non-changing target that is sometimes lower than the actual OEE for the previous year indicates that the OEE-value is not a prioritized measurement at the moment. When asking the personnel about it they explained that they thought that it was a measurement that was hard to work with since so many different things affect it. They also explained that it is hard to motivate the operators using the OEE since it is hard for the operators to see how they can affect it.

As established by Andersson and Bellgran (2011) there are both potentials and challenges with using OEE as an improvement driver. One of the challenges are how to define the measures. In order to have a comparable OEE it must be standardized within the company, which is somewhat lacking in Alfa Laval today with regards to the "Not scheduled time". However if the implementation of OEE is done in a structured and standardized way Andersson and Bellgran (2011) states that it is a good driver for improvements in order to achieve process stability. Should the company strive to use it in a more active way they would gain from establishing what they are aiming for and setting clear targets that they can achieve.

## 6.2.1 Improvement work concerning OEE within Alfa Laval

There has been work conducted at Alfa Laval in order to increase understanding of the effects of OEE and to inspire using the OEE more as a tool for improvement instead of only being a measurement. Table 8 which was done by employees at Alfa Laval shows the effects OEE has on costs if it increased but there is no change in the production volume (the flexible cost does not include the material cost in these examples).

**Table 8 – The changes of cost when OEE increases.**

| OEE | 50% | 60% |
|---|---|---|
| Flexible cost | 5 | 4,2 |
| Fixed cost index | 5 | 5 |
| Total COST | **10** | **9,2** |
| Units | 10 | 10 |
| VA cost | 100% | 92% |

As can be seen there is a reduction of costs by 8% with an increase of the OEE from 50% to 60%. However, an increased OEE together with an increase in production volume leads to even larger cost reductions, as shown in Table 9.

**Table 9 – The changes of cost if the production volume increase at the same rate as the OEE.**

| OEE | 50% | 60% |
|---|---|---|
| Flexible cost | 5 | 5 |
| Fixed cost index | 5 | 5 |
| Total COST | **10** | **10** |
| Units | 10 | 12 |
| VA cost | 100% | 83% |

Since 12 units are produced in the same amount of time as it took to produce 10 units before, the cost for each of those units will go down. These examples show that the costs of production are highly connected to OEE. Therefore the OEE can be used as a cost reduction indicator leading to an even higher usefulness. These calculations can be done using the real values for the costs of a product giving very useful feedback for the company regarding the cost savings that can be achieved from various projects. Should the real values be used they need to be as close to reality as possible since anything else would give a false view of the results.

# 6.3 Downtime causes

The downtime reasons focused on in this discussion are reasons Nr 1 and Nr 2. They are discussed since they can be found in the top five downtime reasons for all of the sites studied which implies that the problems are global to the company and therefore an area which needs attention.

## 6.3.1 Downtime reason nr 1

Reason Nr 1 is the number one downtime cause for all of the sites investigated and no root cause can be identified for this downtime category. Although it is hard to identify the root causes behind them they should have a high priority within Alfa Laval in order to improve the effectiveness of the production lines. An idea expressed by employees during interviews has been to utilize a number of automatic alarms that register the root cause behind the stop in order to gain more knowledge of the stops. This would also mean that there would be less stops for the operators to register making them less stressed. If installed correctly the automatic alarms would probably have a higher rate of correct registrations since the human error is removed from the equation. Something that has been done by Alfa Laval in order to investigate the stops before has been to create a more specific definition for what counts as a stop caused by reason Nr 1. This however means more work for the operators and can make them more likely to commit mistakes or register the wrong downtime cause. In order to lessen the likelihood of mistakes in registration a couple of things can be tried. Giving clear instructions to the operators that during a specific time period their main duty is to register the stops as correct as possible. By doing this the stress from having to keep the production up and running and at the same time registering the downtimes would decrease. Another solution to getting more accurate data regarding the short stops is to utilize an extra employee whose only job is to register the reasons behind every stop that happens. By doing this for a period of time the root causes behind the short stops can be found. However both of these ideas would lead to a higher cost for the company during the periods they are in use, but if the company identifies many of the root causes behind the short stops it could be well worth it.

Another idea Alfa Laval could try is to utilize the information gathered through the use of such attempts as using a more specific definition of reason Nr 1 at the different sites globally and see if the results can be applied at more than the particular site doing the testing. The company can also try to make the system even more reliable than today by working with the software and the user interface. By minimizing the risk of committing mistakes and making it harder to register the wrong downtime causes the data will be closer to reality than today. Standardizing the education of the operators in regards to using the MES, "Reason Group Descriptions" and "Reason Description" may also lead to a higher lowest level in the company and therefore lowering the erroneous registrations.

### 6.3.2 Downtime reason Nr 2

Different kinds of stops depending on reason Nr 2 can be found in all of the sites top five downtime causes which should make it a priority the same as reason Nr 1. During interviews it has been found that the orders are split in to small batches in the production planning. Because of this a large amount of stops related to reason Nr 2 are needed in order to follow the planning. This in turn leads to a large amount of downtime.

A remark from the operators is a slight frustration caused by slow response from the MES. Due to this a registered stop could consist of more than one downtime cause. This could lead to the operators registering three different downtime causes as only reason Nr 2. This gives the downtime contributed by reason Nr 2 an inflated value which can not be trusted fully. But it is hard to tell how inflated the value becomes since it is based on something that has been said and not on data.

## 6.4 Increased use of the MES-data

Qlikview is very useful for visualizing production data and presenting it in a format that is easy for the employees to understand. Today it is used to present many measurements from the production, such as information regarding downtime and OEE, but since the amount of data that is gathered in the MES-system is so broad Qlikview could present even more detailed information. By dividing the OEE in to different parts it is possible to create a KPI that is understood by the recipients more easily and the data to do so is already stored in the system used today but it is not used to that extent.

# 6.5 Corporate standards

As it stands today there exist a standard for many of the measurements within Alfa Laval. The OEE definition for example is the same for all of the sites. But even though it is the same on paper does not mean that it is used the same way in practice. Is has been found that some sites define certain parameters of the OEE differently than others, such as the “Not Scheduled Time”. Since there are sites that use manual labor for loading the production line and there are sites that are automated there can exist differences in what counts as a “Not Scheduled Time”. However some of the differences that were found could not be explained by this reasoning, such as not counting holidays as a part of “Not Scheduled Time”. It is believed that the company would gain from having a clearer definition of OEE and follow up on its use in order to assure that it is used according to definition at all of the sites.

The performance scorecard is standardized to the extent of having the four categories safety, quality, delivery and cost. After that it is up to the different factories or even the cells to decide what should be measured and counted as a PI or KPI. The process and thoughts behind choosing these KPIs/PIs may or may not be documented, but for now the information is not easily available. It has also been expressed by employees that they do not fully understand why certain KPIs/PIs are used. In order for the employees to understand the KPIs/PIs better the documentation process could be standardized. Should the documentation be made available globally it could be used as a system for benchmarking tool, and as stated by Alarcon et al. (1998) benchmarking enables the company to identify performance gaps and to develop continuous improvement. It may become possible to use the documentation as a tool for working with the KPIs/PIs proactively instead of reactively as well. An example of such a documentation and a broader explanation is presented as a suggestion in chapter 7.3.

# 7 Suggestions

These suggestions are made with regards to the analyzed data in order to fill the gaps that has been perceived during the master thesis project concerning the work with KPIs, PIs and data collection.

## 7.1 Directed OEE

The OEE value that is used today at Alfa Laval is not been a prioritized measurement during the most recent years. It is mainly used as a reporting measure and not as a tool for improvement. In fact the target value for the OEE has not been changed in three years for some of the sites that were studied. A reason for this could be that the employees find it hard to work with since it affects so many different departments or that the recipients of the OEE reports that get sent out do not see the value of it. In order to better motivate the employees the OEE value could be more directed to the departments with the possibility to influence it. If the information is directed they can see how their efforts affect the OEE. Directed KPIs is of importance in more than just to motivate the operators, it also creates more detailed data which can be used when identifying improvements. In Figure 19 above a proposed division of the OEE can be seen. It shows how the OEE is lowered from 100 % to 70 % due to different factors causing production losses. This is a model that was created using the data already available within the MES-system. In the same model the target value for the different parts can be visualized as well giving a clear view of how much improvement is needed.

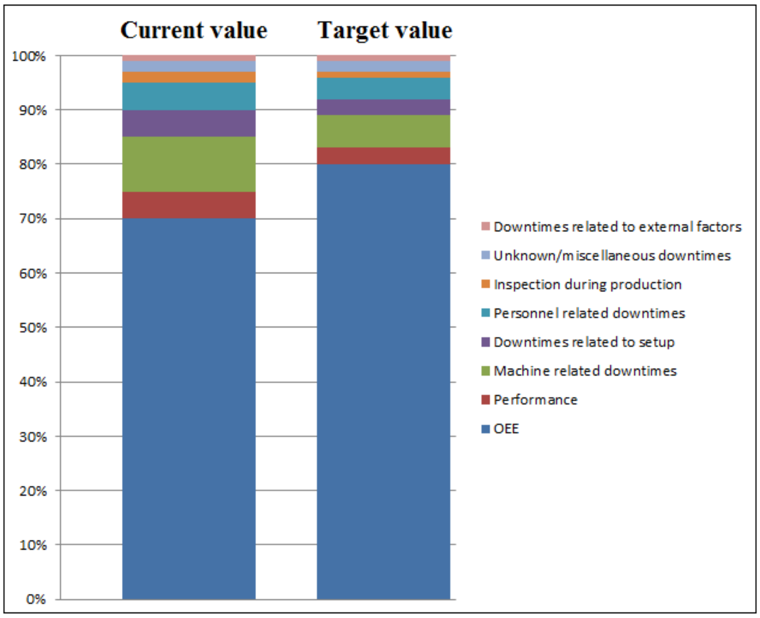



Figure 19 - A visualization of the parts constituting the OEE.

Another thought that is not visualized in this report is to be able to select the different categories and see the "Reason Descriptions" behind each category, all in order for it to be a tool that is as usable as possible for the stakeholders.

Alfa Laval calculates the OEE by multiplying Availability with Performance. What is done in Figure 19 is to divide the availability losses in to different parts. By dividing the availability losses in to different parts the information can be directed to the relevant stakeholders giving them a better possibility to understand how they can improve the OEE. The division of the availability losses can be done in a number of ways depending on what the company wants to focus on. In this example Availability was divided in to six parts which can be utilized by different stakeholders in order to see what they can contribute with for an improved OEE.

- The mechanical downtime causes are something the operators and maintenance department can work with.
- The inspections and personnel related downtimes are dependent on the operators.
- The unknown downtime causes show that more information is needed in order to specify a department.
- The setups are affected by both the amount of time it takes the operators to do change what need to be changed but also on the planners since they control how many setups the operators need to do.
- Lastly the external downtime causes are factors that the operators can not affect, such as power failures or a lack of material delivered to the company.

In appendix 16 the "Reason Descriptions" used when creating these new categories are presented. Since the data needed for a more directed OEE is already gathered and stored by Alfa Laval  the amount of work needed in order to use this kind of visualization would be minimal and it could be presented with the help of Qlikview.

The way the company defines OEE is done at a global level but the ability to highlight different areas that affect OEE makes it a useful tool at a local level as well. It can be used as an investigative tool if for instance the company wishes to study the effect setups or problems with the transfer line has on the OEE.

## 7.2 Discrepancies in the data

Some discrepancies in the production data regarding the performance have been found, see Table 6 and Figure 18. The root causes behind these discrepancies and the effects they have on the KPIs based on them has not been identified during this master thesis. The root causes should be studied in order to know if the OEE value is affected by them and if it is then the company should find out to what extent it is affected. If they wish to use the OEE as a tool for analysis of the production it should be as close to reality as it can be and should it be affected by the discrepancies it can give false impressions to the people using it. Since it is possible that the data used in decision-making today is not fully correct it is recommended to initiate a project with the goal of finding the root causes and investigating the effects of the discrepancies.

## 7.3 KPIs and PIs

When interviewing the personnel at the different sites many felt that it was hard to see the connections between the KPIs at the different levels in the company and there were some confusion as to why some KPIs were used and what they actually measured. A suggestion is therefore to continue working with standardizing the definition of KPIs and to clearly define why they are used and what their goal is. These definitions could be presented in a database or a compilation of KPIs/PIs which can be accessed globally. In the database/compilation the links between the KPIs and how they aggregate from level to level can be shown as well. An example of this is presented in Table 10 below.

**Table 5 – An example of the contents that could be used in the database/compilation of KPIs and PIs.**

KPI/PI

- Definition of the KPI/PI
- Target value for the KPI/PI
- The goal with measuring the KPI/PI
- Example of how to use the KPI/PI
- Which KPIs that is affected by it and how the KPI/PI aggregates to higher levels

This database could be a valuable tool for the employees to understand the KPI structure at Alfa Laval. It could be of great use when evaluating and improving the KPIs, and it is useful when benchmarking which according to Alarcon et al. (1998) is one of the cornerstones when aiming for world class. Today it can be hard to see if there are gaps and in what way these gaps exist. Therefore it is possible for those gaps to go unnoticed until something in a process goes wrong and it is found that the company needs to measure something new or change the way something is measured in order to avoid that problem in the future. This is a reactive way of working since it is not corrected until a problem has already been caused because of it. By having knowledge over the KPIs/PIs used and trying to find if something is lacking by the use of the database/compilation it will instead be a proactive response since the problem can be found before it has happened.

By using a system such as this it would be easier for the employees to learn about and understand the companies KPI/PI structure. And as said by Maslow (1970) humans are purposive. If they know the purpose behind the things they are asked to do they will probably feel more motivated to do so. And as McLagan (1989), according to Ahmed, Siantonas, Siantonas (2008) states, motivated and informed employees are more productive.

It could also be a valuable tool when developing new KPIs/PIs or changing the existing ones since it would show where there are gaps in the current system and it could more easily be understood why the change is needed for the employees tasked with measuring it.

# 8 References


Ahmed, A. Siantonas, G. Siantonas, N. (2008) The 13 Key Performance Indicators for Highly Effective Teams. Greenleaf Publishing in association with GSE Research.

Alarcon, L.F., Grillo, A., Freire, J. and Diethelm, S. (1998), “Learning from collaborative benchmarking in the construction industry”, paper presented at the 9th Conference of International Group for Lean Construction, Singapore.

Bourne, M. Mills, J. Wilcox, M. Neely, A. Platts, K. (2000). “Designing, implementing and updating performance measurement systems”, International Journal of Operations & Production Management, Vol. 20 Issue 7 pp. 754-771.

Ericsson, J. (1997), Disruption Analysis ± An Important Tool in Lean Production, Department of Production and Materials Engineering, Lund University, Lund.

Franco-Santos M, Kennerley M, Micheli P, Martinez V, Mason S, Marr B, Gray D, Neely A (2007). Towards a definition of a business performance measurement system. Int. J. Oper. Prod. Manage., 27(8): 784-801.

Garza-Reyes J., Eldridge S., Barber, K., Soriano-Meier H., 2010, Overall equipment effectiveness (OEE) and process capability (PC) measures, Int. J of Quality & Reliability Management, Vol. 27, No. 1, pp. 48-62.

Keegan DP, Eiler RG, Jones CR (1989). Are your performance measures obsolete? Manage. Account., 70(12): 45-50.

Khan, K. Shah, A. (2011) “Understanding performance measurement through the literature”, African Journal of Business Management, Vol. 5, No. 35, pp. 13410-13418.

Kotze, D. (1993), “Consistency, accuracy lead to maximum OEE benefits”, TPM News Letter, Vol. 4 No. 2, AITPM, Productivity Inc., Norwalk, CT.

Lavy, S. Garcia, J A. Scinto, P & Dixit, M K (2014) Key performance indicators for facility performance assessment: simulation of core indicators, Construction Management and Economics, 32:12, 1183-1204, DOI: 10.1080/01446193.2014.970208

Ljungberg, O. (1998), ``Measurement of overall equipment effectiveness as a basis for TPM activities", International Journal of Operations and Production Management, Vol. 18 No. 5, pp. 495-507.

Maslow, A. H., Frager, R., & Cox, R. (1970). Motivation and personality (Vol. 2). J. Fadiman, & C. McReynolds (Eds.). New York: Harper & Row.

Micheli, P. Mari, L. (2014). “ The theory and practice of performance measurement”, Management Accounting Research, Vol.25, Issue 2, pp. 117-186.

Nakajima S, TPM Introduction to TPM Total Productive maintenance, (1988) Productivity Press, Inc ISBN 0-915299-23-2.

Neely, A. (1998), “Three models of measurement: theory and practice”, International Journal of Business Performance Management, Vol. 1 No. 1, pp. 47-64.

Neely A, Gregory M, Platts K (1995). Performance measurement system design: A literature review and research agenda. Int. J. Oper. Prod. Manage. 15(4): 1228-1263.

Peterson, P., 2000, Process Efficiency and Capacity flexibility, PhD thesis at Dept. of Mechanical Engineering, Linköping University, Sweden

Smajli, E & Olsson, H (2016). KPI analysis, project at Dept. of Mechanical Engineering, Lund University, Sweden.

Smith, R (year unknown) Key Performance Indicators – Leading or Lagging and When to Use Them. From google scholar 6 Maj 2016..

http://scholar.google.se/scholar?hl=sv&q=Key+Performance+Indicators+%E2%80%93+Leading+or+Lagging+and+When+to+Use+Them.+&btnG

Ståhl, J-E. (2015) Development of Manufacturing Systems – The link between technology and economics. Korrekturutgåva 2015: Version 3. Lund.

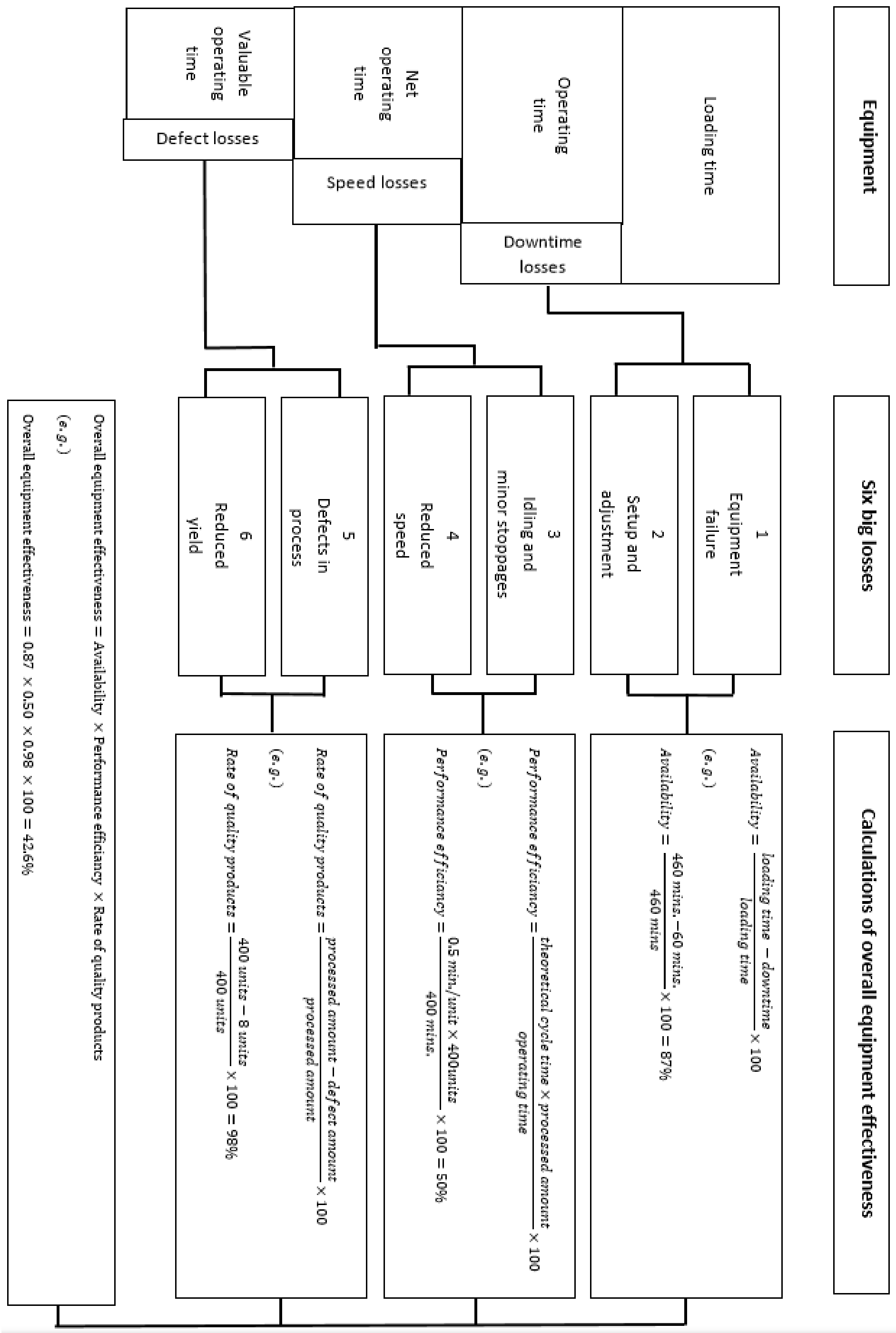
# Appendix 1 – Questionnaires sent out to Site 3

- How much time is spent during each meeting discussing and analyzing the data?
- Does the scrap that is created as a part of the set-up of the machine get registered in Jeeves or in another program? And if so what program?
- What are your goals with the information used at the “pulse meetings”?
  If the wrong reason behind a downtime gets registered, is it possible for the operators to correct it themselves?
- How much of the presented data is used by the operators?
- What are the different KPIs that are used and in what way are they used? How does the KPIs differ depending on the different levels in the company?
- What are your thoughts on the current usage of KPIs? Do you feel that the current KPIs show you the necessary data in order to support and improve the production line?
- Do you feel that there is room for improvement regarding the reporting or the usage of KPIs? If so, in what way?
- Do you know why the production performance is at the level it currently is? Or do you feel that more data is needed to get a clearer view?
- In what way are strategies dependent on the KPIs?

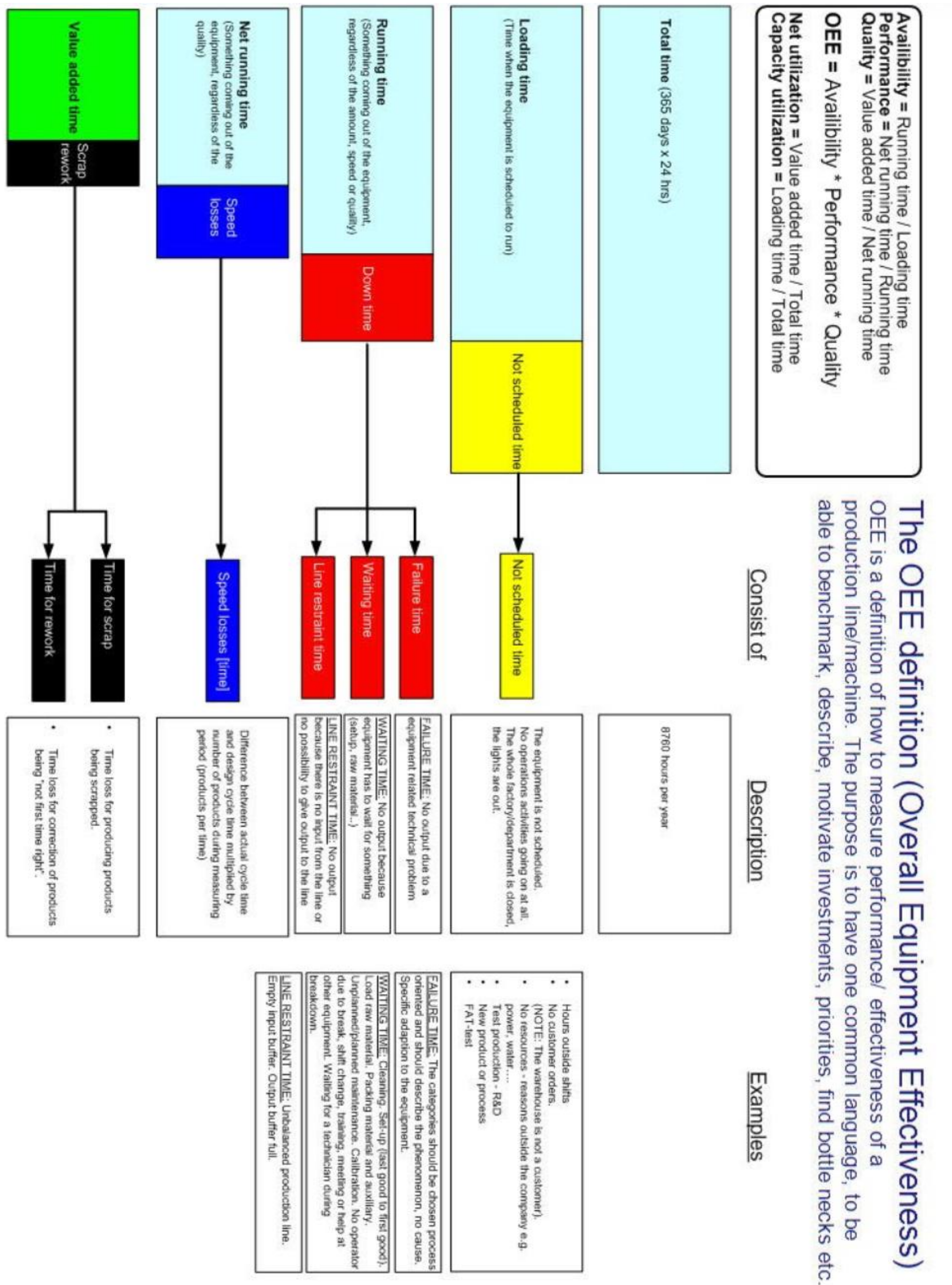
# Appendix 2 – Questionnaires sent out to site 2

- How much time is spent during each meeting discussing and analyzing the data?
- Does the scrap that is created as a part of the set-up of the machine get registered in Jeeves?
- If the wrong reason behind a downtime gets registered, is it possible for the operators to correct it themselves?
- How much of the presented data is used by the operators?
- What are the different KPIs that are used and in what way are they used? How does the KPIs differ depending on the different levels in the company?
- What are your thoughts on the current usage of KPIs? Do you feel that the current KPIs show you the necessary data in order to support and improve the production line?
- Do you feel that there is room for improvement regarding the reporting or the usage of KPIs? If so, in what way?
- Do you know why the production performance is at the level it currently is? Or do you feel that more data is needed to get a clearer view?
- In what way are strategies dependent on the KPIs?

# Appendix 3 – Nakajimas definition of OEE



# Appendix 4 Alfa Lavals definition of OEE



# Appendix 5 – Reason group descriptions and reason descriptions at site 1

Reason Group Descriptions

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Reason Descriptions

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# Appendix 6 – Reason group descriptions and reason descriptions at site 2

Reason Group Descriptions

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Reason Descriptions

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# Appendix 7 – Reason group descriptions and reason descriptions at site 3

Reason Group Descriptions

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Reason Descriptions

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# Appendix 8 – Reason group descriptions and reason descriptions at site 4

Reason Group Descriptions

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Reason Descriptions

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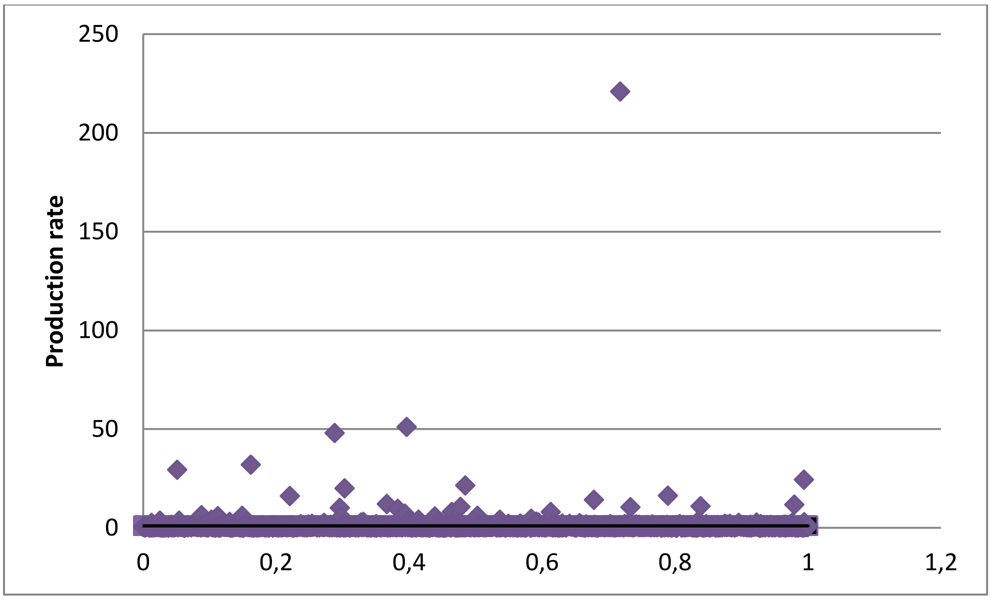
# Appendix 9 – The contents of the OEE reports.

# Appendix 10 – Distribution of downtime reasons for site 1

# Appendix 11 – Distribution of downtime reasons for site 2

# Appendix 12 – Distribution of downtime reasons for site 3

# Appendix 13 – The distribution of production rates registered in MES for site 1 during 2015.



# Appendix 14 – The KPIs used at different levels in the company.

# Appendix 15 – The connection between the KPIs used at different levels in the company.

**Table XX – KPIs missing a connection between the production line and factory level**

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# Appendix 16 – The Reason Descriptions used when creating the categories used when directing OEE

**Machine related downtimes**

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**Downtimes related to Setup**

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**Personnel related downtimes**

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**Inspection during production**

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**Unknown/Miscellaenous downtimes**

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**Downtimes related to external factors**

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