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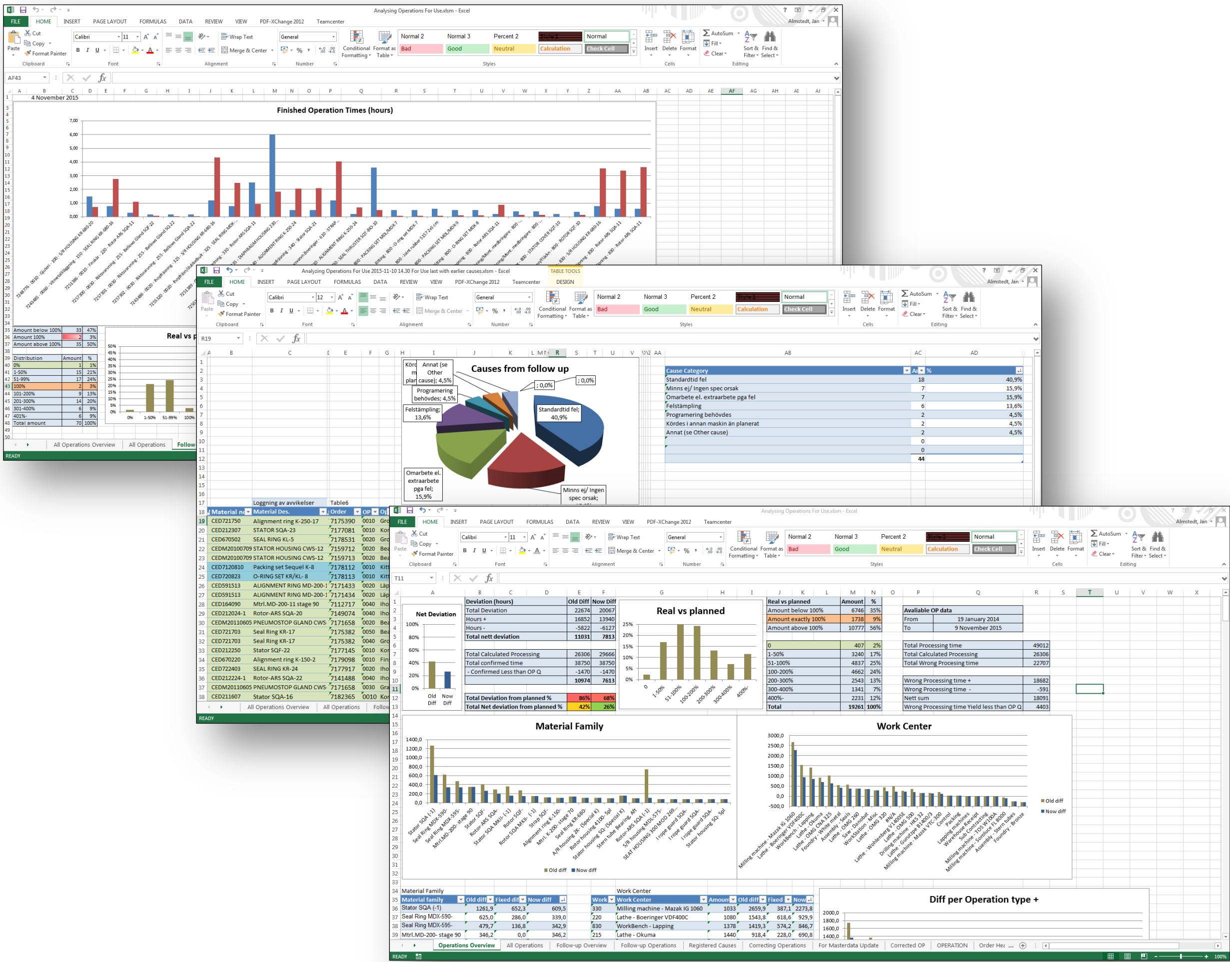

Establishment of correct Standard Operation Times

- by developing an integrated VBA tool at a make to order metal manufacturing unit

Master thesis in *Quality and Operations Management*

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
Some of the sheets and functionalities of the developed VBA-based tool PACSOT (Prototype-tool for Analyzing and Correcting Standard Operation Times) described more in detail in section 4.9 The VBA-Excel tool p.72.

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SUMMARY

This master thesis project was carried out in 2015 at a metal manufacturing unit in West Sweden. The purpose was to find an efficient and reliable way to correct the difference between standard operation times in the ERP system and the real operation times on the workshop floor.

The methodology for this project was action research. Data was collected for instance through observations, discussions at site and extraction of data from the ERP system. Several different steps were used to process and synthesize the data.

Significant variation was observed in the synthesized data. An important finding was for example that during a one-year period the sum of the real operation times was considerably higher than the sum of the planned operation times. One of the reasons was the variety of products and variants and the relatively small production volumes of each variant. Furthermore, incorrect registrations and other problems were discovered.

To address the issue, a Prototype-tool for Analyzing and Correcting Standard Operation Times (PACSOT) was developed. PACSOT is an integrated VBA-Excel tool for efficient analyzing and correcting of multiple standard operation times at once. It also provides built-in decision support and a set of automated VBA-macro procedures for handling the entire workflow of correcting standard operation times. The functions include, extraction of historical data from the ERP system, analysis of different time periods, filtering of material families, regression analysis and synthesizing of material family data into an output file for direct uploading to the ERP system as new Master data.

The company started to use the tool in November 2015 at the end of the project. Other improvement suggestions, for example regarding an automated and more reliable data collection in the shop floor, were also provided.

Keywords: correcting standard operation times, make to order manufacturing, regression analysis of historical production data, VBA-Excel, action research.

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Firstly I want to thank all the personnel at Wärtsilä Seals and Bearings Sweden for allowing me to do the thesis at their site and by helping answering all the questions and providing all the support they did. All of which would not have been possible without the approval and support from the Director of the business Damian O'Toole, R&D Manager Henrik Lundgren and Magnus Eliasson.

A special thanks to my supervisor at Wärtsilä Ellen Lindewall. For always helpfully answering all sorts of weird questions and explaining the wonders of production planning despite being overloaded with work. This was a truly tremendous achievement.

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Finally a great thanks to my supervisor at Chalmers Peter Almström. Firstly by taken me on as a lone thesis worker, then by guiding me during the difficult project and in the end by not giving up on me despite the considerable prolongation of the completion.

Outline of the report

This section presents the outline and structure of the report:

1 *Introduction*

This chapter provides an introduction to the company, problem background, purpose and delimitations. The research questions answered in the report are also introduced in this chapter.

2 *Theory*

In this chapter the theory foundation and theoretical context for the practical problem are reviewed. The method theory is also located in the end of this chapter.

3 Method

This chapter describes the method and in general the different steps and actions carried out in the thesis. The important chain of evidence linking the different parts together is also located in this section. Due to the practical and iterative aspects of the project this chain of evidence will additionally also have traits of both results and analysis.

4 Results

The results from the observations, data collections and synthesizing are presented in this chapter. The developed PACSOT VBA-tool is also described.

5 Discussion

Here the method, results and the progress are reflected upon and discussed.

6 Conclusions

Finally, conclusions are formulated by answering the research questions outlined in the introduction of the report.

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Vocabulary

SOT – Standard Operation Time

PACSOT - Prototype-tool for Analyzing and Correcting Standard Operation Times developed in Excel VBA in this project

ERP – Enterprise Resource Management system.

SBSE – Seals and Bearings Sweden (Division of Wärtsilä Sweden)

MRP – Material Requirement planning

VBA – Visual Basic for Applications. Simplified programing language based on Visual Basic.

RFID - Radio-frequency identification

1 Introduction

This master thesis report is investigating and giving solutions to how the difference between the Standard Operation Times (SOT) in the ERP system and the real operations times can be measured and then corrected at Wärtsilä Sweden Seals and Bearings (SBSE). In this chapter the company background, problem background, purpose, research questions and the delimitation of the study are presented.

1.1 Company Background

Wärtsilä is a global producer of power solutions organized in the three business areas: Marine, Energy and Services. In 2014 Wärtsilä globally had a turnover of 4779 million euro and had 17700 employees in 70 countries (Wärtsilä, 2015a). The Headquarter is located in Helsinki, Finland.

The Swedish branch of Wärtsilä is Wärtsilä Sweden AB with the headquarter in Gothenburg (Wärtsilä Sweden, 2015). The number of employees for Wärtsilä Sweden AB was 150 people at the end of 2014. One division within Wärtsilä Sweden is the Seals and Bearings Sweden (SBSE) manufacturing unit located in Arendal in Gothenburg, where this master thesis has been carried out. At the end of 2014 SBSE employed 48 people.

The products manufactured at SBSE are seals and stern tubes for big vessels such as ferries, cargo ships and oil tankers (see Figure 1). For the manufacturing SBSE has a foundry, workshop, assembly area and a warehouse.

Figure 1: An Oil tankers, a typical application for the SBSE products (Wärtsilä, 2015b)

Seals and bearings are crucial parts for the operation of a ship since they enable the force from the engine in the ship to be transferred to the propeller.

A stern tube is the giant bearing keeping the propeller shaft in place (see Figure 2). The stern tube is filled with oil for reducing friction. The purpose of the two seals is for the aft (outboard) seal to prevent the oil from leaking out to the ocean and for the forward (inboard) seal to prevent leakages into the vessel. If oil would leak into the ocean it would have severe environmental impact on the surrounding water. If on the contrary water would leak into the stern tube this would dilute the oil with water and the lubricating properties of the oil would drastically deteriorate. This subsequently causes increased wear and eventually a breakdown. Downtime for one of the vessels with SBSE's equipment are usually very costly and could cause the ship operator a loss of up to 500 000 Euro per day. Fixing problems with the propeller shaft and bearings also normally requires the vessel to dry-dock and this is also very expensive with an additional cost of approximately 300 000 Euro per day.

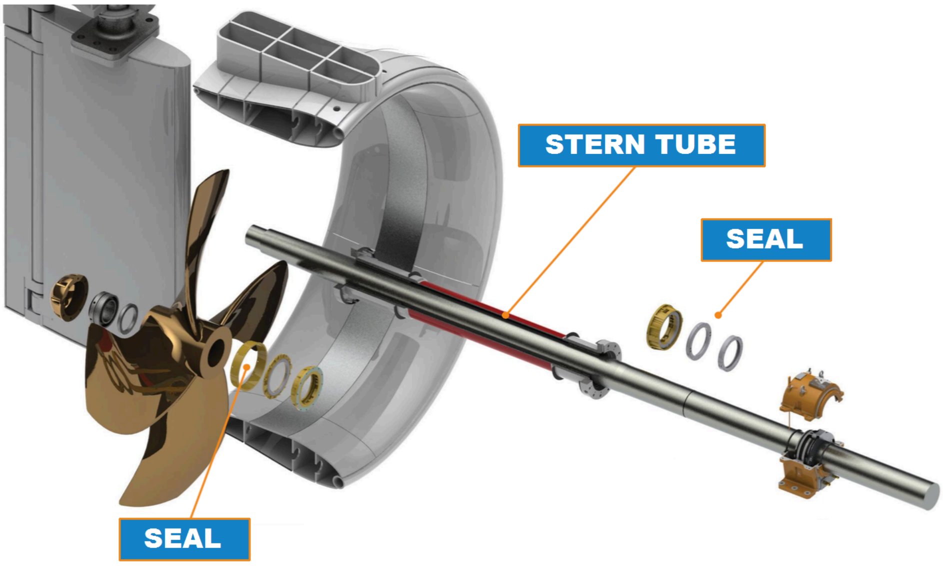


Figure 2: Explanation of the seals and stern tube's relation to the propeller shaft (Wärtsilä, 2015c)

This thesis project focuses mainly on the production of the seals and a seal consists of several components as can be seen in Figure 3.

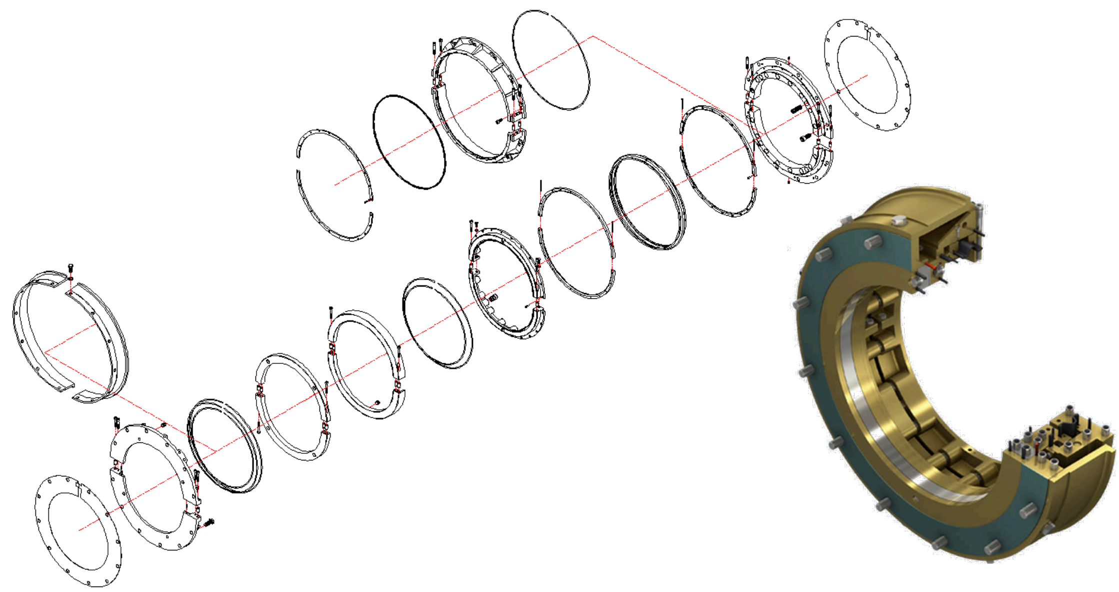


Figure 3: A SQA seal with all components exploded (left) and with a quarter cutouts (right) (Wärtsilä, 2015d)

1.2 Problem background

Because of the seals and stern tubes paramount importance for the operation of a vessel, they are complicated and expensive equipment. The price for a complete seal therefore depends on several factors such as model, size and degree of customization required, but normally range from 30 000 to 100 000 Euro.

The high level of variability and sometimes relatively short lead-times due to the high costs involved in a breakdown put high demands on the supply chain for spare parts and therefore also on the SBSE production.

The production is highly dependent on craftsmanship, and the planning and scheduling processes were currently working much in the same way. Four weeks were regarded as the standard delivery time but sometimes the customer request a shorter delivery time and then the sales representative negotiates with the production manager, foremen and production planner if an earlier delivery can be achieved. Every week the production manager, foremen, production planner and sales representatives have production planning meetings. Experience and combined knowledge of the current production status were utilized to plan the production and actions for the upcoming week and month. It was also decided when production orders should be realized, if any earlier deliveries were possible and if necessary measures like rescheduling or overtime.

The problem with this work method was that sometimes it was difficult even for the skilled and experienced practitioners to know exactly what the demand and available capacity was. When volumes rise or new products and parts were started up in the manufacturing, the complexity was increased even further.

SBSE was using the ERP system SAP that had a built-in capacity-planning module that should be able to assist in this. However, the capacity planning functionality was dependent on the Standard Operation Times (SOT) set for each operation since it is the only way for the system to calculate the demand of man-hours and match it with the available capacity of man-hours and machines. A major obstacle was that SBSE suspected a large amount of these times to be incorrect. The reason was that indications of this had been seen in spot-checks on performed operations.

1.3 Purpose

The purpose of the master thesis project was to find an efficient and reliable way to measure and correct the difference between SOT in the ERP system and the real operation times in the workshop.

1.4 Research Questions

The research questions that will be answered in this master thesis report are:

1. What was the current context of the SOT within the organization? For example: objectives and procedures for the creation of SOT, collecting of real times and follow-up.
2. How can the difference between the SOT in an ERP system and the real operation times be measured?
3. How large was the actual difference between the SOT in the ERP system and the real operation times?
4. What actions can be taken in order to systematically reduce the difference?

1.5 Delimitations

Only the operation times related to a production order are dealt with in the project. This entails all the production orders that were part of a sales order and should eventually be delivered to a customer. The operation times excluded are for example the ones when new parts for product development projects were being machined.

Customer specific parts are included in the total analysis and overview of operations but generally don't have their own material family search criteria due to the often extremely small volumes produced of each version. On the contrary in the cases the customer specific parts are produced in substantial numbers it is fully included and possible to be corrected by PACSOT.

2 Theory

In this section the relevant theory foundation and theoretical context for the practical problem is shortly summarized. This includes for instance how computers are used in production planning, manufacturing strategies and different production processes. Review of the problem with wrong SOT, and ways to correct it. In the end of the chapter the method theory is also presented.

2.1 Using computers in Production planning

In the 1960s the development of the disk memory created possibilities for using computers for planning and control in Material Requirement Planning (MRP) introduced by computer companies such as IBM in the USA (Jonsson and Mattson, 2009). Many companies successfully adopted this but new problems were also created. At the end of 1970 it was clear that MRP was not a perfect solution and it was developed further with: better planning functions, regard played to capacity and improved reporting and feedback from the production. These new improved versions were called MRP 2 systems. The development continued and in the 1990s a new breed of programs was created instead named Enterprise Resource planning (ERP). An ERP system consist of a database with information commonly referred to as Master data. Different software programs are using the master data for different modules providing information for the different functions of the business. The latest versions of ERPs are not only working with planning inside the company but also try to integrate with processes in other companies. This new generation of ERP programs is referred to as ERP 2 or Extended ERP programs.

2.2 Manufacturing strategy

The manufacturing strategy is a way to classify a company depending on at which point in the production process the products get its customer order characteristics, and the integration between the production and the customer orders takes place. Five different types are described by Jonsson and Mattson (2009) with the one with the highest level of integration first:

Engineered to order
This means that the products are engineered and produced against specific customer specifications and that activities such as design, manufacturing preparations and material procurement are controlled to a large extent by the customer orders (Jonsson and Mattson, 2009).

Make to order
Share much of the characteristics with the first type but the products are generally engineered and prepared for production before an actual customer order is received (Jonsson and Mattson, 2009). Most of the material procurement and manufacturing of parts and semi-finished products are carried out independently. However certain operations such as final manufacturing and all assembly are performed against customer orders.

Assemble to order
All the procurement and manufacturing are done before the customer order are received (Jonsson and Mattson, 2009). Only the final assembly of the already procured or produced parts is done according to the received customer orders.

Make to delivery and Make to stock
For make to stock the products are entirely standardized and produced against stock, waiting for immediate delivery when a customer order for it is received (Jonsson and Mattson, 2009). For make to delivery it is also standardized products against a forecast or delivery schedule. It could also be a customer specific product if it is brought in large quantities against forecast and delivery schedules. This is common practice in the automotive industry.

All the above different types call for different methods for the production and material management, and therefore also different approaches to planning (Jonsson and Mattson, 2009). The level of information of the product to be produced also varies greatly between the five types. For the *Make to delivery and make to stock* types 100 percent of the product is known at order**.** However, at the other end at *Engineered to order* what is known is often based on a general quote and the rest remains to be decided. The information level is increasing during the engineering work and preparation for manufacturing, to reach 100 percent first when the product is produced and are ready for delivery.

The production volume often has a correlation with company type and the manufacturing strategy (Jonsson and Mattson, 2009). A company type with mostly engineered to order normally has small production volumes while on the other hand a company with a make to stock manufacturing strategy often has larger production volumes.

2.3 Different manufacturing processes

Jonsson and Mattsson (2009) also characterize a company in regard to how the manufacturing process is organized:

Project process
Has no product flow. Instead the production resources are organized around the product as it is being built (Jonsson and Mattson, 2009). For example roads and bridges.

Job-shop process
Are organized by function and the flow of material is adapted to the production layout (Jonsson and Mattson, 2009). The production process is not product specific hence suitable for different types of products, such as semi-finished items and end products.

Line process
The production resources are organized in the workflow of the product being produced in order to archive rational workflow and higher flow rate and better utilization of the production equipment (Jonsson and Mattson, 2009).

2.4 Control at different levels

A lot of management and coordination is required to control the operations in order to be efficient and competitive (Jonsson and Mattson, 2009). The different coordination activities usually can be assigned at one of three different levels of controls: strategic, tactical or operative.

Strategic control
At this level control is about positioning the company in the business environment (Jonsson and Mattson, 2009). Questions at this level are for instance what products should be produced, what customer should be targeted and what will be produced and what will be purchased from subcontractors. The overall allocations of resources are set and goals and manufacturing strategies are determined.

Tactical control
This control level is about developing the internal structure to fulfill the goals and decisions set on the strategic level (Jonsson and Mattson, 2009). This involves setting sales and production plans, planning of capacity and selection of planning methods.

Operative control
At the lowest level, control of the operations with manufacturing activities and daily decisions are taking place (Jonsson and Mattson, 2009). This level is concerned with the operative planning and control of the company and is concerned with for example; assigning delivery dates to customer orders, planning manufacturing orders, short-term capacity and workload planning and priorities in production.

2.5 Importance of correct operation times

Jonsson and Mattsson (2009) characterize correct basic data for operations as a critical aspect in making adequate decisions to fulfill manufacturing objectives and goals, and therefore also an important prerequisite for planning.

The production basic data consists of item data, bill of material data, routing data, and work center data (Jonsson and Mattson, 2009). Item data describes for example the physical properties of components and key characteristics such as its cost. Bill of Material (BOM) data are listing what components are building up an article. Routing data specifies how items are manufactured and what resources that are needed. The work center data contains information about the capacity of the production equipment.

The routing data consist of the man-hours and machine-hours required to produce the part (Jonsson and Mattson, 2009). This is crucial information for capacity requirement planning. Routing data also consists of a list of all necessary operations. They are often numbered 10, 20, and 30 (to allow future operations to be added in between if necessary) and have a description. The routing file also states at which work center the operation should be carried out. The operation time is a very important piece of data and often consists of a quantity independent setup-time and a processing time equal to the run time per piece multiplied with the amount of pieces being produced. Berry et al. (1982) conclude that data accuracy is a crucial factor for an MRP 2 system to work properly.

2.6 Consequences of wrong standard operation times

Zandin and Maynard (2001) are listing several reasons for the importance of having correct standard operation times. Incorrect standard operation times can result in:

- Scheduling cannot take place and correct delivery dates cannot be promised
- Staffing is difficult when the time required to finalize a part is not known
- Problem with line balancing
- Problems to utilize the MRP systems
- Problem if simulating to predict outcomes
- The inaccuracy of performance wages if they are used
- The inaccuracy of costing calculations to be able to know the correct margin for a product and the correct allocation of production costs to the different products.
- Wrong input data for employee evaluation

Almström and Winroth (2010) are referencing to the problem with wrong SOT as "The Gap" and conclude that wrong SOT cause several problems beyond operative planning problems as can be seen in Figure 4.

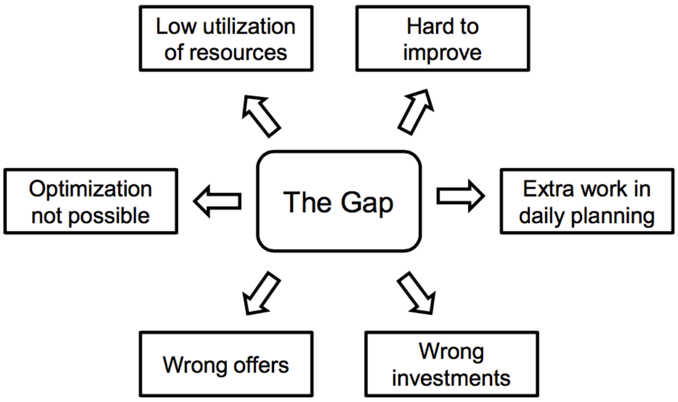


Figure 4: The effects of the gap between operation times in reality and in the planning system (Almström & Winroth, 2010, p.3)

2.7 Shop floor data collection

Several methods for data collection on the shop floor exist (Cecelja, 2002). The most basic are manual recordings on paper, archived in folders. Next step are manual recordings on paper but which later is transferred to digital form with a computer. Next step is to have computers in the production where the times can be reported manually but without doing the extra step of manual recordings. The products and materials can be identified either by manually entering product codes and numbers or by using barcodes or magnetic stripes to identify the material. If the process is line production, scanners can be installed at the line to automatically identify products. Instead of barcodes, RFID chips can be used which take away the need for multiple scanners or needing to ensure that the barcode is facing the scanner during the reading.

2.7.1 Problems with shop floor data collection

Regardless of the level of technology used for collecting the data, the implementation of shop floor data collection often has several problems (Cecelja, 2002). First ownership of the system needs to be clarified, if it is the manufacturing or IT-department that owns system. Secondly the workers' resistance needs to be handled. Since collecting shop floor data means monitoring the work efficiency and utilization of the work force, this can risk creating an alienation of the workers towards the management by fearing a "Big Brother mentality". Moreover, collection of data in manufacturing is a not a value adding activity in itself, since manufacturing exists to produce products. The collected data must therefore contribute to significant improvement of the production process to be worthwhile (Cecelja, 2002).

2.7.2 Implementing shop floor data collection

In the same way a main problem discovered in the actual implementation of shop floor control and data collection systems is the difficulties with the attitude of the personnel. It is often challenging to go from what is known to a new shop-floor scheduling situation. On the upside, it is possible to use priority lists and capacity requirement planning, resulting in up-to date due dates. Another crucial prerequisite are the attitudes of executives and middle management (Cecelja, 2002).

2.8 Reasons behind incorrect SOTs

The reasons for the incorrect SOT can according to Almström and Winroth (2010) be categorized in three main categories: Times are set incorrectly, allowance time is added over time and times are not updated. These are further broken down as can be seen in Figure 5.

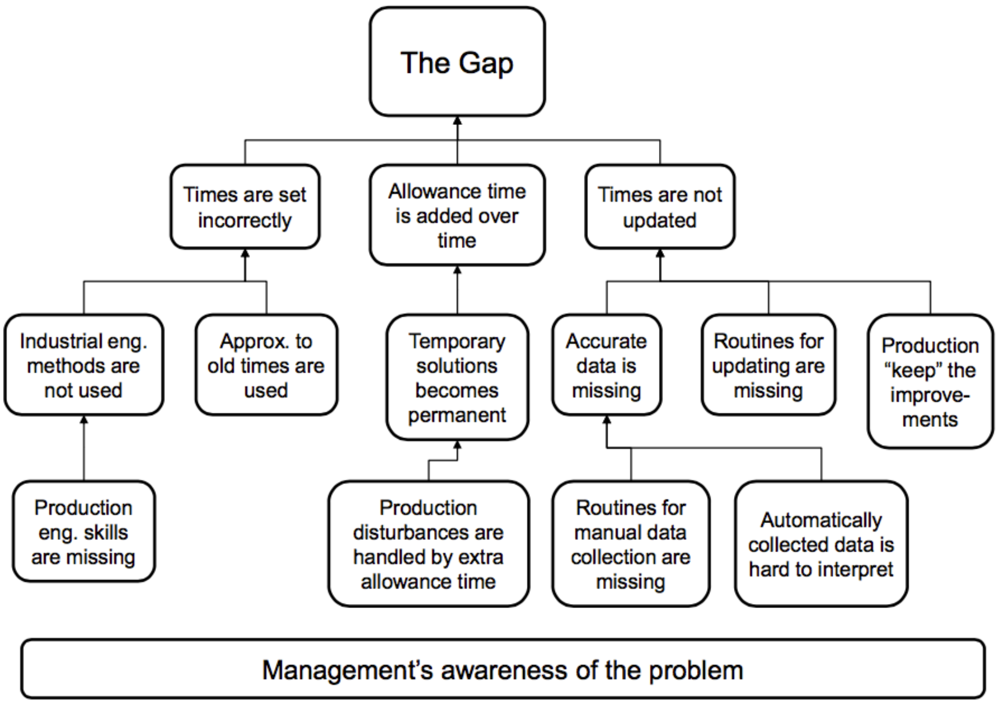


Figure 5: Causes for the gap between operation times in reality and in the planning system (Almström & Winroth, 2010, p.7)

2.9 Variation in SOT for job-shops with differentiated production

An increasing number of products in production also create an increasing variability in the processing time between products (Ali, Ghoniem and Franke, 2014). Smith and Tan (2013) describe that there is a relation between ability to produce a big product portfolio in a job-shop and the variability in processing time.

Characteristics for a job-shop are that the machines in the workshop are grouped by type or similarities (Jonsson and Mattson, 2009). Each job being done has a specific routing determining which machines that will process the jobs and this routing can differ between jobs. This is in contrast to a flow line where the machines are organized in a sequence and all jobs are following the same routing. Flow lines are often used for make to stock production with the aim to maximize the utilization of the manufacturing equipment.

In job shops it is the schedulers and planers who decide when to release jobs and when a job should start at a machine (Jonsson and Mattson, 2009). Priorities are often assigned based on due dates and not in order to maximize the performance of the system in terms of work in progress or utilization.

There will always be variability in the operating time when a human operator performs a task (Smith and Tan, 2013). The level of variation is determined by the cognitive demand of the task and the level of skill posed by the worker. The normal solution to cope with variability is keeping stock, but that is not always possible and creates other costs and problems. Furthermore, the relations between the processing times of different jobs need to be taken into account in order to maximize the work in progress or utilization of the processing time.

2.10 The problem of estimating processing time

Standard processing times are normally only based on a best estimate which often is an average of historical processing times (Lejmi and Sabuncuoglu, 2002). It is difficult to get a correct processing time due to the random factors always involved in the manufacturing setting. For example variations in machining conditions, different operators and material. Actual processing times will therefore often deviate from their estimated values.

This is problematic since the majority of the scheduling studies are deterministic where processing times are considered known factors or only fluctuating in a certain interval (Lejmi and Sabuncuoglu, 2002). Because of this, the carefully developed optimal schedules aiming at optimizing some performance measure, such as lead-time or mean delays, might not actually yield the desired results. An important action is to measure the deviation between the planned and realized processing times and its impact on system performance.

Schuh et al. (2012) recognized that the processing times are often not adequately maintained at the operation charts and the recorded or estimated times deviate from reality. This is mostly common in Small and Medium-sized Enterprises (SMEs) with a high level of product variability. Feedback from production regarding actual deviations is therefore required but is often non-existing or seldom happening in reality.

2.11 Work Sampling

According to Freivalds and Niebel (2009) work sampling is an efficient method to determine the proportions of time devoted to various activates in the production in a statistical way. The law of probability is a foundation for the work sampling since it is being done with random observations. The statistical significance achieved depends on the number of activities used for categorization and the number of performed observations. A confidence interval of 95 percent (represented by the value 3,84 in formula) corresponds to what is regarded as the limit to when something have a high enough level of confidence.

When setting up the work sampling schedule one approach is to decide a specific target accuracy and then calculate the required number of observations (n) to achieve this accuracy. This is calculated with the formula in Equation 1.

$$n=\frac{3.84*p*q}{L^2}$$

Equation 1: The formula for calculating the number of required observations in a work sampling

n=number of observations required
p=probability in percent for the activity one want to observe
q= the opposite probability in percent for the activity you do not want to observe (1-p)
L=accepted accuracy as a decimal for example 2 percent =0.02

Another approach is to have a set number of observations and then calculate the accuracy of the proportion of the observed activities (L). This has to be done for each activity, which is done with the formula in the below Equation 2.

$$L=\sqrt{\frac{3.84p(1-p)}{n}}$$

Equation 2: The formula for calculating the accuracy for a number of observations in a work sampling

2.12 Regression analysis

Regression analysis can be used both to explain relationships and to predict outcomes (Brook and Meyer, 2000). An assumption has to be made that the relationship between two variables is linear (Gupta and Starr, 2014). X is the independent variable and Y the dependent variable. For a number of data points a straight line is fitted to best fit the trend in the data (see an example in Figure 6).

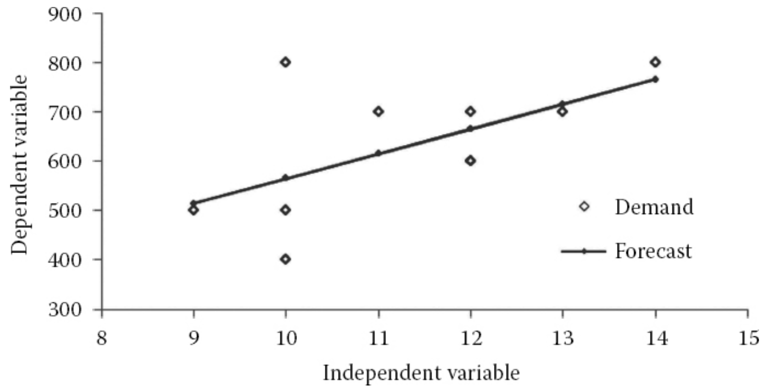


Figure 6: A regression line generated from 10 data points (Gupta & Starr, 2014, p. 98)

Gupta and Starr (2014) explain that the equation for the regression line is Y = a + bX. The variable is a starting variable representing the Y value when the X=0. The slope of the line is represented by **b** and is reflecting the relationship between Y and X in increase of Y per unit of X.

Excel has built in functions for finding the best value for **a** and **b** when a series of X and X values are known.

2.13 Use of Excel and Visual basic in production planning

McKay and Wiers (2004) describe how Excel and Visual basic can be used to improve the production planning and control in five levels summarized in the list below:

1. Can be used to gather and synthesize data for output and used to create mock-ups of reports and prototypes to show what are needed in the communication with vendors of software.
2. Can be used as spreadsheet tools and data repositories, calculators and report generators by processing data exported from the ERP system. Lookup formulas and several worksheets and/or workbooks can be connected. However the different spreadsheets do not often work together as a system or as a fully functional tool for planning and scheduling.
3. Spreadsheet tools can be used to generate slightly functional prototypes to investigate and explore advanced relationships before a more advanced APS (advanced planning and scheduling software) tool are acquired or built. Some level of Visual Basic programing can be needed to archive this but it is difficult to accomplish a fully operational tool.
4. At the next level a quite functional prototype can be developed that can be used in a limited scale in the factory. This requires programing and more effort. If commercial tools cannot meet the needs or if the area has specific and requirements this might be the best way. A decent prototype capable of actually taking ERP data, scheduling and generating reports will cost but substantially less than acquiring a commercial version and then discover that it will not solve the problem to full extent.
5. The most advanced utilization is to create a fully functional planning and scheduling tool. Then the programing needs to be done entirely in Visual Basic and not use any formulas at all. It will be comparable with commercial offerings and therefore be reasonable expensive to develop but might still be

less than for an advanced APS. The major benefit is the custom fitting possible to archive for the functions, screens, terminology, tasks and reports. However this can create a flexible tool since it can be further improved and at least partially maintained by the planers and schedulers themselves.

2.14 Predicting times with regression analysis

An example of when regression analysis was used to predict processing times was found in the agricultural setting and the wood-cutting industry. A time and motion study of the harvesting time using dedicated time study software for building a linear mixed –effects model was done by Hiesl and Benjamin (2015). See Figure 7 of an example of one such harvester in Maine. Hiesl and Benjamin (2015) used the time study data from the observations of the cutting the wood in two different conditions of hardness. These two conditions were used as two different parameters (soft or hard) in the linear mixed –effects model to predict the cycle-time.

Linear mixed-effects models are a more advanced version of linear regression models for data that are collected and summarized in groups MathWorks (2015).

Figure 7 One harvester in Maine (NSRC Forrest, 2016)

2.15 Research strategy

Bryman and Bell (2011) describe theory to be either deductive or inductive in general. Deductive represent a scenario when a researcher carries out the research based upon existing theory and knowledge in the field. Hypotheses is deduced and empirically tested and analyzed. Inductive on the other hand is when theory is formulated with a base of collected and analyzed data.

Another aspect is the epistemological orientation which according to Bryman and Bell (2011) can be either interpretivist or natural science based. Natural science based is also called positivism, representing a line of thought saying that natural science methods also can be used in social science. The alternative, interpretivism, instead claim the researcher also has to understand the subjective nature and purpose of social actions, such as the social and technical context and used concept of leadership.

The ontological position of the research can further either be objectivistic or constructivist. Objectivism is where social phenomena such as organization and culture, are considered as external facts incapable of being influenced. Constructionism, on the other hand, take on the approach that social phenomena are constantly being accomplished by the people involved and are not static but rather in continuous development.

This approach is part of what Bryman and Bell (2011) characterize as the research strategy that could be in general also either quantitative or qualitative. Quantitative research emphasizes quantification in the collection and analysis of the data and takes on the deductive, positive and objective approach. Qualitative research on the other hand emphasizes the social aspects and an inductive, interpretive and constructive approach.

What research strategy the researcher chooses, has according to Bryman and Bell (2011), an important role in the research design. That business research often is case based makes the ontological assumptions and commitments to have an impact on how the research is carried out.

2.16 Operations Management research

Production planning of a manufacturing unit falls within the research field of Operations Management (OM). OM is an applied research field focusing on the transformation of resources in the real world at companies and organizations (Karlsson, 2009). It is a cross-disciplinary field with a managerial perspective. It is covering issues and problems from the so-called real world with contributions from several other disciplines such as economics, finance, organizations, marketing and mathematics merged together as an integrated whole. The results are to be used in the academic world but also in the real world by practitioners really improving real operations. Different perspectives can be used within OM such as the strategic perspective for the role and objectives at a high level but also a more operative perspective for the planning and control of capacity, inventory and internal and external production systems.

2.16.1 Characteristics of good OM research

The close relation to practice for OM makes relevance an important characteristic for good OM research (Karlsson, 2009). The potential value that can be obtained when applying the research results are also an important factor in applied research such as OM. An inbuilt risk in OM is to either form the aim and research questions to generally and therefore not being useful to any target group, or the opposite to be to narrow and solve a specific problem that has no general value beyond the studied case. In particular, to solve a specific problem for a company with well-established knowledge risks being consultancy rather than research.

2.16.2 The Chain of evidence

An important factor for good research quality is that the reader can follow the logic of the study and the report (Karlsson, 2009). This should in theory allow the reader to repeat the study with the same result, also referred to as replicability. Another important aspect is to make what is done and found trustworthy. For this the research steps should fit together, clearly be linked to each other and that the element created in each step fit. For example adequate observations are used to answer the research question. The research report should start with a problem discussion based on both practice and theory. The output from this should be a clear problem definition with a clear link both to practice and theory. Then a thorough mapping of the literature should be done to find relevant knowledge and gaps in knowledge. Then the researcher should be able to formulate the research questions. Then a model of framework should be created linked to the research questions and subsequently used for the data gathering and analysis. Considerations of a suitable methodology should then be taken and a discussion presented linking together the research questions with the empirical and theoretical foundation, the data collection, the analysis and the expected result. Then the data and analysis should be presented and synthesis made and conclusions are reached. A goal is to separate data analysis with creative thinking by the researcher but for Action Research built on a continuously ongoing process of observation, analysis and making changes, it is often difficult to make this separation.

2.16.3 Generalizability

The aim of the study is that both the researcher and the reader should learn something in general from the outcome (Karlsson, 2009). This is an aim in all research but has different meaning depending on the approach and related issues in the related research field. For example, in quantitative research generalization is ensured by statistical sampling, but for qualitative research it is more important to find cases with particular interest for the research issue to do the research on. Either sampling against a certain population can be done or theoretical sampling and comparison with similar cases. The demand for generalizability depend on if a positivist perspective is used advocating an objective reality or a constructivist perspective where the reality is socially constructed by interpretation.

2.17 Research quality

The relevance is an equally important criterion for quality as how well the actual study is done (Karlsson, 2009). A crucial question is if the appropriate methods for data gathering are used with the aim of archiving trustworthiness. Requirements for trustworthiness are construct validity, internal validity, external validity and reliability.

Construct validity ensures that the operational measures are suitable and actually measures what it is intended to measure.

Internal validity is referring to that the study is measuring what it says and that relations really are explained by the factors described and not by some other unknown and not observed factors. Triangulation is often used for this and it can be done both for the method and for the data.

External validity instead deals with if the results are valid in similar conditions but outside that of the studied case.

Reliability finally refers to the objectivity and that another researcher should arrive at the same conclusion under similar conditions. Once again depending on the positivist or constructivist perspective. The goal for the method section is to be credible or trustworthy and show that the research is done well and that the reader can trust the results and not contain too much literature. A key for being credible is instead to use appropriate methods for the specific field.

2.18 Qualitative and quantitative methods

Both qualitative and quantitative methods can be used at the same time (Karlsson, 2009). Quantitative methods are part of a positivist approach. The process is important for the quality and statement of confidence in the result and is measured with statistical measures such as level of significance. Suitable for data collection in controlled circumstances such as labs or structures questionnaires.
Qualitative approaches are instead more constructivists in its nature. In a qualitative approach numbers can still be used as qualitative variables.

2.19 Choosing the method

The chosen research method should have a close fit with the research questions Karlsson, 2009). If it is a bad fit, either the research questions or the method need to be changed since they are often developed iteratively and a more interesting research question than was first formulated might be developed during the data collection.

2.20 Access

A key pragmatic question for OM research is access to the data required (Croom, 2009). Many of the interesting OM research areas are commercially sensitive and the researcher may encounter problems with being able to access and disclosing the data and findings (Croom, 2009).

Correa (1992) illustrate this in a table of the research design choice depending on the possibilities for access provided and the level of involvement desired (see Figure 8).

Research requirements/ characteristics	*Axiomatic and experimental research*	*Survey research*	*Case study*	*Action research*
Presence of the researcher in data collection	Possible	Unusual/ difficult	Usual	Usual
Small sample size	Possible	Unusual	Usual	Usual
Variables difficult to quantify	Possible	Possible	Possible	Possible
Perceptive measures	Possible	Possible	Possible	Possible
Constructs not predefined	Unusual	Difficult	Adequate	Possible
Causality is central	Adequate	Possible	Adequate	Possible
Need to build theory—to answer 'how' question	Possible	Difficult	Adequate	Possible
In-depth understanding of decision-making process	Difficult	Difficult	Adequate	Possible
Non-active role of researcher	Possible	Possible	Possible	Impossible
Lack of control over variables	Difficult	Possible	Possible	Possible

Figure 8: The summery of Research design choice (Correa, 1992). p115. as reprinted by Croom 2009. p.72)

2.21 Action research

Action Research (AR) was first introduced as a concept by Kurt Lewin with his article "Action Research and Minority Problems" in 1946. Lewin was trying to bridge the gap he had perceived between practitioners and researchers by doing research on practical problems in cyclic fact-finding ways with a clear aim to also create a change. At one end the practitioners performed uniformed actions but at the same time the researchers developed theory without real application (Dickens and Watkins, 1999). In AR the researcher plays an active role in solving a management or organizational problem within the organization by applying problem resolution and change management (Karlsson, 2009).

2.22 Characteristics of AR

A key characteristic of AR is the aim that the outcome should both be an action and research-based knowledge (Coughlan and Coghlan, 2009). AR researchers take action in for example areas of process modification and methods improvement. Gummesson (2000) are stating 10 key characteristics of AR:

Is integrative
The researcher and the personal in the organization are working together to resolve or improve a client's issue and at the same time contribute to knowledge (Shani et al., 2008)

Aim is to develop a holistic understanding and recognize complexity
A broad view is needed to be able to cope with formal and informal structures and people subsystems (Nadler and Tushman, 1984)

Change is a fundamental aspect
In order to create action, understanding of the organizational dynamics needed for change by planning and implementation of change are important (Gummesson, 2000).

Requires an understanding of the ethical framework
For example specific norms and value systems since AR involves authentic relationship with the members of the studied organization (Gummesson, 2000).

Can include all type of data collection methods
Consideration has to be taken to the impacts of different data collection events. An interview might for example create anxiety or suspicion in the work force and this need to be attended by the researcher (Gummesson, 2000).

Requires vast pre-understanding
Of the corporate culture, conditions, structures and dynamics of the organization (Gummesson, 2000).

Be conducted in real time
The research should capture the current conditions like a case study been written while it happens (Gummesson, 2000).

Needs its own quality criteria
Should not be judged like positivist science. Important is instead participation, real-life problems, joint-meaning construction and workable solutions (Gummesson, 2000).

2.23 Gaining access

For a good positioning of the AR in relation to the needs of the organization three main things are needed: a real issue, access and a contract (Coughlan and Coghlan, 2009). The access can be divided in primary and secondary. Primary mean getting into the organization and to be able to perform AR. Secondary access refers to getting access to specific areas, levels of information and activities. The contract refers to that key members of the organization need to approve the action research and allow the researcher to work with real-life problems, joint-meaning construction and workable solutions in the organization.

3 Method

This chapter describes the method with the different steps and actions carried out in the thesis and the chain of evidence linking everything together. To link everything it will also accordingly contain some traits of analysis.

3.1 The workflow

The project workflow has consisted of several different activities as can be seen in Figure 9 below:

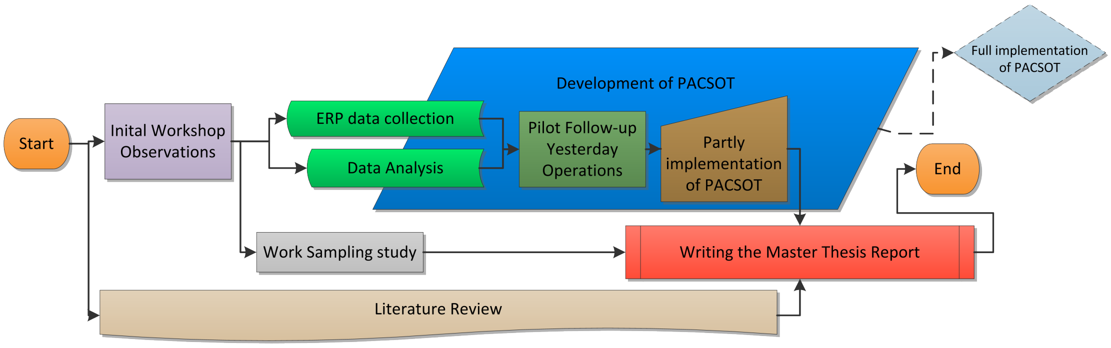


Figure 9: The main activities performed in the project

The aim with the master thesis project was from start to really create something of value for the organization and solve an important problem. Any improvement suggestions, however elegant and brilliant on its own do not contribute to anything if never put into practice. The intention was therefore set clearly from start that the solution should be possible to implement.

3.2 Starting out from the Research questions

Starting with number *1.* What was the current context of the SOT within the organization? In order to answer this, observations and the opportunity to ask questions to the operators, foremen and planners in the workshop were needed. In order to know what to look for and get a framework for the observations, literature of the particular production type, production planning and shop floor data collection was reviewed.

For research question number ***2.*** How can the difference between the SOT in an ERP system and the real operation times be measured? For this the current available data needed to be collected, analyzed and understood. This was done by talking to the production planner and by extracting data from the ERP system. This data was then synthesized in several ways.

For research question number **3.** How large was the actual difference between the SOT in the ERP system and the real operation times? When having solved question number 2 that method could be utilized to answer this question. This question was still relevant to ensure that the scope was correct.

Research question number **4.** What actions can be taken in order to systematically reduce the difference? From start it was unclear how this question should be answered. But during the progress of the project it became clear the methods developed to answerer question 2 and 3 could be automated with the help of VBA to create PACSOT that could help out both monitoring and taking actions on wrong registering but also to correct the wrong SOTs. Other valuable conclusions from the observations were also used to create recommendations to further accomplish this.

3.3 The Match of company

When starting the project the author already had knowledge and contacts at SBSE since it has been the joint-venture company for a part of the Six Sigma Black Belt course at Chalmers. The author together with three other students and a company representative carried out a Six Sigma improvement project in the foundry. This project and the contacts made were strong reasons to why this Master thesis project was carried out at SBSE since the company was satisfied with the outcome of the previous project.

3.3.1 The ungrudging Access

The author was given full access to the facility with own entry codes, allowed to observe in the production and questioning the operators and foremen as the author deemed necessary. Of course without causing too much hassle for the ordinary production activities. The author was also provided with an own workstation in the same room as the supervisor at the company who was the former production planner and currently holding the position as SAP specialist.

A computer connected to the company network with a personal SAP account with clearance similar to a production planner was provided. An account with a similar access level was granted to the time reporting system ProJob.

3.3.2 Fortune position for understanding the context

In April 2015 the current production planner resigned which forced the company supervisor to take up her former responsibilities as a production planner in parallel with her duties as SAP specialist. As the author spent all the days at site a side effect of this was that it allowed the author to get a unique opportunity for insight in the real conditions and problems faced as production planner since a lot of people were coming with daily problems and in all cases but one never asked the author to leave the room.

3.3.3 Handling sensitive material

This is handled by not providing details about specific prices and the real costs related to the different work centers and man-hours. However these are part of the PACSOT tool since the impact of correcting the SOT on stock value are directly analyzed and presented in real time. Also since the issue with assigning correct standard times has impact on the financials the company, names and information about specific product types are left out in the title and abstract.

3.3.4 The timeline

This mater thesis project was mostly performed during the spring 2015 but finalized in the spring 2016. A pause was taken in June 2015 and the project restarted in august 2015 and finished in Mars 2016 due to the authors limited time for the project. The reason was that the author got a full-time employment at another company starting the 1th June 2015.

3.4 Literature review

Relevant theory has been reviewed in a cyclical manner throughout the master thesis project. From start literature about the production planning setting was reviewed and the historical context of production planning. Then theory for carrying out specific types of observations such as the work sampling was reviewed. The literature for possible ways to analyze the data and solve the problem with incorrect standard operation times was reviewed.

The search function used has been the Chalmers Summon which allows the search to be done in all the databases available in the Chalmers library at once. For a full list of databases available visit the Chalmers Library website http://www.lib.chalmers.se/en/search/databases/. Examples of database available are Books24x7, Ebrary, Proquest, Science direct, Scopus, Web of science, Emerald, Retriever business.

The exact key words used depended on the subject but were for example:

Planning and scheduling
Production planning, Manufacturing scheduling, Production master planning, Master scheduling, Collection of shop floor data, production research, capacity planning, operational capacity planning

Correcting Standard Operation times
Correcting Standard Operation times, More accurate production Operation times, Setting processing times, correction standard production data, correcting master data, correcting setup-times, correcting standard data, correcting operation data with regression analysis, correcting processing time with regression analysis

Research methods
Operations Management research methods, Operations research, Production research methods, manufacturing research

3.5 Data collection methods

Several methods for data collection were used as advocated crucial when trying to address real complex problems at companies (Gummesson, 2000).

3.5.1 Observations and discussions

The observations from the two weeks of initial observations were recorded mostly at breaks and after the workday in a notebook. The idea was to have an open mind and just taking in the reality as the operators perceived it. Sticking up a notebook at the same time as asking questions was considered to create a barrier making the operator feeling assessed and prevent the creation of a positive communication environment that was believed to be needed later. Because of this a blue workers overall was also used by the author to both actually be able to take part in the work and sometimes give a hand but also as a symbol representing the authors desire to really get the operators perspective and not just be considered an office person telling them how to do their jobs. The aim was instead to create the feeling of if not being one of the workers so at least really care for their situation and opinions. Because of this the author also actively tried to assist in the work observed when possible to further try to reduce this barrier

Besides and insight in the production methods and procedures this also created a good understanding of the workflows and nature of work going on in the factory workshop. A goal was also to get to know the operator in their natural environment and if possible directly identify issues with the methods and procedures currently used or at least create a foundation for future dialog regarding this in the following work.

Sometimes discussions did take place in a more interview like manner when talking to a person in an office and then the notebook was used more actively to directly take notes of what was said.

However no formal interviews were held. Instead discussions on daily basis have taken place with the planners and foremen around procedures and events regarding production planning.

3.5.2 Work sampling

A limited work sampling study was conducted in the workshop with the operators for the machines carrying out machining of the parts. The foundry and the assembly were excluded since the activities both in the foundry and assembly were radically different from the machining taking place in the workshop, and the same categorization of tasks would then not have been possible. Actions were taken to minimize possible negative perceptions of the work sampling from the workers by informing and anchoring with the IF Metall union.

The work sampling was recorded with a tablet running an app version of Microsoft Excel. Excel was first used to generate the random order of which the operators were observed but also enabled the data to be sampled in a form that would allow easy analysis of it later. In fact a sheet for summery of the collected data was created from start in order to be able to explain outcome of the work sampling to the operators.

When actually starting the work sampling, each operator was given a more detailed explanation of the objectives and the anonymity of each individual operator. They were also shown the spreadsheet on the tablet where the observations were recorded and the different categories used. To help with understanding when activates hard to distinguish such as searching for a tool at another part of the factory or when being away discussing problems with a foreman the operators were asked if they could apply these type of information upon leaving their workstation. The operators agreed to do so since they recognized the problem of searching for missing tools or drawings.

3.5.3 ERP data collection

Massive amounts of data have been extracted from the ERP system SAP that SBSE has been using since January 2014. All available SOT times and the corresponding confirmed time per operation have been extracted. These times comes from the manually registering of each operation and part by the operators done in the time reporting system ProJob implemented in 2011.

Data from ProJob for the period 2011-2014 was extracted from the previously used ERP system iScala. Unfortunately this data was found to be structured in an entirely different way than the SAP data and it was estimated to be very time consuming and difficult to transform this data to a form when it could be analyzed together with the SAP data.

Also it was described that several startup problems were encountered when implementing ProJob such as errors and uncertainties of how to properly register times. Erroneous registrations by the operators were still being seen in 2015. Because of this it was concluded that it should not be worth the effort to try to transform this data prior to 2014 to a comparable format.

3.6 Creation of the VBA Excel-tool

To handle all the different procedures required for analyzing the collected ERP data the author started to use macros in Excel. To run the macros again and again but with different input, improvements to make them generic were needed. To accomplish this, more code and functions had to be added to the VBA-code, which was building up all the macros. These new code and functions could not be recorded as macros usually are but instead had to be programed by writing the code manually for these functions.

It started off as a way to make the analyzing work more efficient but the focus shifted during the project towards instead trying to create a prototype of a fully integrated tool. The tool should be able to get the necessary data from SAP, process it to be able to draw conclusions, make follow-ups but foremost to in a structured and efficient way be able to actually correct the SOT in the ERP system. The tool created was named (Prototype-tool for Analyzing and Correcting of Standard Operation Times) PACSOT to clearly communicate the complexity and prototype-like characteristics. PACSOT will be described in detail later in the report and in the created PACSOT usage guide found in Appendix 5 – The PACSOT Usage Guide.

3.7 Chain of evidence

In this section the chain of evidence and the workflow of the master thesis project are described.

3.7.1 First scope

From start the scope was set wide too "improve production planning" since SBSE perceived the level of control in this area to be too low, and problems with wrong operation times had been seen in spot-checks. Also the newly implemented ERP system SAP and some years earlier implemented time reporting system ProJob was perceived to be suitable for a wide investigation and analysis to understand what could have been done better and formulate some kind of best practice.

3.7.2 Initial shop-floor observations

The author started by spending two full weeks with participating in most of the operators work at the beginning. This was done to get an understanding of the manufacturing flow but also to get to know the operators in order to create a platform for future dialogs around production planning. It was valuable to do this from the start since the author perceived this a crucial knowledge.

This was also important to do before getting tangled up in the management perspective of planning, which the author was suspecting would come when later working with the planners, foremen and production manager.

This could be seen as active observations where the workflows for each machine and operator were understood at a high level with the aim to understand "what's really going on" at the shop floor. When introducing myself as doing the thesis with improving production planning, open questions were asked regarding the operators thoughts around production planning, time reporting but also general thoughts and ideas concerning the production.

3.7.3 Refocusing of the scope

Some week after the start of the project a meeting was held at the company with the Chalmers supervisor participating. In the discussions it was concluded that the previous scope had been too wide and a more suitable research possibility was available by focusing on the company's problem with wrong operation times. The scope was then revised and as a first step a work sampling study was planned to get a better understanding of the components of the standard operation time.

3.7.4 Literature review

With this new more specific scope a literature review was conducted to create a more in-depth understanding of the operation times in production planning and how a work sampling study should be performed.

3.7.5 Conducting the Work sampling study

Work sampling is a different method than the infamous time study measurement known as an important part of the scientific management movement in the beginning of the 1900s. However as Cecelja (2002) describe, one of the big problems with shop floor data collection in general was the attitude towards it and the operators feelings of being watched. Tendencies to this were seen in the first two week of general observations.

A risk was therefore identified that by performing the work sampling study, this would further increase this already partly prevalent view from the workers. A set of steps and precautions were performed in order to reduce this risk.

Firstly, the HR department helped communicating the work sampling with the IF Metal Union. The IF Metal Union did not have any objections or further requests for more detailed information.

Secondly, the work sampling was introduced to the workers at the once a month meeting with all the personal at SBSE called "Speakers Corner". The author showed a PowerPoint slide and briefly introduced the work sampling. Information was provided regarding the objectives (improve production planning by correcting SOT), the method and when and where it was going to be carried out. The PowerPoint slide used is found in Appendix 1 – The Work Sampling Powerpoint.

After this the actual work sampling study began and each operator was then again informed in the same way and allowed to ask questions and review the different categories and the tablet with the random numbers used for the sampling.
The work sampling was performed during a two-week period with observations each day both before and after the lunch break. The observations were done at two different places and the number of observed operators was 2-4 at each time. One observation of a random chosen operator was done every 60 second. The first place was the "Saw area" with for example the machines Boeringer (220), Mazak 300

(325), Mazak 800 (340) and Danobat saw (610). The numbers in the parenthesis represent the work center code in SAP. The second place was the “main hall” with the Soraluce (335), IG 1060 (330) and Okuma (215). For a map showing the two different areas see Appendix 2 – Work sampling areas.

At which place the observations were carried out depended on how many operators that were actually available to observe at the moment at each place and where the previous observations had been done since the goal was to spread the observations evenly between the two areas. The foundry, assembly area and warehouse were not observed in order to be able to use the same categories, such as for example “run automatic machine”, which do not happen or is not an easily defined task for the excluded areas.

From start the target was to archive 3000 observations and a relative accuracy of 10 percent. However the number of different activity types used made this a too high accuracy to archive. It was calculated that for some activities over 20000 observations were needed which were equivalent to 31 days of full time observations. Instead the target was set to collect 1000 observations and then calculate the relative accuracy achieved.

3.7.6 Initial ERP data extraction

Historical production data was collected from the ERP system and exported to Excel for review and analysis.

The available data was at the start of the project 13713 rows of different operation times for produced parts. To be able to know which exact material (this means part but are referred to as material at SBSE) the operations are executed on, interlinking had to be done with other exported SAP data with even more rows for each individual records on each operation. This was from start done with the COOIS – Confirmations, a file that at the same time contained 32681 rows of data.

To be able to draw meaningful conclusions from the data, a number of columns with different calculations were added for each row. From this all the planned time could be compared with all the real time by summarizing formulas on the columns.

3.7.7 Calculating the first totals

For example the total difference referred to as Total diff between the planned and real time could be summarized. For a single operation the difference against the standard time could be either positive or negative meaning it took longer or less time than the standard time, usually more. If subtracting the total negative diff from the total positive diff a Net diff is generated.
For example if for a material with a SOT of 5 hour are produced 4 times. The first it took 6 hour, the second it took 8 hour, the third it took only 4 hour and the fourth it took 4,5 hour. Two times the real time was longer than the SOT. The difference was 1 hour the first time and 3 hour the second time. This would create a cumulative diff for these two operations of 4 hours. The third and fourth time the real time on the contrary was lower than the SOT. The difference the third time was -1 hour and the fourth time -0,5 hour. This creates a cumulative diff on these two operations of -1,5 hours. If subtracting the -1,5 from 4 a Net diff of 2,5 are calculated for the four operations together.

The logic behind this is that these numbers are used to calculate the costs between different products and the total time for one material therefore can be viewed upon as an integrated whole.

3.7.8 Calculating a material

Certain materials were also filtered out for analysis by the Excel built-in Autofilter function. For example Rotor SQA and Stator SQA that are components in the most frequent produced seal SQA Seaqual at SBSE. From these it could be seen that considerable variation existed for the real operation times for the finished operations.

From the active observations in the workshop it was known that only one single operation time was collected and this one contained all the activities an operator was carrying out for each part such as handling, loading, setup-time of machine, actual processing, unloading and resetting of the machine and.

One question was how the standard operation time often could be so much lower than the real times. To answer this question, discussions with the planners and engineers took place that had inserted the current SOT in ProJob back in 2011 when the shop-floor time reporting system was implemented.

Another track was to follow up on recent deviations and directly ask the operators for the reasons for the deviation against the SOT. A decision was made together with the planners and foremen to do a follow-up each day of the finished operations from the previous day. The author started doing this in a pilot for a couple of days.

When doing this it became clear that filtering out the daily operations in Excel and structure it in a form for communicating it with the operators was a repetitive task. To simplify this some macros were developed. This removed some repetitive maneuvers from needing to be carried out each day in excel.

The daily extractions of data from SAP were also being done by the similar standard maneuverers and work to automate these steps as well was started. It was discovered that SAP has a built-in Scrip recorder similar to the Macro recorder in Microsoft office and Excel. A script was then generated which when run, either from the dedicated script player in SAP or by clicking on the script-file in the windows file-browser, automatically generated and exported the selected SAP data.

Since two separate lists were required, two separate scripts had to be run. The output from the SAP script was a new Excel workbook with the COOIS – Operation and a separate Excel workbook with the COOIS – Confirmations data. From both these workbooks the data was manually copy-pasted into a master Excel sheet. Then the previously created Excel-macro could be run to filter out yesterday’s operations for analysis. To continue to improve the process further a need to integrate all these three automated procedures was seen. However configuration of the code in the recorded macros and scripts was needed in order to accomplish this.

In parallel analysis of specific materials was also carried out. The available SAP operation time data was extensive but so was the product portfolio and available size variants. For each material a different number of size variants existed. All in all a big number of products and variants existed and the different sizes were indicated by a one or two digit number in the material code. The different sizes made the materials different versions of the part. Because of this to simply use a mean value of the historical operation times for all the parts with different size (like all Stator SQA) was considered to be a bad match.

3.7.9 Visual analyzing

When visualizing the data it was discovered that it seemed to be a correlation between the size and the standard operation time when sorting the data both in relation to the time used for the operation and the size, even though sometimes vague. An idea to try to fit the data to a linear model was born. This was discussed with the production planner and the foremen and they confirmed that a bigger part generally took longer time to produce. This is also perfectly logical since bigger parts create longer parts for the lathe-tool to travel and the handling becomes more difficult for a larger and heavier part.

To fit the data to a model was done with the built-in regression analysis tool in Excel available in the analysis ToolPak add-in. By this a much bigger amount of data was available for the analysis. Instead of only calculating a mean value for all sizes or a mean for each size of a specific material, all the combined data for all produced sizes could then be used to generate estimates for each size. This also decreased the effect of that for some materials only few or none parts of a certain size were produced, but several of another.

3.7.10 Creating the Material family list

To filter out one specific material from the SAP data a filtering criterion was needed. Since the filtering of yesterday's operations had been possible to automate with a macro, the logical next step was to do that for this procedure as well. However then a defined list of filtering criteria was needed to filter out one type of material such as the Stator SQA or Rotor SQA.

In the material code structure the size could often be found at a specific location for a specific material (see Figure 10 below). A list of search criteria with "??" representing the size was created by utilizing a pivot table of all the operations. By searching for example with "1??" all the numbers between 100 and 200 are found. In the list the most frequently produced materials in different sizes can be found. This list was extended to include all materials with more operations executed than 10 at the time of creating the list. By using sum.if formulas with the newly developed criteria it could be seen that the developed criteria were covering 80 percent of the total amount of operations and 91 percent of the total net diff at the time. To get 100 percent would require filters for each unique material due to the big variation in materials produced. The created list are named Material family list since one criterion are covering all the different sizes of one material. To filter out for example the material family Stator (in Figure 10 below) the criterion CED21??07 is used. New material family criteria can easily be added afterwards in PACSOT.

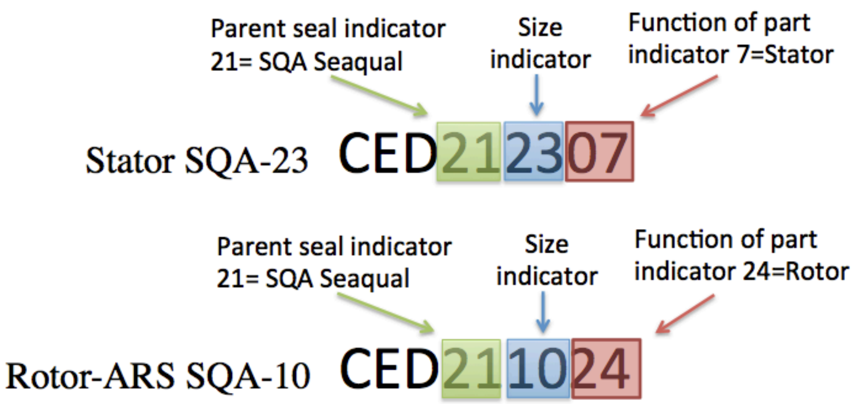


Figure 10 The material code structure for Stator and Rotor

For each material a number of operations are required to produce the material and these operations are similar but not the same for the different material families. The total number of available operations is the number of sizes*number of operations required to produce the particular material.

The material families with assigned criteria were about 150 and the sizes for each material around 17 and mean number of operation per material around 5. This gives a total of approximately 150*17*5=12750 unique operations for covering 80 percent of the total amount of operations and 91 percent of the diff.

If correcting each operation individually more than 12750 operations would then need to be corrected and that is still only covering 80 percent of the total amount of operations.

The regression analysis that enable correction of all the sizes of one material at the same times removes the factor 17 but only if correction can be done of all the 17 sizes at the same time. Knowledge of how the current times in SAP were set, acquired in discussion with engineering and the production planner, pointed at a possible solution. When implementing the SAP, all the production data was not inserted manually, instead it was imported all at once in a specific form in a spreadsheet as master data. If the SOT could be updated in the same way the process of updating big amounts of SOT would be considerably less time consuming.

But even so this method only removed the factor 17. Still 150*5=750 operations would need to be corrected. However while analyzing the data it was clear that the variation was bigger for certain operations and for certain materials. What if a way to find the ones with the biggest differences could be found and only correct them? Also still the steps and maneuverers required to go all the way from the importing of data, selection and correcting a material were massive and all steps needed to be done correctly.

Somewhere while working on the different tracks the idea was born to integrate everything in one single tool with automated VBA-macros. The goal was a system that enabled importing, analyzing and correcting entire material families and their operations. All while at the same time getting decision support in what operation to correct to get most value out of the correction i.e. to be most efficient.

Another benefit with such a solution was that all the steps and methods would not need to be learned in detail or risking to be done in a different way and therefore not fulfilling its purpose. By this the threshold to implement the solution would be much lower.

The different blocks for creating such a tool were created but the challenge was to connect these to work together in one single and user-friendly workflow. Data from other sources was also used such as other exports of master data from SAP like the routings for all materials and the material master with all the sizes for each material listed. A file with the current stock situation named MB5L for determining the effect of changes of the SOT was also used. This is important since the stock value is depending on the current SOT in SAP.

The functionalities of the tool were in cooperation with the production planner decided to be monitoring of the total operation status, functions for performing monitoring and analyzing of the operations time for a specific period, usually that would be yesterday. Finally it should constitute the functionalities to generate new corrected master data. From this PACSOT was developed which is described more in detail later in the report and in the created PACSOT Usage Guide found in Appendix 5 – The PACSOT Usage Guide.

4 Results

In this chapter the results from the observations, discussions, data collections and the data synthesizing is presented and described. The development of PACSOT and the result from some PASCOT analysis are also presented.

4.1 The current situation

In the section below all the collected data from the observations and discussions is presented to describe the present situation at SBSE.

4.1.1 The business

SBSE was part of the acquisition of the Cedervall Group by Wärtsilä in 2011. SBSE was before this an independent enterprise with the name Cedervall och Söner AB (Cedervall och Söner, 2012). The fusion between the two companies was finished in February 2014 (Wärtsilä Sweden, 2015). After the Wärtsilä acquisition the pressure for more financial control and reporting of the business emerged and SBSE also started the journey to implement the ERP system SAP that sere used by the rest of the Wärtsilä Enterprise worldwide.

After the takeover by Wärtsilä in 2011, the Seals & Bearings Sweden was a strategic business turnaround project. The turnaround had a planned completion in 2020 but was completed already in 2015 and Seals & Bearings Sweden is now a growth business.

SBSE had until recently internally been referred to as Product Company Sweden (PCSE). The new and correct name is however SBSE and that abbreviation will be used throughout this report. SBSE has a 6200 square meter production facility (see Figure 11) with workshop, foundry, warehouse and assembly area with pressure testing. For R&D purposes it also possesses a test facility.

Figure 11: The SBSE manufacturing unit in Arendal (adopted from Wärtsilä, 2007) with in-picture of the four level office section added in 2009 as it appeared in November 2015.

SBSE has its own: Purchasing, Production planning, R&D department and sales support department with order, delivery and aftermarket handling. The office area takes up approximately 1000 square meter.

4.1.2 Stern tube and seals

Stern tubes are mainly used for new build ships planned long ahead. But for the Seals and bearing business speed is crucial since demand often is recognized when a vessel is due for dry docking. In such a situation the need for spare parts is imminent and short notice deliveries are crucial for the vessel owner.

The seals and bearings are complicated pieces of equipment composed of several machined parts with specific measurements for the conditions for the boat its intended for. These are then assembled and tested before they are sent to the customers where technicians trained at the SBSE factory are installing the seal on the ship.

The batch sizes in the production are small with usually one single component being produced at a time. A component type is always represented with one individual work order. It can sometimes be more than one component of the same type on the work order but one is the most usual case. This together with a big variety of sizes and variants creates variances in the required time to produce and execute the necessary operations for each component.

4.1.3 The Production

The production at PCSE consists of a foundry and a workshop. The foundry is using sand-casting where pre-produced wood patterns are used to form the sand into a mold for the metal (see Figure 12).

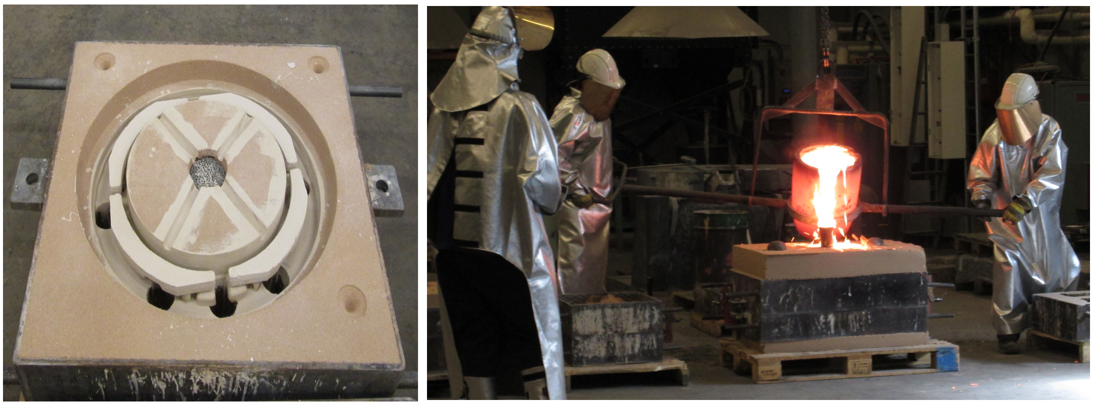


Figure 12: A sand mold (left) and the pouring of metal during a casting (right)

The casting is then performed in a manual craftsmanship process but with the help of an electric overhead crane. The 3-4 foundry operators are carrying out the work under the supervision of the foundry foreman. The material in the workshop is handled on wooden pallets and the identification method of the materials is a document called “Object_list”, commonly referred to in the workshop only as the “work order” (see Figure 13 and Appendix 3 – An Object_list/work order.

Figure 13: Parts on pallet and a Stock Operation List, also called "work order"

The workshop consists of several machines with computer (CNC) or manual controlled machines for drilling, turning and milling. Not all pieces machined are casted in SBSE's own foundry and casting of pieces that is not machined in the workshop also takes place.

Figure 14: A CNC controlled machine and a part loaded and ready for machining

Some manual work also takes place at the machines or in certain areas such as assembly and pressure testing (see Figure 15).

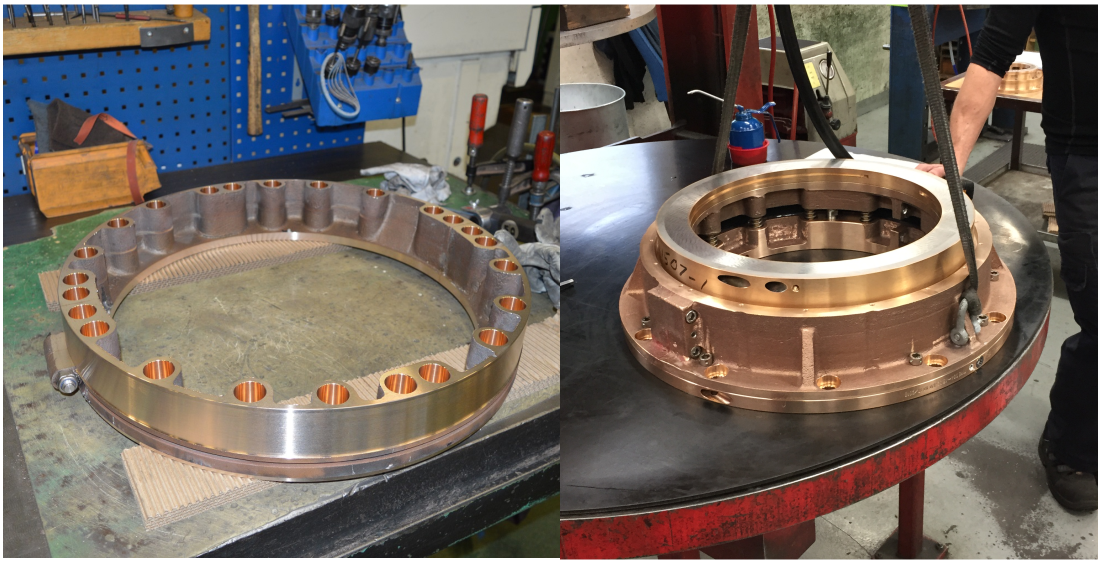


Figure 15: Work bench for manual work (left) an assembled seal at pressure testing (right)

4.1.4 Pro job

The attendance of the workers and the work they have carried out is tracked with a computer program called ProJob. Workstations with computers dedicated solely for this purpose is positioned at several places in the SBSE workshop (see Figure 16).

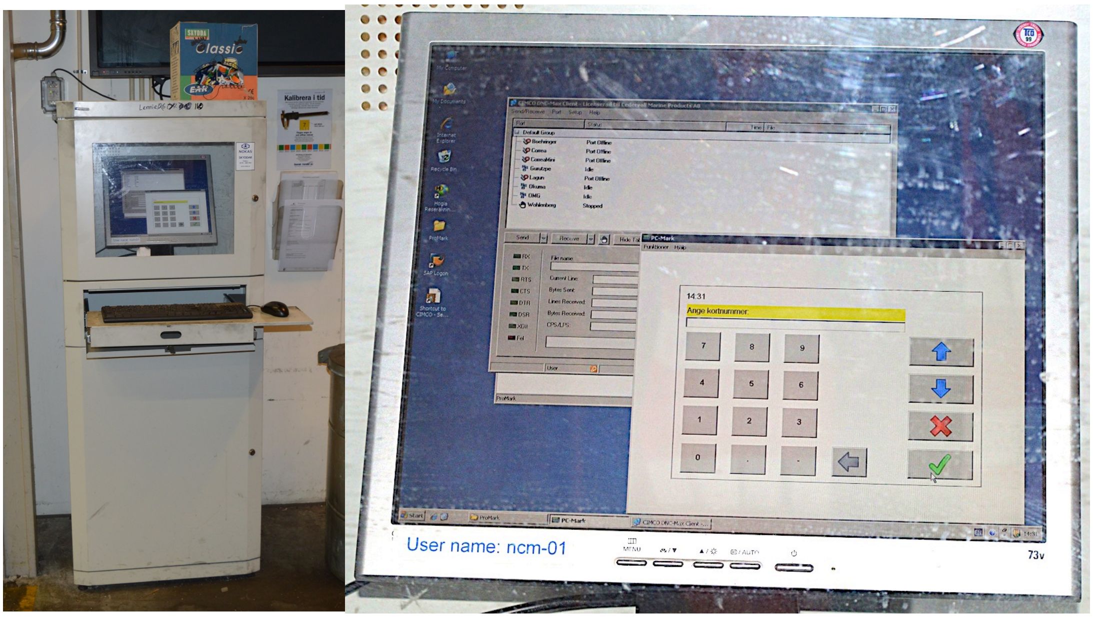


Figure 16: A Shop-floor workstation for registering operations

In ProJob each operator first signs in at his arrival to work in the morning. Hi is then also automatically logged into the orders and operations he was working on the previous day as long as they have not been finished and reported as closed by another operator. Rules are set in ProJob saying that an operator always has to be signed in on an order all the time. So when an order is finished the system will ask for the production order and operation for a new work task. The only way to not sign in on a new work order is to instead sign in to “non order driven work” with code 01. Then one of the sub-activities “cleaning”, “Machine repairs”, “meeting” or “education” has to be selected.

Each operator register the time for his operation in ProJob, from Pro Job the data are automatically transferred to SAP. But follow-up of a number of times had showed that some were several hundred percent higher than the SOT in SAP and sometimes considerably smaller like 5 percent of the standard time. Sometime the operator also forgot to register any time at all.

4.1.5 Registering an operation

The actual procedure of reporting an operation in ProJob is as follows:

First the worker states his employee number, which is a four-digit code like 1234. Then he could either state the seven digit production order number visible on work order/Object_list or choose in a list of work orders pending for the work center he is registered on. The operator is pre-registered at a specific work center which usually is one or a group of machines.

When the operator is finished with the operation he repeat the procedure with his employ number and the production order number and is asked to state the number of confirmed parts and if the operation is completed and should be closed. After this he is requested to sign in to a new job and the process starts all over again.

The registered SOTs are not seen on the production order document but in ProJob when the operator is signing in to the job. However most operators don't look at or care about this time and no different action is required if the time is exceeded when the operator report the operation as completed.

This information is then used to track the parts and be able to see the status of current orders and the time used to finish the associated operations. Work on an operation can be registered even though the part is not registered as completed from the previous operation. This is due to that an operator can forgot to sign out and close the operation or if mistakes were made in the registering process. Another error could be that no part is reported as confirmed or that too many parts are reported as confirmed.

The fact that more parts than on the initial order can be reported as confirmed is due to the fact that one operation that is carried out is when several narrow rings are machined from a casted work piece. The dimension of the casted work piece can vary with the result that the number of rings possible to create varies from time to time.

The process of registering the time for each operation like this is not appreciated by the operators. It is perceived as a disturbance in the work to have to go to the computer workstation and register the work and is also looked upon with suspicion as a mean to monitor and control the workers.

This method of registering the operation times has also only been used since 2011 and since many of the operators have worked for the company or in similar industries for 30-40 years they are not accustomed to have to report their work in this way.

However already before this reporting system was launched some tracking of the operation times was used. But then the operator manually stated the time used on work order itself.

4.1.6 Work sampling

In order to find out the distribution of the activities carried out by the operators the work sampling was performed. The accuracy and exact number of observations for each activity observed can be seen in the below table. The accuracy can be measured as a total accuracy (labeled Accuracy) or as accuracy in relation as a share of the percentage of the activity (labeled as Relative accuracy). From start the aim was to have a 10 percent relative accuracy. However it was concluded during the work sampling that for the large number of activities observed with some having relatively small shares, over 15000 observations would be needed. Instead it was decided to limit the works sampling to 1000 observations. This however had the effect that the activities seen most rarely got a relative accuracy of over 40 percent. Like for example “Assisting other operator” with a relative accuracy of 45,8 percent.

The total number of observations was 1052 taken during a two week period and the full result can be seen in Table 1.

No.	Activities	Amount	Activity share (%)	Accuracy	10 % of activity	For 10% relative Accuracy Required observations	Relative accuracy
1	Read production order / Register time	34	3,2%	1,07%	0,32%	11502	33,06%
2	Read drawing / Measurement	36	3,4%	1,10%	0,34%	10842	32,10%
3	Bring/ Move material	71	6,7%	1,52%	0,67%	5308	22,46%
4	Wait for material	0	0,0%	0,00%	0,00%		
5	Bring/ Look for tools	42	4,0%	1,18%	0,40%	9238	29,63%
6	Wait for crane/ forklift	0	0,0%	0,00%	0,00%		
7	Program/ Prepare machine	157	14,9%	2,15%	1,49%	2190	14,43%
8	Chucking of machine/ Prepare material	89	8,5%	1,68%	0,85%	4157	19,87%
9	Manual machining	83	7,9%	1,63%	0,79%	4485	20,64%
10	Supervise CNC-machining	205	19,5%	2,39%	1,95%	1587	12,28%
11	Manual work during machining	34	3,2%	1,07%	0,32%	11502	33,06%
12	Unloading of machine	34	3,2%	1,07%	0,32%	11502	33,06%
13	Manual work after machining	20	1,9%	0,83%	0,19%	19823	43,40%
14	Disturbance	0	0,0%	0,00%	0,00%		
15	Rework	0	0,0%	0,00%	0,00%		
16	Rework on dedicated rework order	0	0,0%	0,00%	0,00%		
17	Cleaning/ Clean-up of machine	80	7,6%	1,60%	0,76%	4668	21,06%
18	Machine maintenance/ Repairs	23	2,2%	0,88%	0,22%	17187	40,41%
19	Planning/ Help from foreman / Look for info	63	6,0%	1,43%	0,60%	6031	23,94%
20	Conversation with other operator or colleague	34	3,2%	1,07%	0,32%	11502	33,06%
21	Assisting other operator	18	1,7%	0,78%	0,17%	22068	45,79%
22	Meeting	0	0,0%	0,00%	0,00%		
23	Education	0	0,0%	0,00%	0,00%		
24	Personal time	29	2,8%	0,99%	0,28%	13552	35,88%
25	No observation		0,0%	0,00%	0,00%		
	Total	**1052**	**1**				
*	Machine running	310	29,5%	2,75%	2,95%	920	9,35%
n	Machine standing still	742	70,5%	2,75%	7,05%	160	3,91%
	Total	**1052**	**1**				

Table 1: The result from the work sampling observations

However it was some problems with carrying out the work sampling. For example it was difficult to distinguish some related activities so afterwards it was decided to merge some activities. The merging was done like can be seen in Table 2 bellow.

Activities – Running machines
Prepare machine and material
- Read production order / Register time
- Read drawing / Measurement
- Program/ Prepare machine
- Chucking of machine/ Prepare material
Run machine
- Supervise CNC-machining
- Manual machining
Manual Work
- Manual work during machining
- Manual work after machining
Material handling
- Bring/ Move material
- Unloading of machine
Help or conversation with foreman or other colleague
- Planning/ Help from foreman / Look for info
- Assisting other operator
- Conversation with other operator or colleague

Table 2: Merged activities from the work sampling

The final result with the merged activities can be seen in Figure 17 and Table 3 bellow.

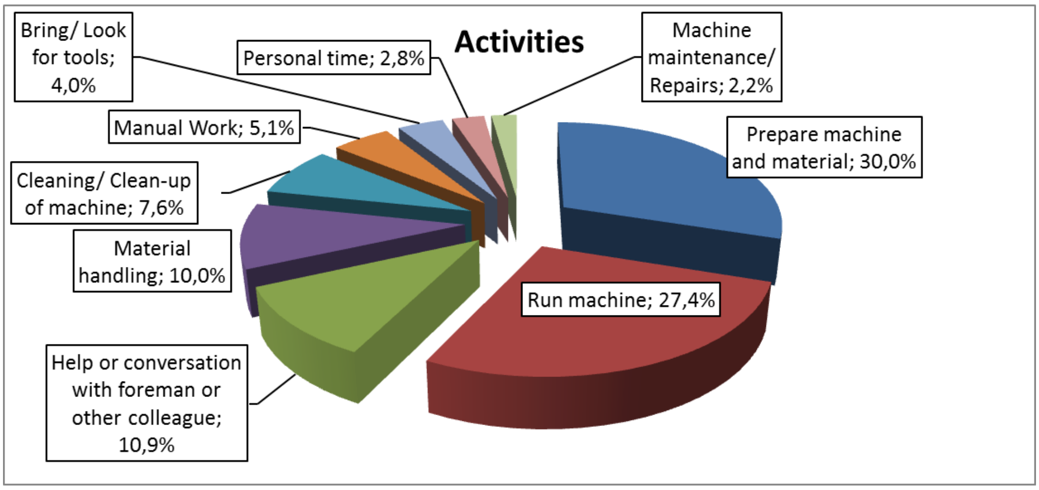


Figure 17: Graph of the Emerged activities from the Work sampling

Activities	Amount	%	Accuracy	10 % of activity	For 10% RA Required observations	Relative accuracy (RA)
Prepare machine and material	316	30,0%	2,77%	3,00%	895	9,22%
Run machine	288	27,4%	2,69%	2,74%	1019	9,84%
Manual Work	54	5,1%	1,33%	0,51%	7100	25,97%
Material handling	105	10,0%	1,81%	1,00%	3465	18,14%
Help or conversation with foreman or other colleague	115	10,9%	1,89%	1,09%	3130	17,25%
Bring/ Look for tools	42	4,0%	1,18%	0,40%	9238	29,63%
Cleaning/ Clean-up of machine	80	7,6%	1,60%	0,76%	4668	21,06%
Machine maintenance/ Repairs	23	2,2%	0,88%	0,22%	17187	40,41%
Personal time	29	2,8%	0,99%	0,28%	13552	35,88%
Total	1052					

Table 3: The result of the work sampling for the merged activities

4.2 Follow up pilot on Yesterday's operation times

A pilot of the follow-up functionality was carried out investigating the reasons for the deviations on the operations performed yesterday. During this pilot a categorization of the causes for the deviations on the filtered operations for action was created. The screen Follow-up operations in PACSOT are intended to be directly printed and used when talking with the operators. It was improved several times during the pilot, for example to only display the operations for actions, removing certain columns, adding other columns and reviewing the categories. The result of the pilot can be seen below in Figure 18 visualized in the selected categories.

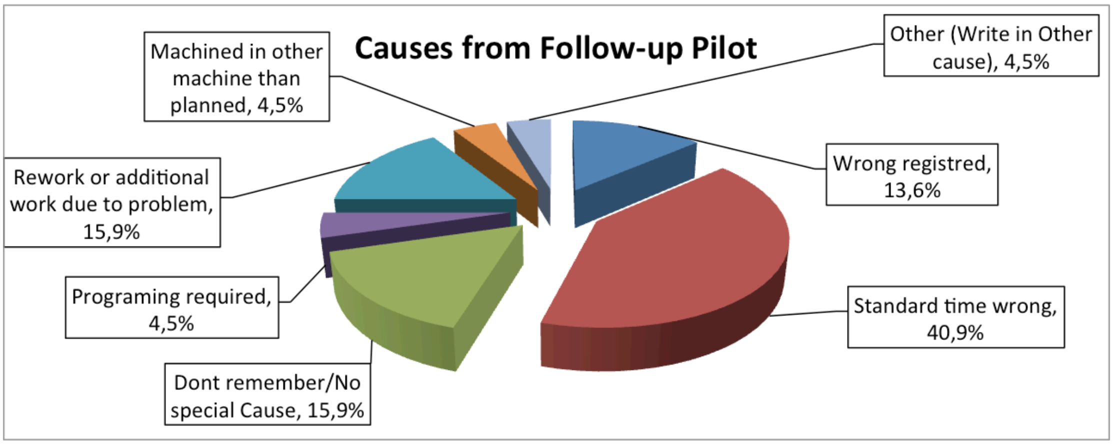


Figure 18: Registered causes from the Follow-up Pilot

4.3 Context of the current standard operation times

The existing operation times in SAP were for the most part transferred directly from the old ERP system iScala that the company used before the incorporation into Wärtsilä 2011 and the implementation of SAP in 2014. The times in iScala were either created when ProJob was implemented in 2011 or existing since even earlier.

During this implementation of ProJob in 2011 a major review of the operation times was done since it was decided that all the standard components should have a SOT when the time reporting system was launched. This review was carried out together with the foremen and the times missing were either set by looking at the times for a similar component or by the foremen estimating a reasonable time. The times existing before this review were also estimated by either the foremen or production manager or by the previous owner and factory manager. These old times were in many cases an example of how long the operation was supposed to take, which in many cases did not correspond to the time actually required to produce it.

This had the effect that before ProJob the operator sometimes was stating the time the operation should have taken (according to the owner) on the production order rather than the actual time.

During the implementation of ProJob it was also uncertainties regarding exactly what should be included in the SOT. For example if the time only represented the actual processing time of the machine or if the setup and loading time of the component was included as well. However due to pressure to not delay the implementation of ProJob, this was not possible to fully investigate so many times were just copied. The big amount of products, and as a consequence the even bigger number of operations, was one of the paramount causes for this.

4.4 One time to rule them all

The current SAP-setup where processing time per part is not distinguished from setup time or loading time is the easiest way to register an operation since only one start and finish registration has to be carried out by the operators. If the setup-time should be registered separately this will double the time and effort the operators have to spend on this. Also the effort required to calculate and estimate the times in the first place are growing exponentially by dividing each operation in that way.

4.5 Hassle for operator to register all activities

Another aspect is that already now the operators consider the registering of time a disturbance. It is also suspiciously frowned upon as a way to monitor the operators and be reasons for selecting possible candidate for lay-offs. Because of this the implications of trying to capture setup-time as well have to be carefully considered. The potential gains in retrieving this additional information have to be weighed against the extra disturbance this will create for the operators and the increased feelings of surveillance this probably will cause.

4.6 ERP production data

SAP is built up by several modules with different screens where the user can interact with the program. One such screen is called a transaction. Through these transactions, data about the production can be showed and altered depending on your access level in the system. An important transaction when wanting to analyze operation times is the “Production Order Information System” transaction. All transactions also have transaction codes that enable quick access to the transaction and the corresponding one is “COOIS”. An access level similar to production planner is required to be able to access this transaction.

When running this transaction one of the options is to choose what type of information that should be retrieved. One could for example choose “Order Headers” and get info about all the production orders.

Another option is to choose “Operations” and then all information about each operation carried out or planned will be retrieved. A number of choices can be made on the first screen like for example Plant, where SE10 has to be selected in order to only view the operations for the SBSE site. A limit in dates is also possible but since the purpose is to retrieve all available data for the analysis, this was generally not done. Another reason is that since SAP only has been operational at SBSE since January 2014, the amount of data retrieved like this is yet possible to handle. If the available data for example had covered 10-20 years, a selection would always have been necessary. Still the number of operations available the 5 of May 2015 was as many as 20392.

From each row retrieved by Operations in COOIS; important characteristics of the operation can be reviewed and analyzed. An extraction of such information can be seen in Figure 19 bellow when Operations and Confirmations have been interlinked.

Order	Material Numbe	Material description	Operation/Activity	Wor	Operation short te	Confirmatio	Work center descri	System Status	Operation Quantity (MEINH)	Confirmed yield (MEINH)	Act./Operation UoM (=MEINH)	ActStartDateExecution	ActFinishDate	Confirmed activ. 3 (ILE03)	Processing time (BEAZE)	Standard value 3 (VGE03)
1954409	CED5750701	S/R housing MDL-5	0040	850	Gradning	13524949	WorkStation - Misc	CNF PRT REL	1	1	PC	2014-04-17	2014-04-17	0,1	0,1	0,100
1954409	CED5750701	S/R housing MDL-5	0050	800	Montering	13524950	Assembly - Seals	CNF PRT REL	1	1	PC	2014-04-17	2014-04-17	0,330	0,3	0,330
7013783	CED210807-1	Stator SQA- 8	0060	150	Vitmetalliläggning	13033912	Foundry - White me	CNF PRT REL	5	5	PC	2014-02-10	2014-02-10	3,3	3,3	0,660
7013783	CED210807-1	Stator SQA- 8	0070	830	Ihopslipning	13033913	WorkBench - Lappi	CNF PRT REL	5	5	PC	2014-02-10	2014-02-21	9,967	2,9	0,580
7013783	CED210807-1	Stator SQA- 8	0080	330	Bearbetning IG10(	13033914	Milling machine - M	CNF PRT REL	5	5	PC	2014-02-11	2014-02-21	2,834	2,5	0,500
7013783	CED210807-1	Stator SQA- 8	0090	800	Montering	13033915	Assembly - Seals	CNF PRT REL	5	5	PC	2014-02-21	2014-02-21	2,5	2,5	0,500
7013791	CED211107-1	Stator SQA-11	0050	260	Grovsvarvning 2	13033971	Lathe - OMG 320	CNF PRT REL	2	2	PC	2014-02-17	2014-02-17	1,0	1	0,500
7013791	CED211107-1	Stator SQA-11	0060	150	Vitmetalliläggning	13033972	Foundry - White me	CNF PRT REL	2	2	PC	2014-03-03	2014-03-03	1,320	1,3	0,660
7013791	CED211107-1	Stator SQA-11	0070	830	Ihopslipning	13033973	WorkBench - Lappi	CNF PRT REL	2	2	PC	2014-03-03	2014-03-03	1,160	1,2	0,580
7013791	CED211107-1	Stator SQA-11	0080	330	Bearbetning IG10(	13033974	Milling machine - M	CNF PRT REL	2	2	PC	2014-02-28	2014-03-03	2,683	1	0,500
7013791	CED211107-1	Stator SQA-11	0090	800	Montering	13033975	Assembly - Seals	CNF PRT REL	2	2	PC	2014-03-03	2014-03-03	1,0	1	0,500
7013794	CED163990	Mtrl.MD-200-10 sta	0020	260	Svarvning	13034622	Lathe - OMG 320	CNF PRT REL	1	1	PC	2014-10-21	2014-10-30	6,484	1,2	1,161
7013794	CED163990	Mtrl.MD-200-10 sta	0030	335	Bearbetning	13034623	Milling machine - S	CNF PRT REL	1	1	PC	2014-10-24	2014-10-24	1,567	1,5	1,500
7013794	CED163990	Mtrl.MD-200-10 sta	0040	830	Ihopslipning	13034624	WorkBench - Lappi	CNF PRT REL	1	1	PC	2014-10-29	2014-10-29	0,9	0,5	0,500
7013794	CED163990	Mtrl.MD-200-10 sta	0050	800	Provtr/Kylansl/Gra	13034625	Assembly - Seals	CNF PRT REL	1	1	PC	2014-10-30	2014-10-30	0,330	0,3	0,330
7013795	CED164090	Mtrl.MD-200-11 sta	0040	830	Ihopslipning	13034629	WorkBench - Lappi	CNF PRT REL	2	2	PC	2014-09-08	2014-09-08	1,350	1	0,500
7013795	CED164090	Mtrl.MD-200-11 sta	0050	800	Mont. VA/Provtryc	13034630	Assembly - Seals	CNF PRT REL	2	2	PC	2014-09-11	2014-09-11	0,660	0,7	0,330
7013796	CED164090	Mtrl.MD-200-11 sta	0020	220	Svarvning	13034637	Lathe - Boeringer V	CNF PRT REL	2	2	PC	2014-10-21	2014-10-22	5,433	2,3	1,160
7013796	CED164090	Mtrl.MD-200-11 sta	0030	335	Bearbetning	13034638	Milling machine - S	CNF PRT REL	2	2	PC	2014-10-24	2014-10-25	2,533	3	1,500
7013796	CED164090	Mtrl.MD-200-11 sta	0040	830	Ihopslipning	13034639	WorkBench - Lappi	CNF PRT REL	2	2	PC	2014-10-29	2014-10-29	4,683	1	0,500
7013796	CED164090	Mtrl.MD-200-11 sta	0050	800	Mont. VA/Provtryc	13034640	Assembly - Seals	CNF PRT REL	2	2	PC	2014-10-31	2014-10-31	0,660	0,7	0,330
7013797	CED211150	Stator SQF-11	0110	215	Bearbetning-Okun	13034652	Lathe - Okuma	CNF PRT REL	1	1	PC	2014-01-27	2014-02-05	3,750	1	1
7013797	CED211150	Stator SQF-11	0130	215	Kona	13034654	Lathe - Okuma	CNF PRT REL	1	1	PC	2014-02-05	2014-02-05	0,250	0,3	0,250
7013797	CED211150	Stator SQF-11	0140	800	Läppning/Fläcknin	13034655	Assembly - Seals	CNF PRT REL	1	1	PC	2014-02-05	2014-02-05	0,250	0,3	0,250
7013798	CED211007-1	Stator SQA-10	0070	830	Ihopslipning	13034662	WorkBench - Lappi	CNF PRT REL	2	2	PC	2014-02-11	2014-02-21	1,177	1,2	0,580
7013798	CED211007-1	Stator SQA-10	0080	330	Bearbetning IG10(	13034663	Milling machine - M	CNF PRT REL	2	2	PC	2014-02-08	2014-02-21	3,306	1	0,500
7013798	CED211007-1	Stator SQA-10	0090	800	Montering	13034664	Assembly - Seals	CNF PRT REL	2	2	PC	2014-02-11	2014-02-21	2,143	1	0,500
7013799	CED211750	Stator SQF-17	0020	260	Grovsvarvning 1	13034666	Lathe - OMG 320	CNF PRT REL	1	1	PC	2014-07-31	2014-08-04	1,617	1	1
7013799	CED211750	Stator SQF-17	0030	610	Kapning	13034667	Saw - Danobat	PCNF PRT REL	1	1	PC	2015-01-23	2015-02-17	0,267	0,3	0,250
7013799	CED211750	Stator SQF-17	0040	340	Ihopfräsning	13034668	Milling machine - M	CNF PRT REL	1	1	PC	2014-10-01	2014-10-02	3,584	2,5	2,500
7013799	CED211750	Stator SQF-17	0050	260	Grovsvarvning 2	13034669	Lathe - OMG 320	CNF PRT REL	1	1	PC	2014-10-03	2014-10-03	2,267	1	1

Figure 19: The interlinked SAP COOIS Operations data exported in 2015-02-25

Both data from COOIS Operations and COOIS Confirmations was used from start. The number of rows retrieved by COOIS - Confirmations was 32680 in 2015-02-25. Confirmations were later replaced with Order headers since it was discovered that all necessary information still could be retrieved by this, but much quicker. Confirmations or Order headers data are imported since COOIS Operations are missing the important information about on which material the operation is carried out.

Exactly what information that should be shown in the columns can be selected but in order to retrieve all the necessary information for the analysis of operations a layout called "/S_E10_OP" was created. This is created as a global layout accessible from all of Wärtsilä. The most important columns then shown will be described below.

4.6.1 The COOIS Operation attributes

Production order
This is normally a seven-digit number starting with a 7, like 7187038. This is a unique number for each production order in the workshop and is normally one per material on the sales order.

Operation number and description
The operation number (labeled "Oper./Act.") describes the order of the operation carried out on the material and is displayed on the "Stock operation list" that follows the material through the workshop. This is a 4-digit number always starting with a Zero ranging from 0002 to 0180 (see Table 5). Operation description is text explaining the operation like for example rough turning (Grovsvarvning).

Actual Finish date
This is the date when the operation is reported as completed and closed.

Planned quantity (Operation Quantity (MEINH))
This is the planned quantity for the order and this specific operation. The unit is pieces.

Confirmed quantity (Confirmed yield (MEINH))
This is the number of parts reported as finished and confirmed by the operator. The unit is pieces.

Scrapped quantity
This is the number of parts that cannot be made into confirmed parts due to for example error in the machining or in the material from earlier operations. The unit is pieces.

Standard operation time (labeled Standard value 3 (VGE03)**)**
This value is the most important value for the purpose of this report since it represents the planned time for a specific material for one specific operation. The unit is hours. For example 1 hour and 30 minutes is displayed as 1,5.

Processing (Processing time (BEAZE))
Processing time represent the total planned time for this operation for this order and material. The unit is hours. If the planned quantity is 1 the processing is the same as the Standard operation time. But if the planned quantity is greater than 1 the processing time will be Planned quantity*Standard operation time. For example if the Standard operation time is 1,5 hour and the planned quantity is 3 the processing time will be 1,5*3=4,5.

Confirmed activity (labeled as Conf. act. ILE03)
This is the actual time reported that is comparable with the processing time.

System status
This describes the status of the operation with a number of letter combinations. A completed and closed operation contains the code CNF that stands for confirmed. Other codes in this field are PRT that stands for printed and REL representing released. Several of this codes is combined in the field and a big amount of letter codes is available and therefore also a great number of possible variants. A normal finished operation has the system status “CNF PRT REL”

Confirmation number
This is also a unique number for one specific operation on one specific production order.

4.6.2 One-year Totals

In PACSOT different selections for calculations can easily be filtered out. Some such examples of one-year totals are shown in Figure 20 and Figure 21 bellow.

Deviation from planned (hours)	
Total Deviation from planned	16273
Hours +	12021
Hours -	-4252
Total nett deviation from planned	**7769**
Total Calculated Processing	19036
Total confirmed time	27218
Total Deviation from planned %	**85%**
Total nett deviation from planned %	**41%**

Figure 20: PACSOT Deviation totals from the Follow-up a manually filtered period (July 2014- June 2015)

Amount below 100%	4966	35%
Amount 100%	1260	9%
Amount above 100%	7888	56%

Distribution	Amount	%
0%	341	2%
1-50%	2415	17%
51-99%	2210	16%
100%	1260	9%
101-200%	3406	24%
201-300%	1904	13%
301-400%	956	7%
401%-	1622	11%
Total amount	14114	100%

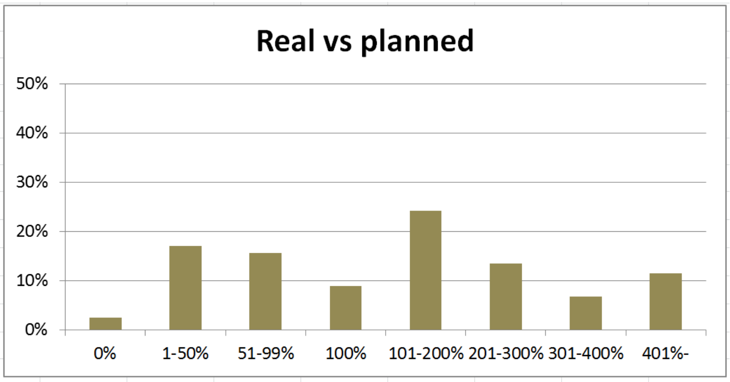


Figure 21: The real vs. planned PACSOT totals from the Follow-up a manually filtered period (July 2014- June 2015)

Interesting is the amount 341 with a real/std of exactly 0 percent in Figure 21 since that is totally impossible.

If the usual criteria for Real/Standard are used: selection of operations outside of the interval 50 percent to 300 percent, 5334 operations out of totally 14114 are filtered out as can be seen in Figure 21. This corresponds to 38 percent.

The amount below 50 percent is 2756 as can be seen in Figure 22. The amount above 300 percent is 2578 as displayed in Figure 23.

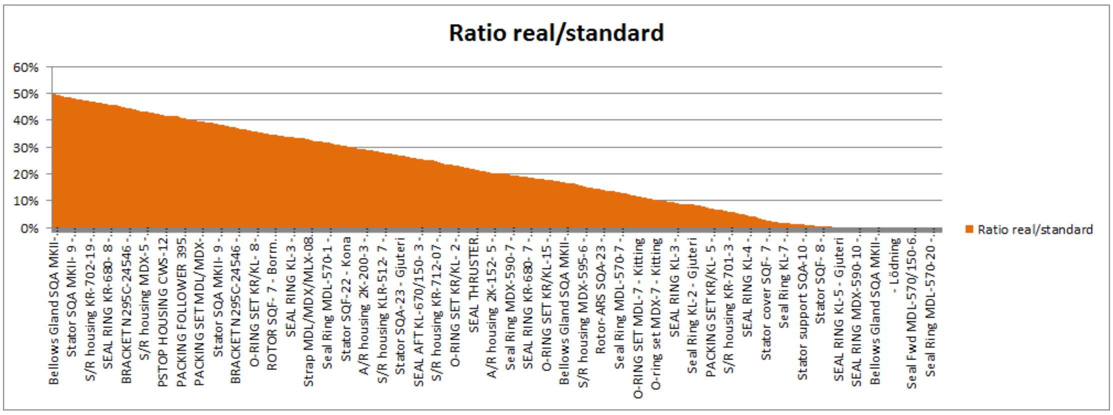


Figure 22: Showing the 2756 operations with a real/std below 50 percent during July 2014-June 2015

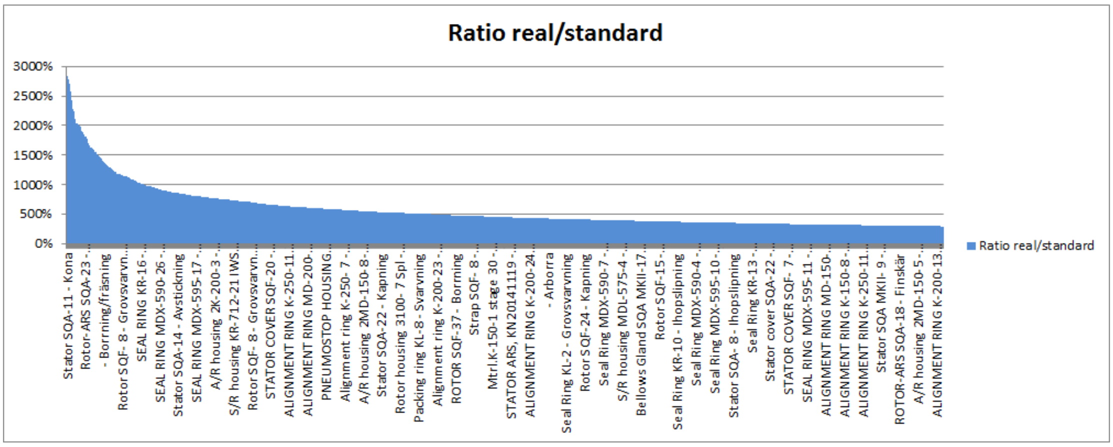


Figure 23: showing the 2578 operations with a real/std above 300 percent during July 2014-June 2015

4.6.3 The worst cases with over 3000 percent deviation

The most differing operations from the sheet Follow-up Operations in PACSOT with a high limit set to 3000 percent instead of the normal 300 percent is listed in Figure 24.

	1 July 2014	to		30 June 2015				Change limit values in sheet "Period Overview"										>3000%	<50%	
Material no.	Material Des.	Order	OI	OP short text	W	Work Center description	Sys.Status	Act.finis			S	T Dif	Std	Pro	Co	T Co	Upp	Bel	A
CED211506	Stator support SQA-15 Spl	7091470	0070	Gradning	850	WorkStation - Misc	CNF PRT REL	10.09.2014	1	1	0	2,34	0:04	0:04	2:25	2:25	3021%		Yes
CED7122301	S/R housing KR-712-23	7119461	0090	Planförs.flänshål	405	Drilling machine - HKS 32	CNF PRT REL	24.11.2014	1	1	0	8,85	0:18	0:18	9:09	9:09	3050%		Yes
CED5951202	Seal Ring MDX-595-12	7080716	0090	Svarvning-kona	215	Lathe - Okuma	CNF PRT REL	22.08.2014	1	1	0	4,88	0:09	0:09	5:02	5:02	3148%		Yes
CEDK981023	SEAL AFT KL-670/150- 5	7099514	0060	Emballering	820	Packing	CNF PRT REL	16.09.2014	1	1	0	5,03	0:09	0:09	5:11	5:11	3246%		Yes
CED6800801	S/R housing KL-680- 8	7105788	0040	gradning	850	WorkStation - Misc	CNF PRT REL	13.10.2014	1	1	0	3,02	0:05	0:05	3:07	3:07	3247%		Yes
CED211007	STATOR SQA-10	7074387	0010	Kona	225	Lathe - OMG CNA 325	CNF PRT REL	18.07.2014	1	1	0	5,06	0:09	0:09	5:12	5:12	3260%		Yes
CED212007	STATOR SQA-20	7197523	0010	Kona	225	Lathe - OMG CNA 325	CNF PRT REL	25.06.2015	1	1	0	8,44	0:15	0:15	8:42	8:42	3295%		Yes
CED211024	ROTOR-ARS SQA-10	7082518	0020	Läppning	800	Assembly - Seals	CNF PRT REL	05.09.2014	1	1	0	5,41	0:09	0:09	5:33	5:33	3479%		Yes
CED722503	SEAL RING KR-25	7068878	0100	Kona	215	Lathe - Okuma	CNF PRT REL	07.07.2014	1	1	0	6,66	0:11	0:11	6:51	6:51	3605%		Yes
CED211507	STATOR SQA-15	7091471	0010	Kona	225	Lathe - OMG CNA 325	CNF PRT REL	22.08.2014	1	1	0	6,34	0:10	0:10	6:31	6:31	3621%		Yes
CED720750	Alignment ring K-250- 7	7080006	0040	Ihopslipning	830	WorkBench - Lapping	CNF PRT REL	06.08.2014	1	1	0	12,99	0:19	0:19	13:18	13:18	4035%		Yes
CED7120702	S/R housing KR-712-07	7077946	0060	Gängning p-ringhål	215	Lathe - Okuma	CNF PRT REL	15.07.2014	1	1	0	6,35	0:09	0:09	6:30	6:30	4071%		Yes
CED670120	Alignment ring K-150-1	7080002	0010	Finskär	265	Lathe - OMG 260	CNF PRT REL	16.07.2014	1	1	0	6,33	0:06	0:06	6:26	6:26	6434%		Yes
CED212007-1	Stator SQA-20	7076133	0030	Kapning	610	Saw - Danobat	CNF PRT REL	24.07.2014	1	1	0	5,35	0:04	0:04	5:26	5:26	6793%		Yes
CED570514	A/R housing 2MD-150-5	7096001	0030	Gradning	850	WorkStation - Misc	CNF PRT REL	23.09.2014	1	1	0	4,14	0:03	0:03	4:12	4:12	7000%		Yes
CED211005	Stator support SQA-10	7074385	0030	Gradning	850	WorkStation - Misc	CNF PRT REL	16.07.2014	1	1	0	7,37	0:04	0:04	7:27	7:27	9313%		Yes
CED591902	SEAL RING MDX-590-19	7068877	0080	Gängning/Gradning	850	WorkStation - Misc	CNF PRT REL	06.08.2014	1	1	0	13,78	0:07	0:07	13:54	13:54	11583%		Yes
CED210756	Bellows Gland SQF- 7	7118723	0005	Gjuteri	100	Foundry - Bronze	CNF PRT REL	07.11.2014	5	5	0	-7,36	2:00	10:00	0:31	2:38		26%	Yes
CED211712	X-ring gland SQA-17	7170599	0005	Gjuteri	100	Foundry - Bronze	CNF PRT REL	26.03.2015	5	5	0	-7,33	1:30	7:30	0:02	0:10		2%	Yes
CED210712	X-ring gland SQA- 7	7181171	0005	Gjuteri	100	Foundry - Bronze	CNF PRT REL	29.04.2015	7	7	0	-1,29	0:15	1:45	0:03	0:27		27%	Yes
CED212456	Bellows Gland SQF-24	7198247	0005	Gjuteri	100	Foundry - Bronze	CNF PRT REL	29.06.2015	4	4	0	-0,71	0:15	1:00	0:04	0:17		29%	Yes
CED211350	STATOR SQF-13	7031144	0010	Gjuteri	100	Foundry - Bronze	CNF PRT REL	07.10.2014	1	1	0	-0,93	1:00	1:00	0:04	0:04		7%	Yes
CED212350	Stator SQF-23	7046328	0010	Gjuteri	100	Foundry - Bronze	CNF PRT REL	15.10.2014	1	1	0	-1,61	2:00	2:00	0:23	0:23		20%	Yes
CED212350	Stator SQF-23	7046329	0010	Gjuteri	100	Foundry - Bronze	CNF PRT REL	28.10.2014	1	1	0	-1,81	2:00	2:00	0:11	0:11		10%	Yes
CED211243	Rotor SQA MKII-12	7053643	0010	Gjuteri	100	Foundry - Bronze	CNF PRT REL	31.07.2014	2	2	0	-2,52	1:30	3:00	0:14	0:28		16%	Yes
CED670102	Seal Ring KL-1	7058889	0010	Gjuteri	100	Foundry - Bronze	CNF PRT REL	05.08.2014	2	2	0	-1,96	1:00	2:00	0:01	0:02		2%	Yes
CEDM20140621	STATOR COVER SQF-20	7073037	0010	Gjuteri	100	Foundry - Bronze	CNF PRT REL	24.07.2014	1	1	0	-1,98	2:00	2:00	0:01	0:01		1%	Yes
CED213312	X-ring gland SQA-33	7073060	0010	Gjutning	100	Foundry - Bronze	CNF PRT REL	14.07.2014	7	7	0	-13,82	2:00	8:00	0:01	0:10		1%	Yes
CED570702	Seal Ring MDL-570-7	7074211	0010	Gjuteri	100	Foundry - Bronze	CNF PRT REL	01.07.2014	1	1	0	-0,99	1:00	1:00	0:00	0:00		1%	Yes

All Operations Overview | All Operations | Follow-up Overview | Follow-up Operations | Registered Causes | Correcting Operations | For Masterdata Update | Corrected OP | OPERATION | Order

EADY FILTER MODE

Figure 24: The PACSOT Follow-up operations with 3000 percent set as the high limit criteria for July 2014-June 2015

A comparison of the planned vs. standard times are presented in PACSOT with the sheet Follow-up Overview. But this will show too much information when reviewing an entire year. Instead the below separate graphical displays are created to illustrate this big amount of data.

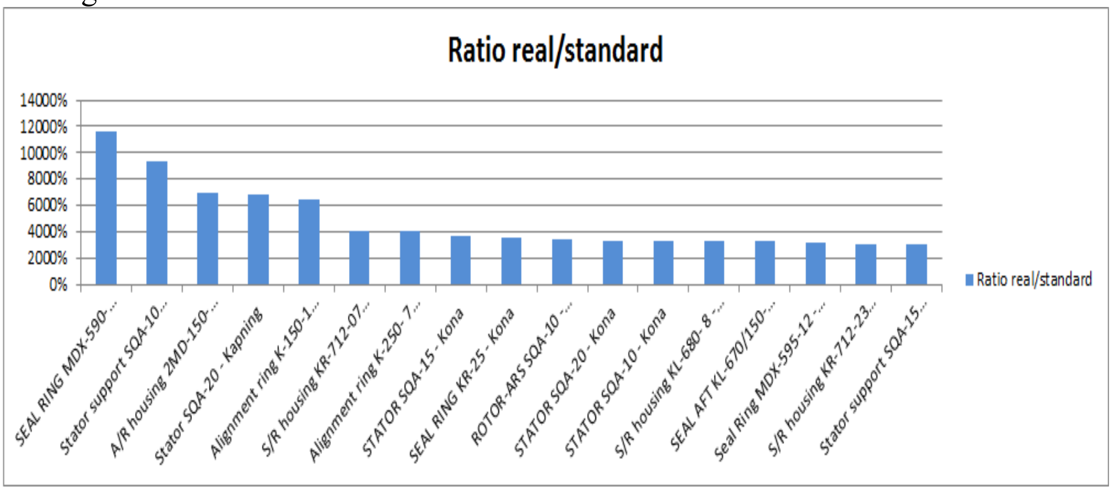


Figure 25: Graphical overview of the 17 operations with a real/std above 3000 percent during July 2014-June 2015 marked in blue in PACSOT the Follow-up Operations list in Figure 24

4.6.4 Big product portfolio and different sizes

A major problem was the considerable variance in product types and sizes where a specific product in a specific size could be made only once per year, if at all.

A list with all the materials codes currently registered in SAP is kept by SBSE on the G:\DATABAS\SAP_DownLoad. It's a spreadsheet-file called SapTD_MM_Material Master but it can only be exported from SAP with Super User clearance. It shows that in November 2015 the total number of materials existing was 11126 pieces.

As explained most of these materials is not produced during a year and an examination of the data available in SAP for all materials produced from January 2014 until 5 may 2015 show that the number of unique materials produced was 1241 pieces.

These make up the total amount of produced products for the period with 5173 produced products. The most commonly produced material was the Seal Aft KL-670/150- 3 CEDK20060237. During the period it was produced 93 times which correspond to 1,8 percent of the 5173. A list of the top 20 most produced materials in found in Table 4.

Material	Count of Orders	%	Cumulative %
Seal Aft KL-670/150- 3 CEDK20060237	93	1,80%	1,80%
Alignment ring K-150-3 CED670320	69	1,33%	3,13%
A/R housing 2K-150- 3 CEDK20060416	40	0,77%	3,90%
S/R housing KL-670- 3 CEDK20060415	38	0,73%	4,64%
Seal Ring KL-3 CED670302	31	0,60%	5,24%
Rotor-ARS SQA-23 CED212324	25	0,48%	5,72%
Stator SQA-23 CED212307	25	0,48%	6,21%
Maintenance KIT SQA-23 CED212340	24	0,46%	6,67%
Packing set MDL/MDX-10 CED571009	23	0,44%	7,11%
Stator SQA-23 CED212307-1	21	0,41%	7,52%
Alignment ring K-150-8 CED670820	21	0,41%	7,93%
Packing set KR/KL- 5 CED720510	21	0,41%	8,33%
Rotor-ARS SQA-10 CED211024	20	0,39%	8,72%
Rotor-ARS SQA-23 CED212324-1	19	0,37%	9,09%
Alignment ring MD-200-15 CED591513	19	0,37%	9,45%
Mtrl.K-150-3 stage 30 CED148530	19	0,37%	9,82%
O-ring set KR/KL- 5 CED720523	19	0,37%	10,19%
Packing set MDL/MDX-7 CED570709	19	0,37%	10,55%
Stator SQA-10 CED211007	18	0,35%	10,90%
O-ring set KR/KL- 7 CED720723	18	0,35%	11,25%

Table 4 Top most produced material 2014.01.11 – 2015.05.05

In Figure 26 below it is shown what happening on the number of produced materials per materials for the following of the top 500 of the totally 1241 produced materials. As can be seen the number of produced parts per materials is quickly falling below 10 pieces per material. The Y-axis is cut at 18 since the ones produced 18 or more times are the top 20 covered in Table 4. The 500 in Figure 26 represent 71 percent of the produced materials for the period.

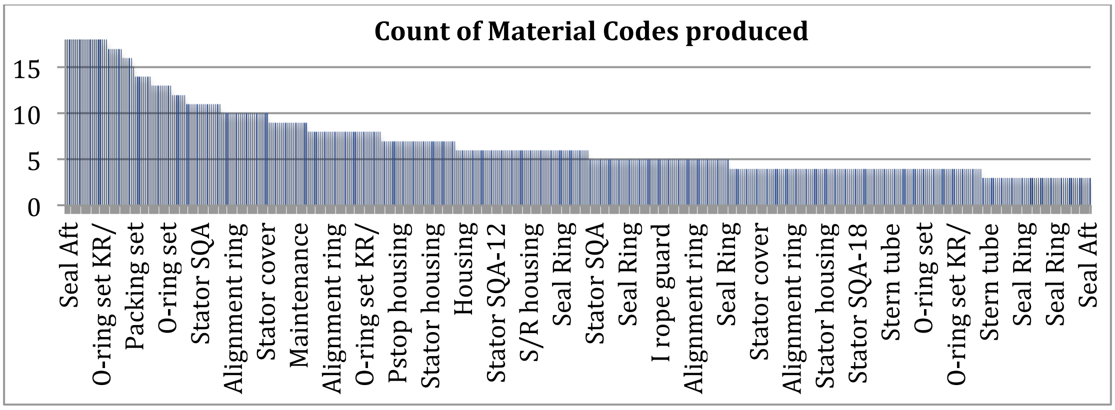


Figure 26: Count of Material Codes produced top 500 Jan 2014 - May 2015 (y=max 18, top 17 ones out of scale)

The 20 percent top-most produced material codes, 248 ones cover 50 percent of the total volume. The rule of thumb that 20 percent of the products represent 80 percent of the total production volume is clearly not true in this case.

More interesting is then how many materials that are only produced in really small numbers. 396 of the 1241 materials produced are only produced one single time. This represents 32 percent of material produced, as can be seen in Figure 27. 273 materials are only produced two times (22 percent) and 124 materials are produced three times (10 percent). This creates a situation where 54 percent of the materials produced were only produced one or two times and when materials produced less than 7 times correspond to 83 percent.

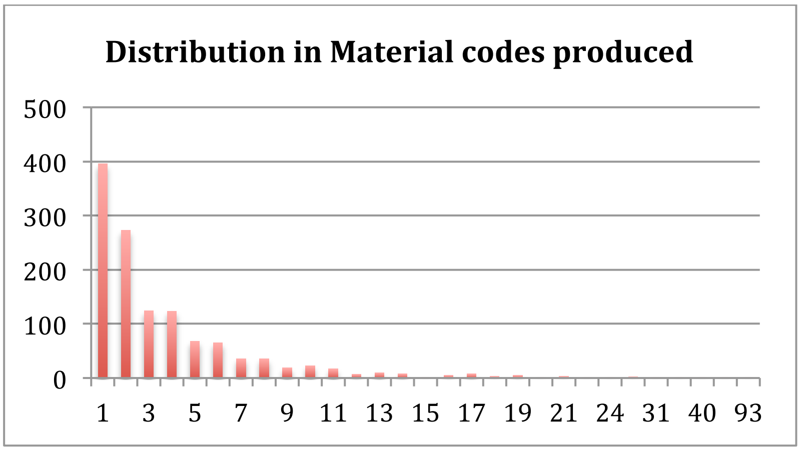


Figure 27: Distribution in Material codes produced Jan 2014 - May 2015

4.7 The problem of analyzing single materials

The total number of operations executed since January 2014 was 20391 in the 5 may 2015. The Operation description (labeled Operation short text) is what actually describes what type of operation is carried out. The starting operation is often 0010 so if the material was casted at the site, then 0010 are casting (labeled in Swedish as "Gjuteri" or "Gjutning" in the Operation description). If the material should not be casted the 0010 can for example instead be milling (labeled in Swedish as "fräsning"). The number of different number combinations is 43 (all listed in Table 5).

Operation	Count of Operations
0002	3
0005	71
0006	2
0007	18
0008	4
0010	5239
0011	5
0012	3
0013	2
0014	2
0015	25
0020	3614
0021	1
0022	1
0025	19
0027	2
0030	2438
0032	10
0035	3
0040	2107
0045	10
0050	1728
0051	8
0055	41
0060	1443
0061	1
0065	19
0067	1
0070	1152
0075	6
0080	831
0085	10
0086	10
0090	626
0100	437
0110	210
0120	116
0130	68
0140	49
0150	21
0160	9
0170	13
0180	13
Grand Total	20391

Table 5: All Operation numbers and their number of executed operations Jan 2014 - May 2015

However since the number only describe the place of the operation on the work order, one has to look at the description of the operations to know what they are and how many they are. Such counting shows that 434 different descriptions exist. See Table 6 with the top 20 ones carried out the most.

Swedish	Operation Description English	Count of OP
Gjuteri	Foundry	1454
Kitting	Kitting	1196
Ihopslipning	Grinding together	1115
Kapning	Cutting	855
Ihopfräsning	Milling Together	776
Grovsvarvning	Roughing	748
Provtr/Läppn/Fläckn	Pressure Testing / Lapping / Staining	743
Bearbetning	Processing	725
Gradning	Deburring	609
Vitmetalliläggning	White Metal filling	592
Finskär	Finishing	570
Kona	Cone	531
Svarvning	Turning	525
Montering	Mounting	519
Läppning/Fläckning	Lapping / Staining	490
Emballering	Packaging	372
Finsvarvning	Fine turning	354
Gängning/Gradning	Tapping / Deburring	343
Bearbetning-Okuma	Processing-Okuma	335
Provtryckning	Pressure Testing	319

Table 6 The top 20 carried out Operation descriptions carried out in Jan 2014 - May 2015

But if for example the operation Grinding Together is carried out at different materials it will involve different steps of treatment. How long each step takes to perform will also depend on the size of the component being produced. So if a count of the different possible unique operations carried out should be produced the list will contain 5800 unique operations carried out for the period Jan 2014 - May 2015. See Table 7 for the top 20 most carried out.

OP no + OP text + Material	Count of OP via Order
0020 Emballering Seal Aft KL-670/150- 3 CEDK20060237	93
0010 Montering Seal Aft KL-670/150- 3 CEDK20060237	93
0020 Läppn/Fläckn/Sprängs Alignment ring K-150-3 CED670320	62
0010 Finskär Alignment ring K-150-3 CED670320	61
0040 Provtr/mont.knapar A/R housing 2K-150- 3 CEDK20060416	39
0030 Borrn/Fräsn/Grada A/R housing 2K-150- 3 CEDK20060416	39
0020 Svarvning A/R housing 2K-150- 3 CEDK20060416	38
0030 Bearbetn/gängn/grada S/R housing KL-670- 3 CEDK20060415	37
0020 Sv.baksida/Grada S/R housing KL-670- 3 CEDK20060415	37
0010 Gjuteri S/R housing KL-670- 3 CEDK20060415	35
0050 Provtr/Märkn/Knapar S/R housing KL-670- 3 CEDK20060415	26
0040 gradning S/R housing KL-670- 3 CEDK20060415	26
0010 Kona Stator SQA-23 CED212307	25
0010 Finskär Rotor-ARS SQA-23 CED212324	25
0010 Kitting Maintenance KIT SQA-23 CED212340	24
0070 Provtr/Läppn/Fläckn Seal Ring KL-3 CED670302	23
0060 Kona Seal Ring KL-3 CED670302	23
0050 Borrning/gängning Seal Ring KL-3 CED670302	23
0030 Vitmetallsiläggning Seal Ring KL-3 CED670302	23
0020 Läppning/Fläckning Stator SQA-23 CED212307	23

Table 7 The top 20 carried out unique Operation/Material produced Jan 2014 - May 2015

4.7.1 Number of operations per Work center

The work center describes at which machine, machine group or area the operation was carried out. It is a three-digit number like 610. It never starts with a zero. The number of work centers is in total 25. Work center description describes in text what the work center is. All the work centers with description are listed below in Table 8.

Work Center	Work center description	Count of Operations
100	Foundry - Bronze	1528
150	Foundry - White metal	735
205	Lathe - Gurutzpe B1400/3	88
210	Lathe - Wohlenberg V1400SE	191
215	Lathe – Okuma	1317
220	Lathe - Boeringer VDF400C	1000
225	Lathe - OMG CNA 325	1238
255	Lathe - OMG 500	195
260	Lathe - OMG 320	653
265	Lathe - OMG 260	633
305	Milling machine - TOS W100A	19
325	Milling machine - Mazak VTC-300	1210
330	Milling machine - Mazak IG 1060	901
335	Milling machine - Soroluce FL 8000	425
340	Milling machine - Mazak VTC-800	888
405	Drilling machine - HKS 32	410
505	Lapping machines	7
610	Saw - Danobat	938
700	Assembly - Stern tubes	77
800	Assembly - Seals	4957
810	Control	16
820	Packing	370
830	WorkBench - Lapping	1177
850	WorkStation - Misc	1417
910	Warehouse Receipt	1
	Grand Total	20391

Table 8: All the 25 work centers with descriptions

4.7.2 Mean number of operations per material

But as said some of these unique materials belong to the same material family just with different sizes. During the production of the material a number of operations are carried out before the material is completed. This is normally from 1-10 per material as could be seen in Figure 13. The total amount of operations needed to produce the 5173 materials for the period was 20240. This gives a mean of 3,9 operations per material. However since operations is what will be evaluated the most in this report the total number of operations will often be used as reference number for the entire distribution instead of number of materials produced.

4.7.3 The size of a material

But as explained a lot of the materials produced is of the same material family, which means that the size is the only thing differing. The material family is then for example Alignment ring K-150. An example of a material in this family is the Alignment ring K-150-3, second in the list of most produced materials in the period. Besides the Material description the Material code can also be found in the list, which for this material is CED670320. This material code is unique for this material. The last number 3 in the material description represent the size and this could also be found in the middle of the material code as 03.

4.7.4 Material code structure

If considering a complete seal this is built up by a number of materials such as the mentioned Alignment ring K-150-3 CED670320. All the materials making up the same Seal share the same starting numbers in the material code, in this case 67. The finishing digits 20 after the size signals that it is an Alignment ring K for the dimension 150. This structure is important since it is the only way to filter which products that belong in the same material family. The material family is then defined by that these (often two) digits after CED and the last (often two) digits after the size is the same. To filter out a material, question marks are utilized instead of the digits representing the size like CED67??02. The size often ranges from approximately 1 to 40.

Extra complexity is then added to this by the fact that sizes sometimes are reported with three digits instead of two. The reason for this is that for some materials the smallest size was already 1 but a new even smaller size was needed. In the material description size 1 then was referred to as 01. The new size 01 was created but 01 in the material code was already occupied. Then size 01 needed instead to be represented with something else in the material code and 001 was chosen.

Another thing causing complexity is that some materials are supposed to be semi-manufactures with most of the operations carried against stock except the final operations with the lath. This semi-manufactured has the same material description but with a "-1" added in the end of the material code. An example of this is the Stator SQA-23 from the list in Figure 13 that are on the list both as a finished material at place number 7 with the material code CED212307 and as a semi-manufacture with material code CED212307-1 at number 10.

4.7.5 The Material family list

The Material family list, with the 150 different material families representing 81 percent of the operations, shows a similar pattern. The reason for only 81 percent is that rules have to be set to capture all the different material codes. Considering that 396 of the 1241 materials were only produced once the number of different rules required to capture all is too big. Therefore focus is the operations most often carried out and the operations causing the biggest total deviation between the SAP standard times and real times captured. The top 30 seen in Figure 28 cover 59 percent of all the operations and the top 64 (50 percent) cover 75 percent. The remaining 50 percent of the list covers the remaining 6 percent with only two operations in the end. The “tail” with similar small material families makes up the rest 19 percent together.

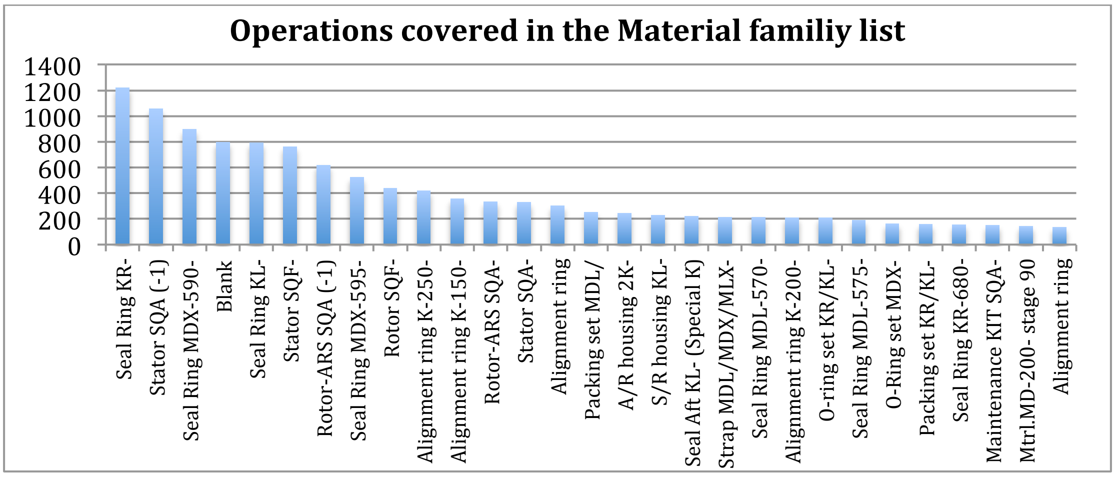


Figure 28: This shows the top 30 of 150 material families covered by the Material family search criteria list

4.8 The variation in material families

In the below section some examples of the variation within a material family is illustrated by graphs of planned and real operation times for Stator SQA which is one of the most commonly produced parts. Each graph represents one different operation. The blue staples represent the planned time and the red staples the real time in hours. They are sorted by size with smallest sizes to the left and the biggest ones to the right. Enlarged versions of the below graphs are also found in Appendix 4 – The graphs for variation in the SQA Stator material family.

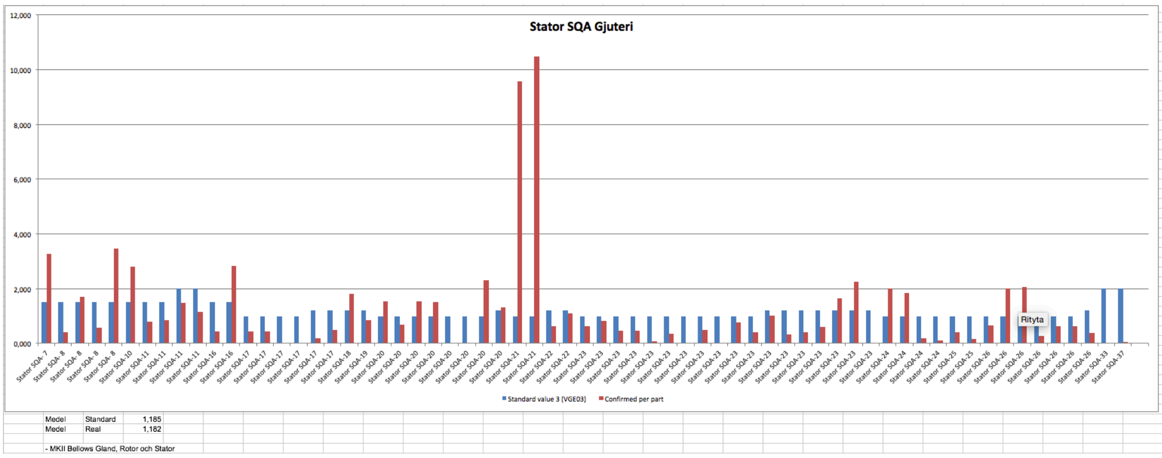


Figure 29 The planned and real operation times for casting in the foundry (Gjuteri) of the Stator SQA extracted from the SAP the 2015-03-16

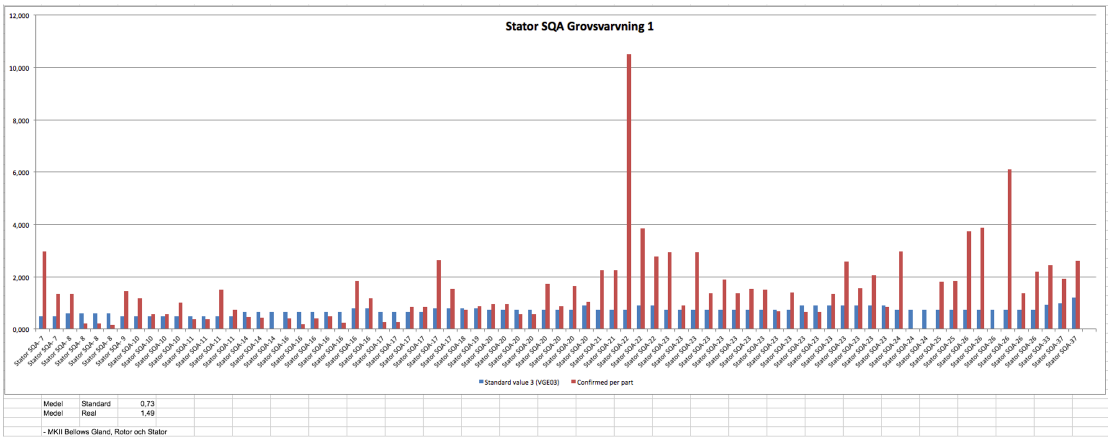


Figure 30 The planned and real operation times for Roughing 1 of the Stator SQA extracted from SAP the 2015-03-16

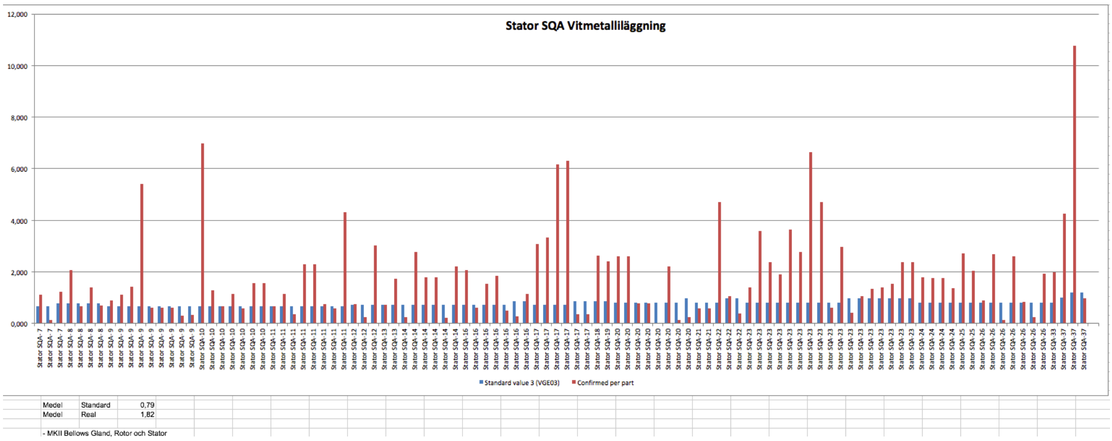


Figure 31 The planned and real operation times for White Metal filling of the Stator SQA extracted from SAP the 2015-03-16

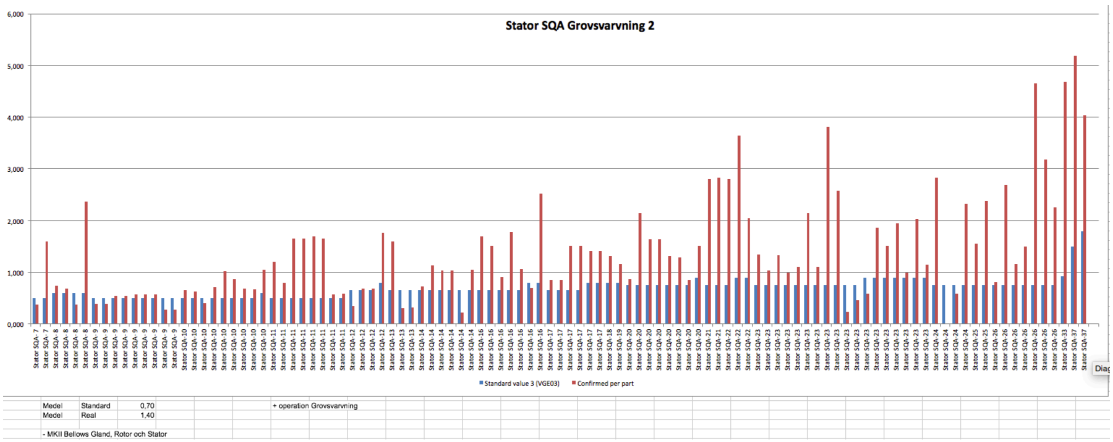
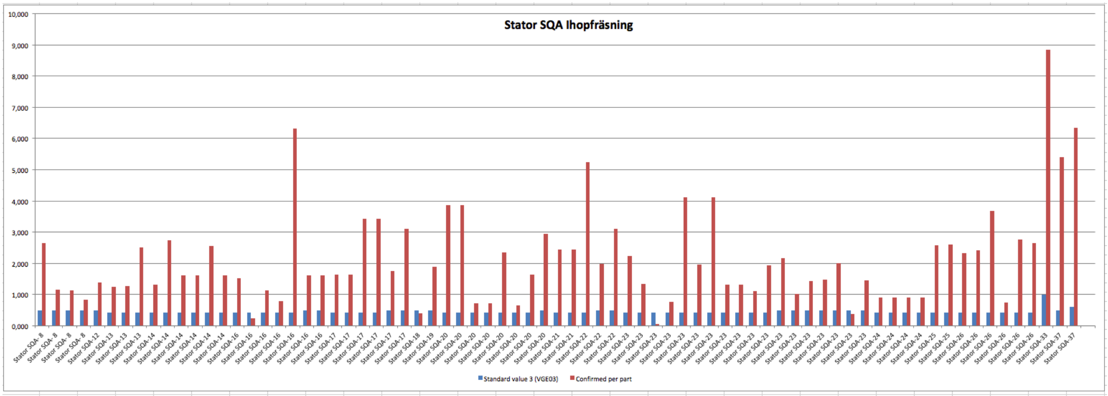


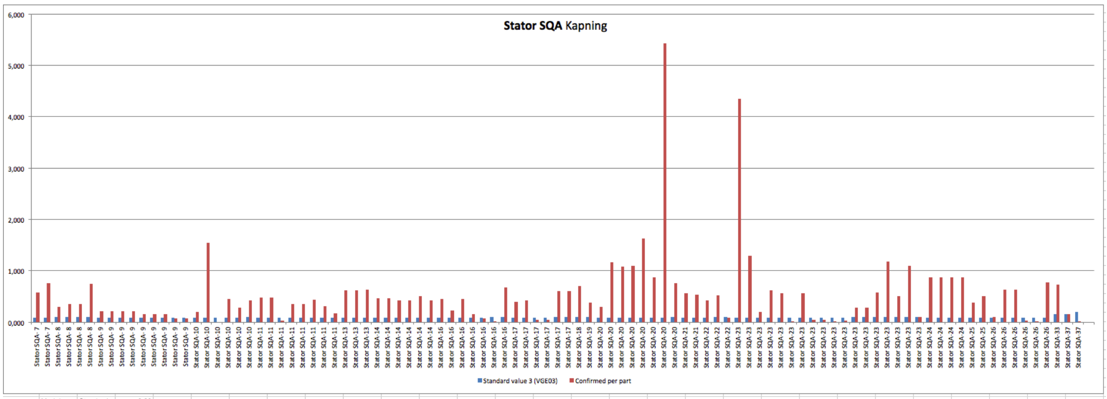
Figure 32 The planned and real operation times for Roughing 2 of the Stator SQA extracted from SAP the 2015-03-16



Medel	Standard	0,45
Medel	Real	2,14

- MKII Bellows Gland, Rotor och Stator

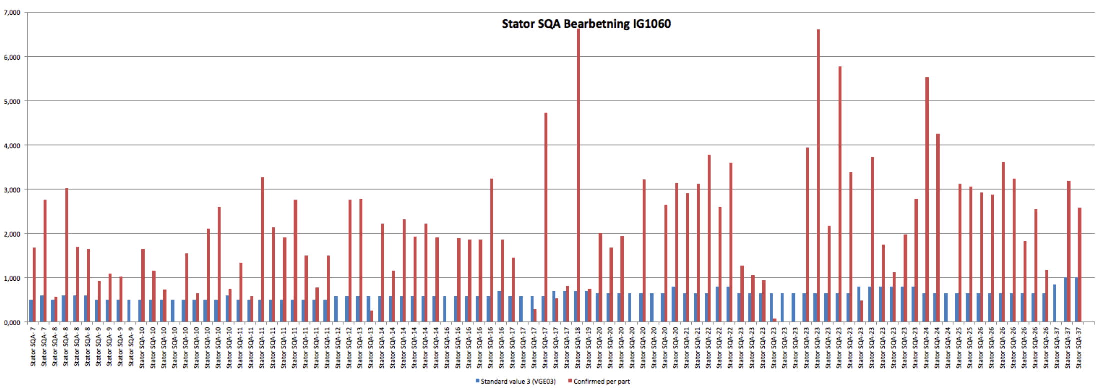
Figure 33 The planned and real operation times for Milling Together of the Stator SQA extracted from SAP the 2015-03-16



Medel	Standard	0,09
Medel	Real	0,54

- MKII Bellows Gland, Rotor och Stator

Figure 34 The planned and real operation times for Cutting of the Stator SQA extracted from SAP the 2015-03-16



Medel	Standard	0,63	37 körs i Okuma o heter Bearbetning
Medel	Real	1,99	

- MKII Bellows Gland, Rotor och Stator

Figure 35 The planned and real operation times for Processing 1060 of the Stator SQA extracted from SAP the 2015-03-16

4.9 The VBA-Excel tool

This Excel-file is a tool for monitoring, analyzing and if required update operation times by generating new master data for upload to SAP. With its VBA-Macros it can be compared to simple Business-Intelligence software but tailored to the needs and specific situation at SBSE.

This section explains the main usage scenarios intended for the Excel-file which are:

- Overview of all Operations
- Follow up Operation times for specific period (for example yesterday)
    - Follow-up yesterday's operations
    - Follow-up manually filtered
    - Follow up on deviations
    - Export deviations
    - Monitor causes
- Analyzing and correcting a Material Family

4.1 Overview of all Operations

The current total status of all planned vs. real operation times can be viewed in the All Operations Overview sheet (see Figure 36).

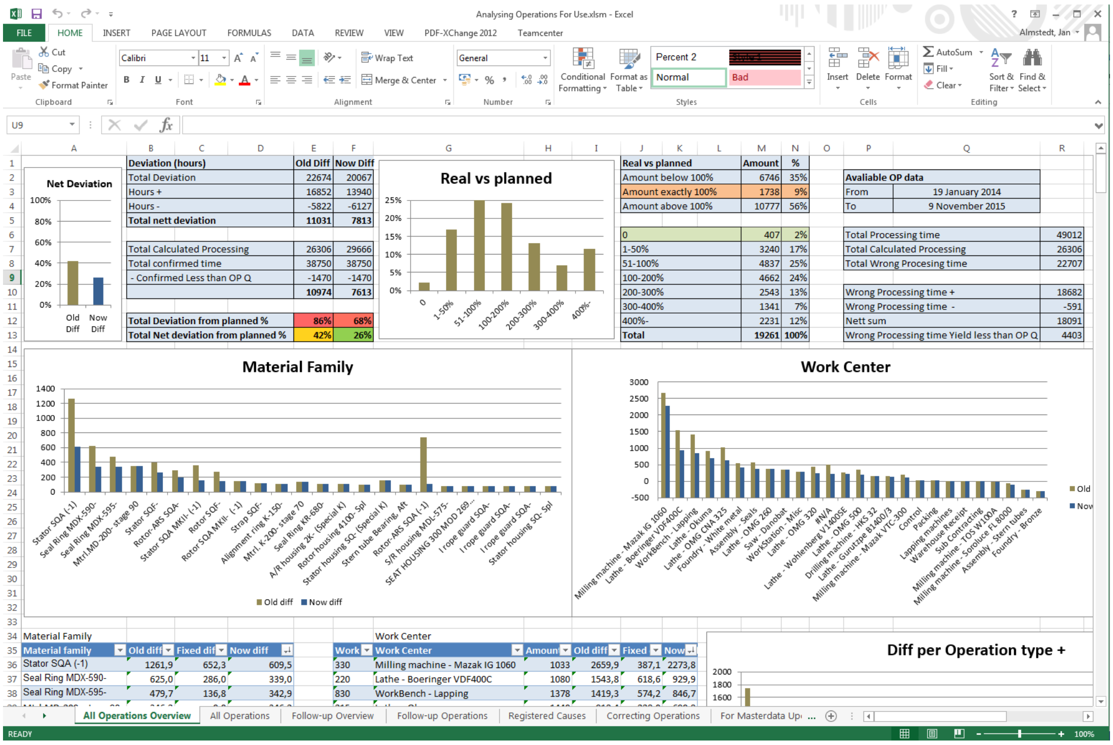


Figure 36: PACSOT all Operations Overview sheet.

To see the current total status, the latest operation times have to be imported from SAP with the button Import SAP Data on the All Operations sheet (see Figure 37 Arrow 8).

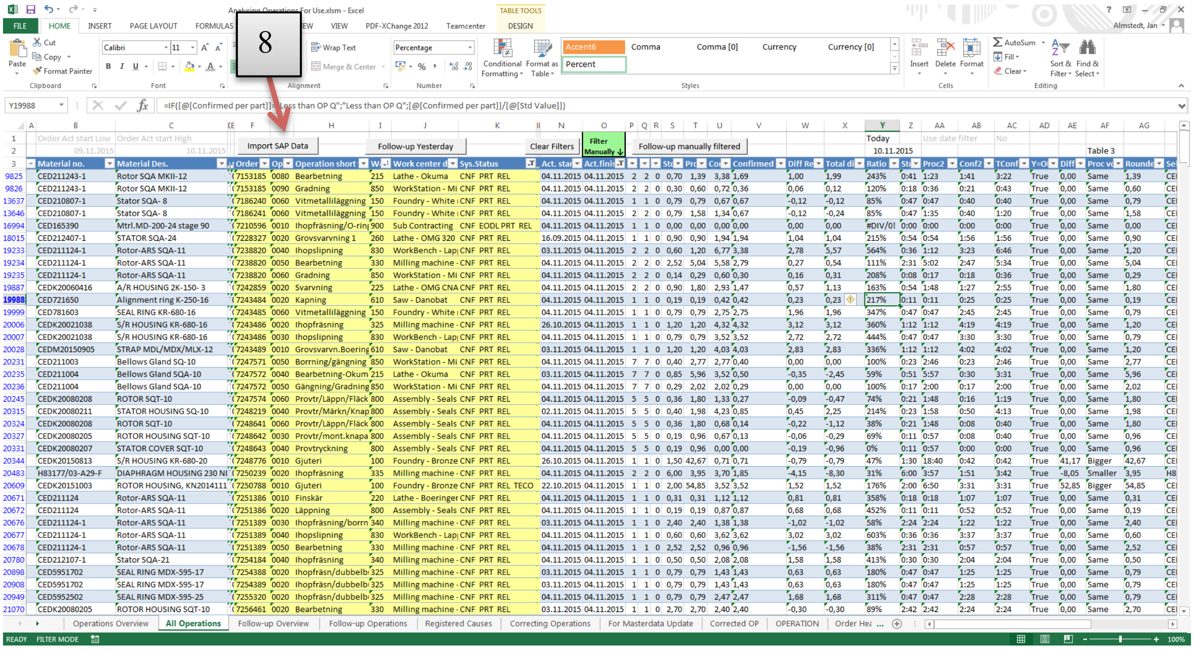


Figure 37: PACSOT All Operations sheet.

4.2 Follow up Operation times for specific period (for example yesterday)

The status of planned vs. real operation times for a selected period can be viewed in the Follow-up Overview sheet (see Figure 38). All the operations in the selected period outside the limit criteria are shown. New criteria can be set to filter a lesser or bigger amount of operations by changing the High and Low Limit percentage in the "CHOOSE" table for limit criteria (see Figure 38 Arrow 9).

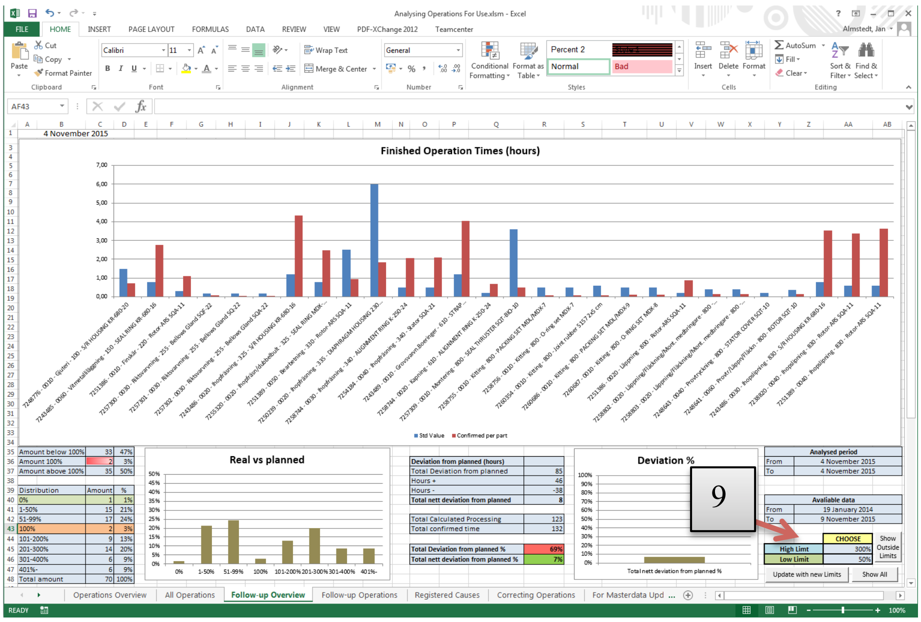


Figure 38: PACSOT Follow-up Overview sheet.

4.2.1 Follow-up yesterday's operations

A specific use for this sheet is to monitor the operations finished yesterday and follow up on deviations from the SAP times.

To show data for a recent period, its operation times first have to be imported from SAP with the macro/button Import SAP Data on the All Operations sheet (see Figure 39 Arrow 10). Then to filter yesterday's operations for analyzing simply use the macro/button Follow-up Yesterday (see Figure 39 Arrow 11). After the macro is run you will end up on the Follow-up Overview sheet (see Figure 38).

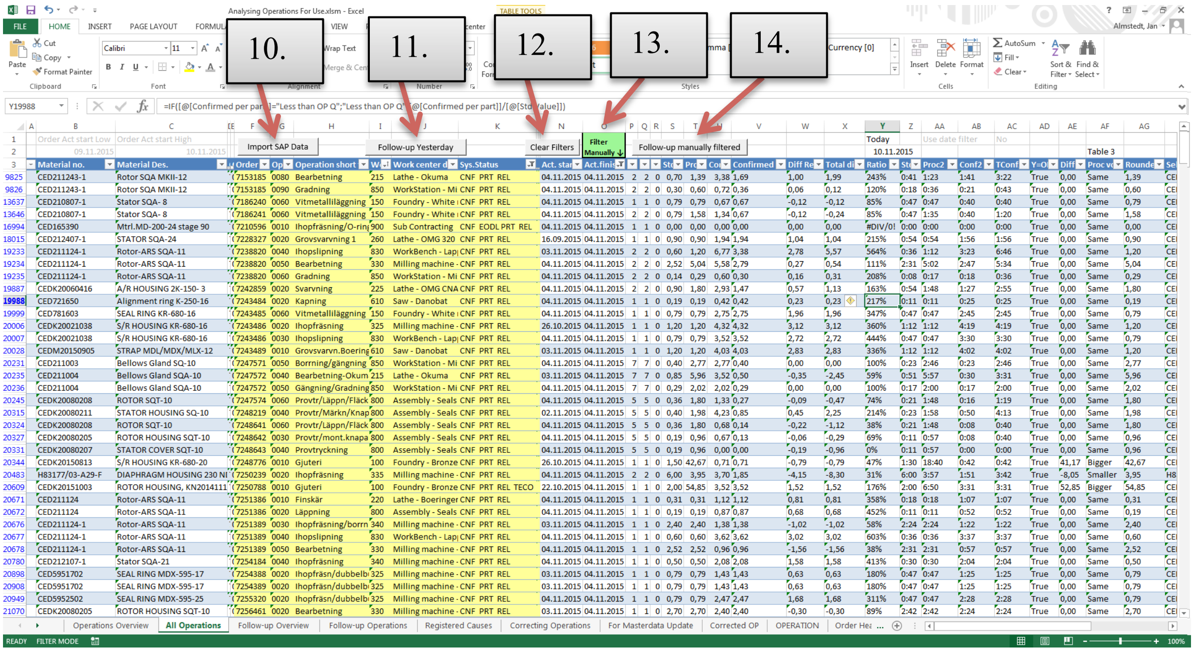


Figure 39: PACSOT All Operations sheet.

4.2.2 Follow-up manually filtered

If another period than yesterday is to be filtered, this has to be done by manually filtering out this date or dates on the Follow-up Operations sheet. Then first press the button Clear Filters (see Figure 39 Arrow 12). Then select the dates for the wanted period in the "Act.finish" column with the green box above with the text "Filter Manually ↓" (see Figure 39 Arrow 13). More than one date can be chosen. Then press the button Follow-up manually filtered (see Figure 39 Arrow 14). After the macro is run you will end up on the Follow-up Overview sheet (see Figure 40).

4.2.3 Follow-up on deviations

To see more details or follow up on the deviations, assign causes and suggest better times the Follow-up Overview sheet can be used (see Figure 40). In this sheet all operations for the chosen period meeting the Limit criteria can be seen. The limit criteria can be seen at the top (see Figure 40 arrow 15) but only changed on the Follow-up Overview sheet (see Figure 38 Arrow 9).

Data for the individual operations can be monitored. When for example checking with the responsible operator causes and status for the deviation can be assigned. When registering a cause a suitable category for the deviation has to be selected (see Figure 40 arrow 20). If the SAP standard time is considered to be wrong a suggestion for a new time can be inserted in the field "New standard" (see Figure 40 arrow 19). If

needed an additional free-text comment may be written in the “Cause (free text…)” column (see Figure 40 arrow 17).
If one wants to see all operations for the selected period regardless of the set Limit criteria press the button Show all (see Figure 40 arrow 21). To again only show the ones outside the Limit criteria press the button Show outside Limits (see Figure 40 arrow 22).

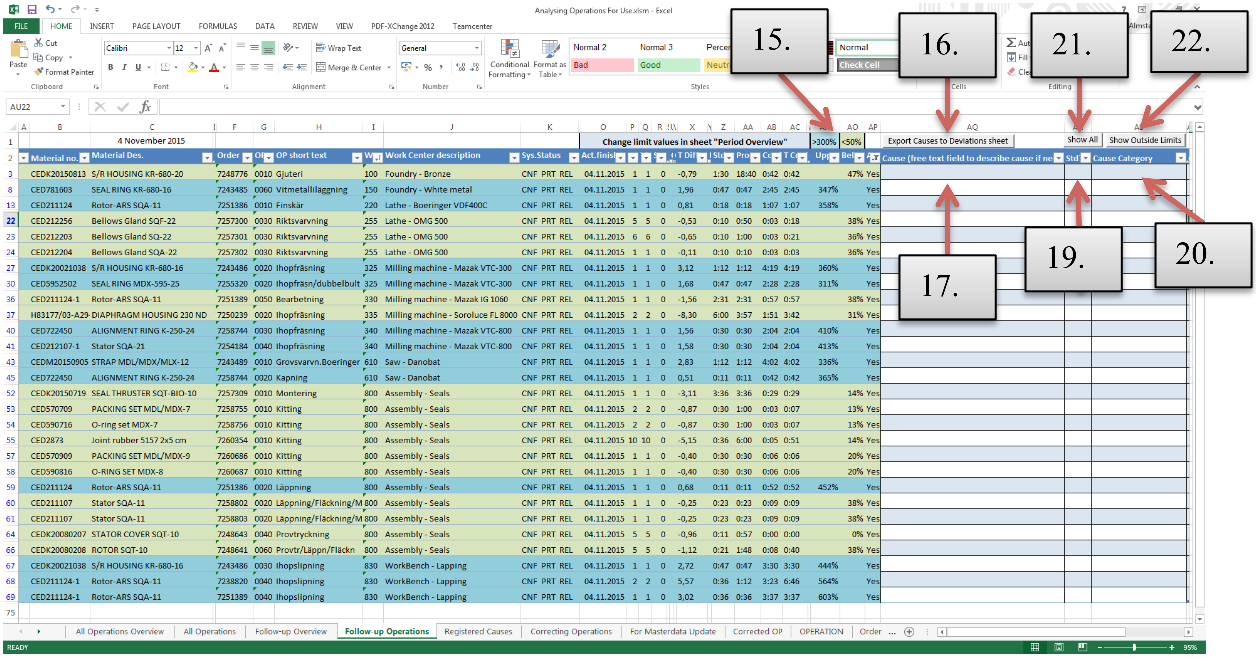


Figure 40: PACSOT Follow-up Operations sheet.

4.2.4 Export deviations

After all found causes are written in they can be exported to the Registered Causes sheet for saving and overview together with earlier reported causes (see Figure 41). To do this press the button Export Causes to Deviations sheet (see Figure 40 arrow 16).

4.2.5 Monitor causes

At the Registered Causes sheet all the exported causes can be monitored. Numerous possibilities for analyzing exist on this page. The total distribution for the cause categories is shown in the Graph “Causes from follow up” (see Figure 41 arrow 21). Different filtering can be done in all the columns and for example only show the deviations for a specific: material, operation or work center (see Figure 41 arrow 22).

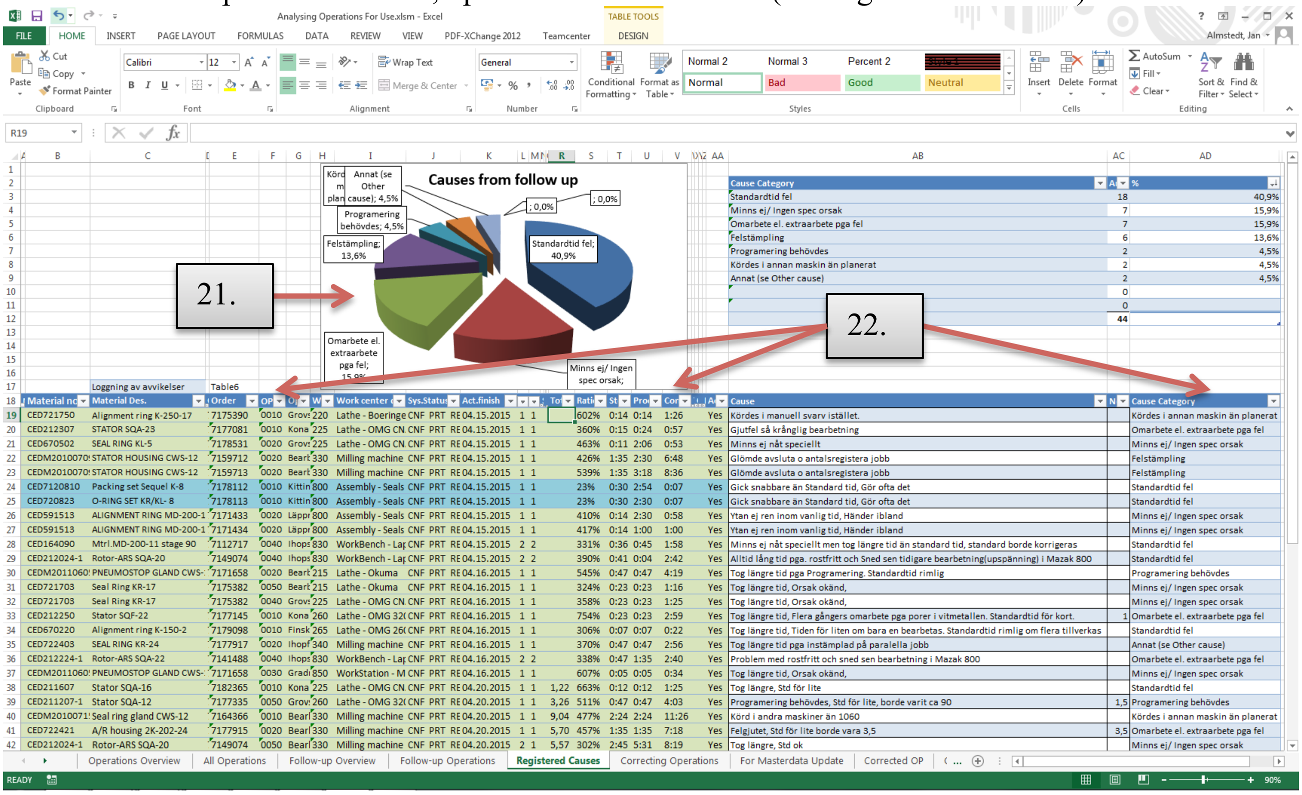


Figure 41: PACSOT Registered Causes sheet.

4.3 Analyzing and correcting a Material Family

To analyze and if needed generate new operation times for a specific operation for a material family use the Correcting Operations sheet (see Figure 42). A material family is defined as a material in different sizes with a similar material number structure to enable to filter out the material. An example is Stator SQA with the material number CED21??07-1 where "??" represent the size. The (-1) describe that it is a material usually produced against stock but without the last operation carried out until a customer order for the material is issued. Then it gets the similar the material number CED21??07 but without the (-1).

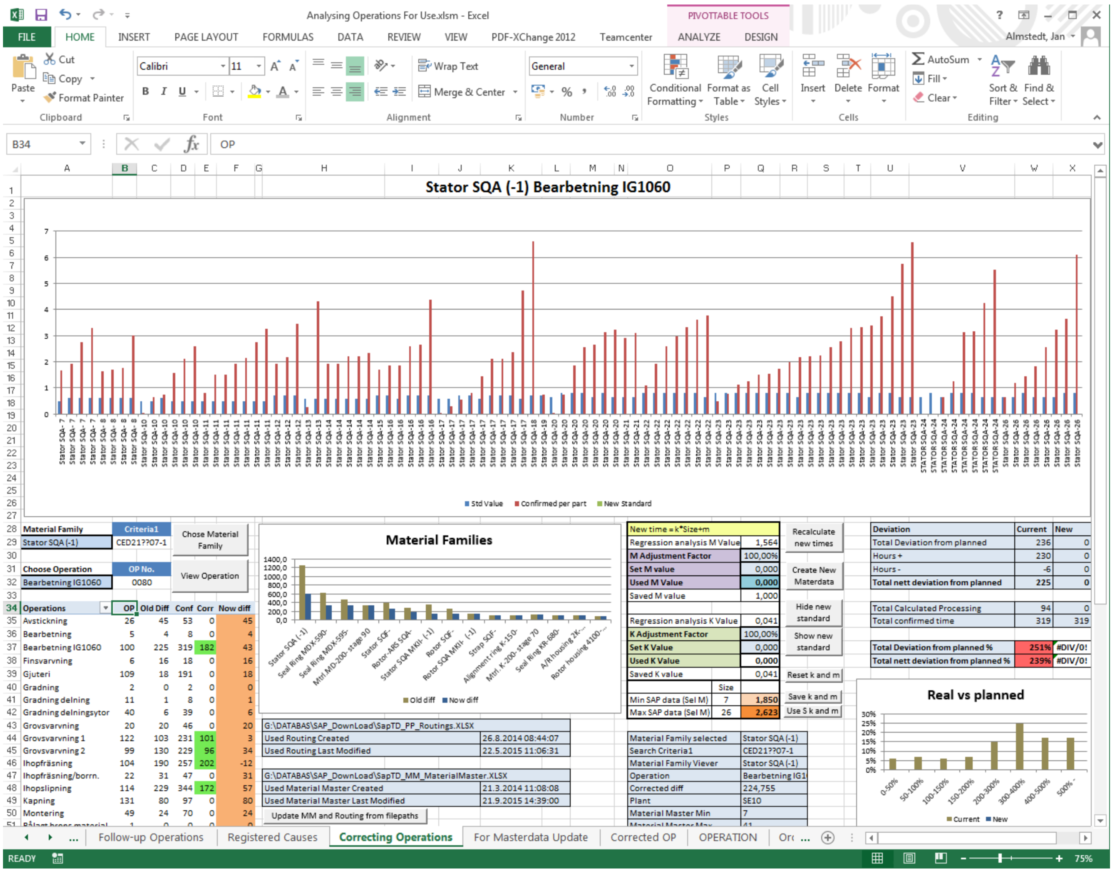


Figure 42: PACSOT Correcting Operations sheet.

The sheet show a graph illustrating both the old diff and the now diff for the material families with the highest now diff. A material family can be selected in the dropdown list and then the button "Choose Material family" should be pressed. Then details about the different operations for the selected material family are viewed at the pivot table below. An operation can then be selected based on which operation that has the highest "Now diff" and then press the button View Operation.

The operation times for the selected operation are shown in the top graph and all the calculations on the sheet are updated so the status of the selected operation can be analyzed. A suggestion for new standard operation times is also generated with regression analysis and also displayed in the graph trying to find the linear expression best representing the real operation times. The formula is Y=kx+m where Y is the planned time and X is the size. The k and m values are created in the regression analysis. These values can then either be adjusted or entirely replaced by the user. The status of the operation if these new standard operation times would have been used is also shown. The net deviation for both the old and new standard operation times is shown. If new master data is to be created the button Create New Master data should be used. New master data is then generated on the sheet For Master data Update (see Figure 43).

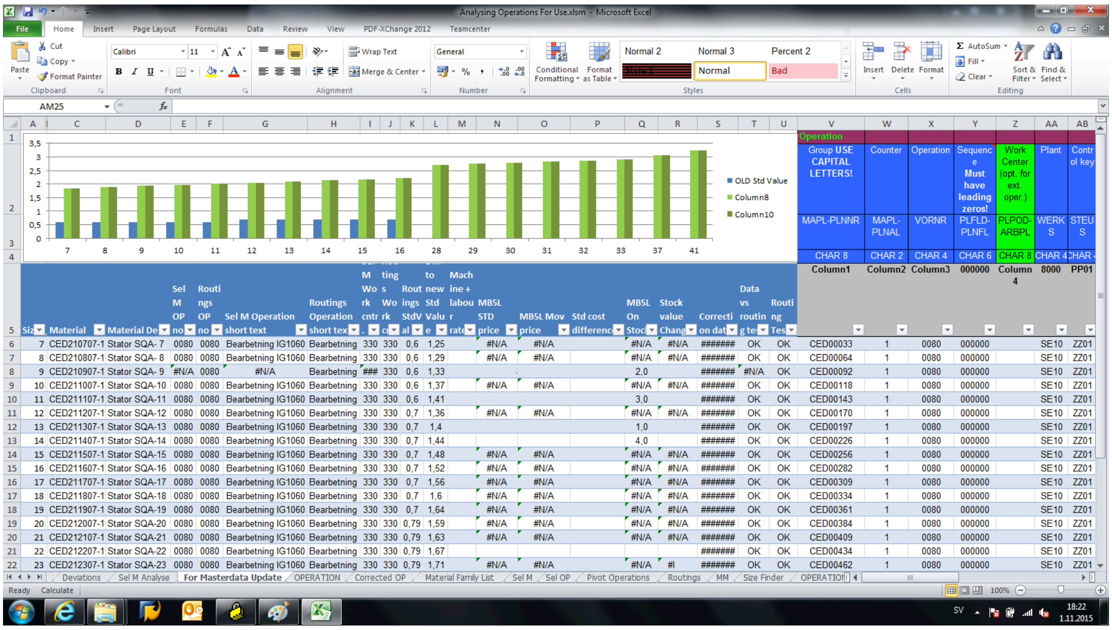


Figure 43: PACSOT For Master data Update sheet left.

On the sheet For Master data Update (see Figure 43) a graph showing the old standard times and the new times are displayed. A test is also done to check so the other routing data is matching. If not, the rows representing these sizes have to be removed or changed in order to proceed. When potential problematic size rows are removed the button Confirm and Copy New Master data can be used (see Figure 44).

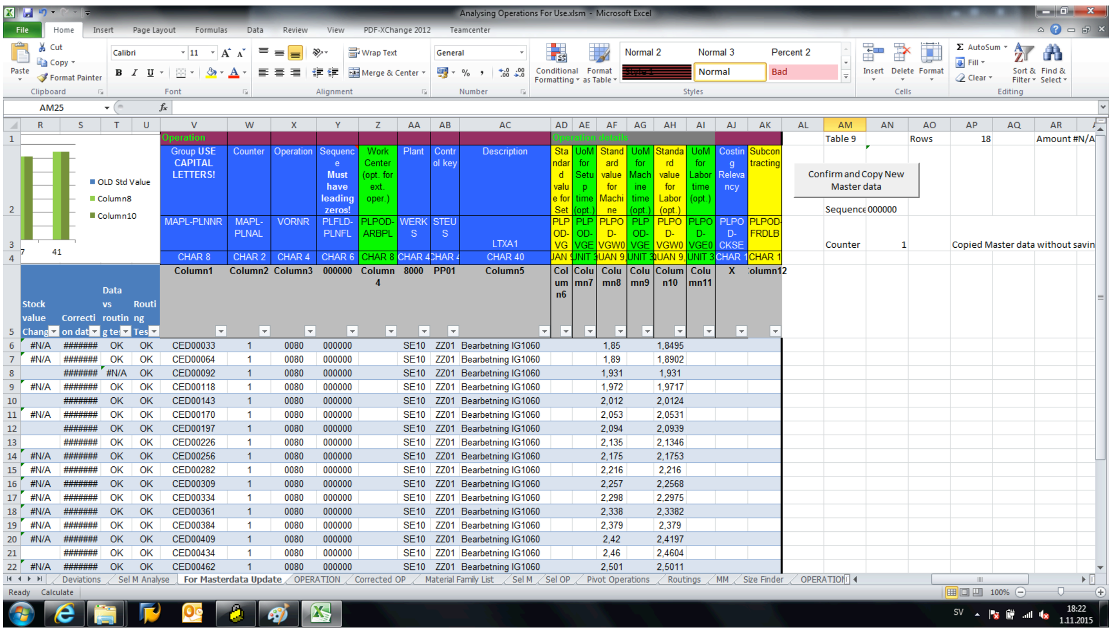


Figure 44: PACSOT For Master data Update sheet right.

The new master data is copied as values to the OPERATION sheet and converted to the correct format (see Figure 45). This sheet can then be saved as a separate excel file by using the button Export Master Data Sheet "OPERATION" for upload to SAP.

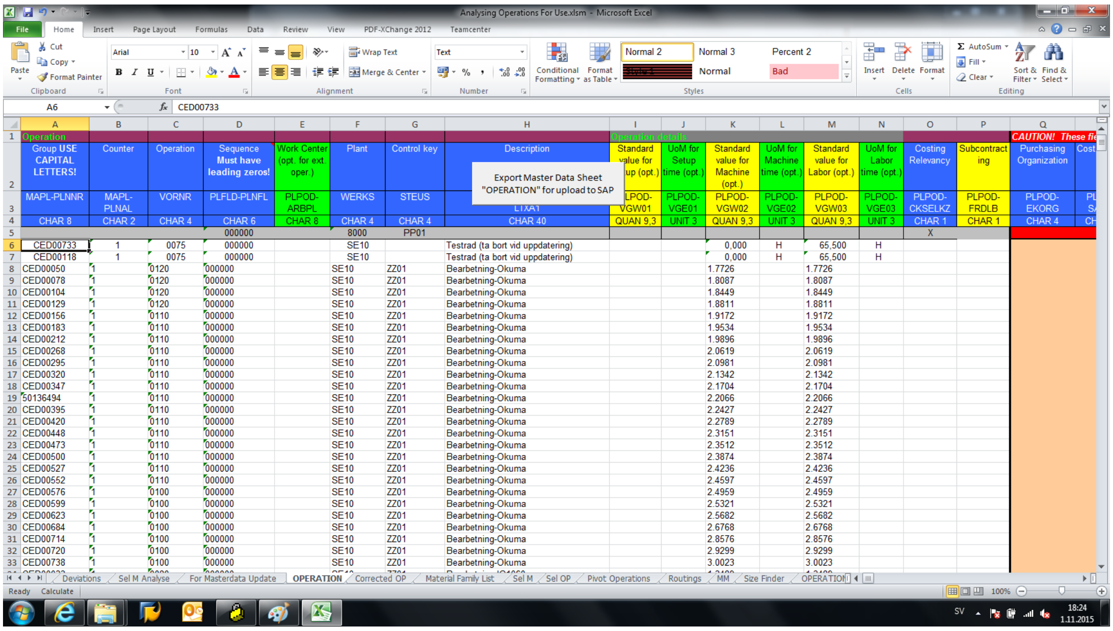


Figure 45: PACSOT OPERATION sheet.

When new standard operation times are created on the OPERATION sheet, all records of the correction and all the correction operations are being stored on the sheet Corrected OP (see Figure 46).

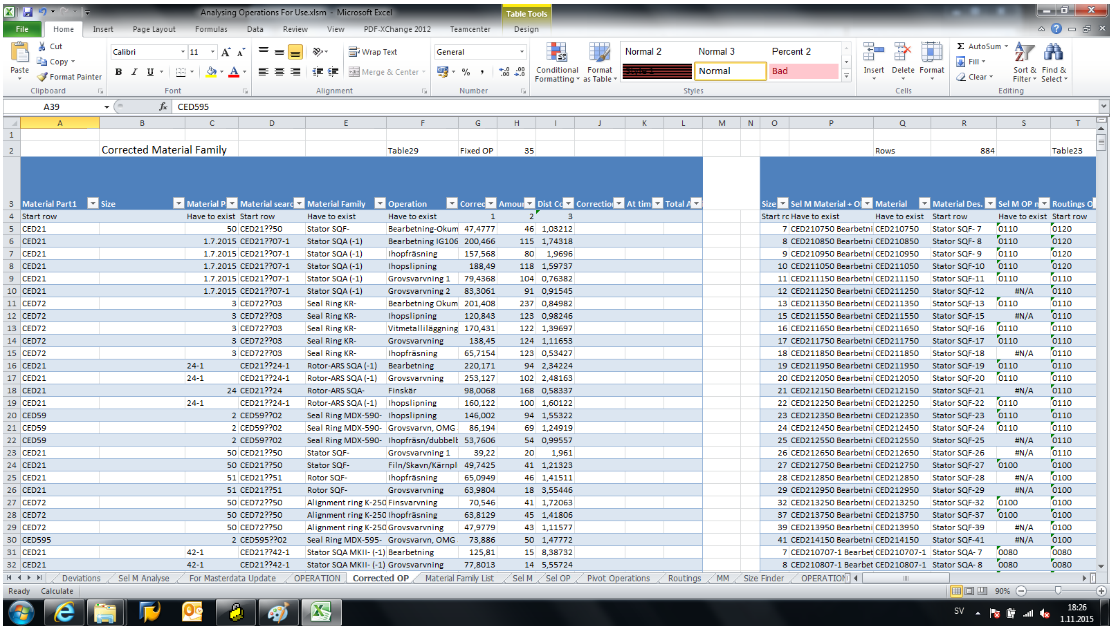


Figure 46: PACSOT Corrected OP sheet.

4.10 VBA-macro code example

Below follows an example of the VBA macro-code in the PACSOT file. The rows with text in green starting with a ' are not actual program codes being executed but instead information written to explain specific sections of the code that are not easy to understand. For example executing operations on a table and the table are only referenced as “Table 1”. These green lines are however visible in the actual VBA-macro and are used for a simpler overview during programing and helping out if someone else should understand the code in the future. The following code are what are being executed when the “Follow up a manually filtered period” button are pressed. That is one of approximately 20 macros needed to operate the PACSOT file and some are much more complex, like for example the macros integrating directly with the EPR system.

4.11 The FollowUp_manually_filtered code

```
Sub FollowUp_manually_filtered()
'
' FollowUp_manually_filtered Macro
'
'
    ' Check if all causes are registred and tell if not

 ActiveSheet.Calculate

    If Range("total_causes").Value > Range("registred").Value
Then
        Dim retur_type2 As Integer
        retur_type2 = MsgBox("Some visible or hidden causes are
not registred. Do you want to continue and clear the 'Follow-up
Operations' sheet anyway?", vbExclamation + vbYesNo, "Causes not
registred")
        If retur_type2 = 7 Then ' If answer is "NO" end macro
            End
        End If
    End If

    ' Check if all causes have an assigend category and are
registred and tell if not
    If Range("cause_category_missing").Value > 0 Then
        Dim retur_type3 As Integer
        retur_type3 =
MsgBox(Range("cause_category_missing").Value & " causes are
missing cause category and is not registred. Do you want to
continue and clear the 'Follow-up Operations' sheet anyway?",
vbExclamation + vbYesNo, "Causes not registred")
        If retur_type3 = 7 Then ' If answer is "NO" end macro
            End
        End If
    End If

    ' Shows warning if the rows for Follow-up are more than 200
    If Range("OP_visible_rows_onOP").Value > 200 Then
        Dim retur_type4 As Integer
```

```
        retur_type4 = MsgBox("You are about to send " &
Range("OP_visible_rows_onOP").Value & " rows for follow-up. Do
you wanna proceed?", vbExclamation + vbYesNo, "Many rows selected
for Follow-up")
        If retur_type4 = 7 Then ' If answer is "NO" end macro
            End
        End If
    End If

    Sheets("Follow-up Operations").Select

    Range("registred").Value = "0" ' Clear Register control cell

    Application.Calculation = xlManual

    Sheets("All Operations").Select

    ActiveSheet.ListObjects("Table3").Range.AutoFilter Field:=11,
Criteria1:= _
        Array("CNF  EODL PRT  REL", "CNF  EODL PRT  REL  TECO",
"CNF  MILE OPGN PRT  REL" _
        , "CNF  MILE OPGN PRT  REL  TECO", "CNF  MILE PRT  REL",
_
        "CNF  MILE PRT  REL  TECO", "CNF  OPGN PRT  REL", "CNF
OPGN PRT  REL  TECO", _
        "CNF  OPGN REL", "CNF  OPGN REL  TECO", "CNF  ORSP PRT
REL", _
        "CNF  ORSP PRT  REL  TECO", "CNF  PRT  REL", "CNF  PRT
REL  TECO", "CNF  REL", _
        "CNF  REL  TECO"), Operator:=xlFilterValues

    Sheets("Follow-up Operations").Select
    ActiveWorkbook.Worksheets("Follow-up
Operations").ListObjects("Table1").Sort.SortFields. _
        Clear

      Application.Calculation = xlManual
    ActiveSheet.ListObjects("Table1").Range.AutoFilter
    ActiveSheet.ListObjects("Table1").Range.AutoFilter
    'Application.Calculation = xlAutomatic


    'Clear all rows in sheet Follow-up Operations but save the
top row for formulas
    Range("Table1[[#Headers],[No]:[CM]]").Select
    Selection.Offset(2, 0).Select
    Range(Selection, Selection.End(xlDown)).Select
    Selection.Clear

    'Clear Cause to Cause category in top row
    Range("Table1[[#Headers],[Cause (free text field to describe
cause if necessary)]:[Cause Category]]").Select
    Selection.Offset(1, 0).Select
    Selection.ClearContents


    'Resize table
    Dim rownum As Integer
    Dim colnum As Integer
    rownum = 3
```

```
    colnum = Range("Table1[#All]").Columns.Count
    ActiveSheet.ListObjects("Table1").Resize Range(Cells(2, 1),
Cells(rownum, colnum))

    Range("Table1[Material no.]").Select

    Sheets("All Operations").Select
    Range("Table3[[#Headers],[No]]").Select
    Range(Selection, Selection.End(xlToRight)).Select
    Selection.Offset(1, 0).Select
    Range(Selection, Selection.End(xlDown)).Select
    Application.CutCopyMode = False
    Selection.Copy


    Sheets("Follow-up Operations").Select
    Range("Table1[[#Headers],[No]]").Select
    Selection.Offset(1, 0).Select

    Application.DisplayAlerts = False 'remove popup asking if
rows should be inserted even if it risks writing over data. This
is asked even if exist no data in the related cells

    Selection.PasteSpecial Paste:=xlPasteValues,
Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False

    Application.DisplayAlerts = True 'turn on error messages
again

       Application.CutCopyMode = False
    ActiveWorkbook.Worksheets("Follow-up
Operations").ListObjects("Table1").Sort.SortFields. _
        Clear
    ActiveWorkbook.Worksheets("Follow-up
Operations").ListObjects("Table1").Sort.SortFields. _
        Add Key:=Range("Table1[[#All],[OP]]"),
SortOn:=xlSortOnValues, _
        Order:=xlAscending, DataOption:=xlSortNormal
    With ActiveWorkbook.Worksheets("Follow-up
Operations").ListObjects("Table1").Sort
        .Header = xlYes
        .MatchCase = False
        .Orientation = xlTopToBottom
        .SortMethod = xlPinYin
        .Apply
    End With
    ActiveWorkbook.Worksheets("Follow-up
Operations").ListObjects("Table1").Sort.SortFields. _
        Clear
    ActiveWorkbook.Worksheets("Follow-up
Operations").ListObjects("Table1").Sort.SortFields. _
        Add Key:=Range("Table1[[#All],[WC]]"),
SortOn:=xlSortOnValues, _
        Order:=xlAscending, DataOption:=xlSortNormal
    With ActiveWorkbook.Worksheets("Follow-up
Operations").ListObjects("Table1").Sort
        .Header = xlYes
        .MatchCase = False
        .Orientation = xlTopToBottom
```

```
        .SortMethod = xlPinYin
        .Apply
    End With

    Sheets("All Operations").Select
    Range("B1").Select
    Sheets("Follow-up Operations").Select

    ActiveSheet.Calculate
    ActiveSheet.ListObjects("Table1").Range.AutoFilter Field:=42,
Criteria1:= _
        "Yes"
    Range("Table1[[#Headers],[No]]").Select

    ActiveSheet.Calculate
    Sheets("Follow-up Overview").Select
    ActiveSheet.Calculate
    'Sheets("Follow-up Operations").Select

    Application.Calculation = xlAutomatic
    Application.ScreenUpdating = True

End Sub
```

5 Discussion

Here the theory, method, results and development of PACSOT are discussed.

5.1 The current situation

The manufacturing strategy used at SBSE is mostly a combination of the Make to order and Engineered to order described by Jonsson and Mattson (2009). All seals are made against a customer order and some seals are even designed for a specific customer and vessel. That some usual components however can be produced earlier (the -1 materials) are also part of the Make to order strategy. The manufacturing process at SBSE share most characteristics with the Job-shop process described by Jonsson and Mattsson (2009). Regarding the levels of control the production planning at SBSE was at the control level described by Jonsson and Mattson (2009) as Operative control.

People in several positions within Wärtsilä have recognized the problem with wrong SOT and its negative implications like problem to schedule with SAP and creating incorrect costing and investment calculations. This is in line with what are advocated in theory that correct basic data are a prerequisite to planning (Jonsson and Mattson, 2009). Wrong SOTs make it difficult to utilize the ERP system (Berry et al., 1982; Zandin and Maynard, 2001), make costing calculations and staffing difficult (Almström and Winroth, 2010; Zandin and Maynard, 2001).

The reluctance and suspicion perceived among the workers towards the time reporting system ProJob was manifestations of the worker resistance towards shop floor data collection described by (Cecelja, 2002).

The reasons for the wrong SOT in the systems were that many SOTs were set incorrectly from start and then not updated in a structured way, if updated at all. This is in coherence with the two out of three high level causes: Times are set incorrectly and Times are not updated described by Almström and Winroth (2010).

The situation at SBSE with Make to order and Engineered to order in a Job shop process make it difficult to correct this since the product portfolio is so extensive and therefore also the number of operations to correct. For the data collection period January 2014 until May 2015 only 1241 materials were manufactured out of the total 11126 materials registered in the Material Master. However to produce this 1241, totally 5800 unique operations were needed. From this it is possible to conclude that the total amount of unique operations needing SOT is much higher.

From the analysis of the ERP data it was discovered that a considerable variation existed in the historical ERP data regarding the real operation times compared to the SOT. This is described in literature to often be the case when a big amount of variants are produced as explained by Ali, Ghoniem and Franke, 2014; Smith and Tan 2013.

5.2 The method

In the following sections the method is discussed.

5.2.1 The access

Without the high levels of access given to both key people and related computer systems the results in the project would have been close to impossible to archive. Now questions could be asked immediately to the key person with the crucial knowledge for the project of both production planning and of the SAP and the time reporting system. Data collection from these systems could be extracted from the own computer with access to all systems and when problems or uncertainties emerged the expert was sitting only two meters away. All these were corresponding to the key prerequisites stated by Croom (2009) and Correa (1992). The six Sigma project previously carried out at the company by the author was also an important prerequisite for the outcome of the project, which are coherent with the necessity of pre understanding of the company (Gummesson, 2000) and importance of access and approval from key members of the organization (Coughlan and Coghlan, 2009).

5.2.2 Observation in the workshop

The initiative to start by only relatively passively observe and get to know the operators and the production was perceived as a good decision. It helped to quickly establish an understanding of the workflow in the workshop and to get the operators perspective and opinions on matters. Without this the negative consequences still perceived from doing the work sampling would probably have been much worse.

5.2.3 The literature review

Due to the specific conditions at SBSE and their decision to register only one single time it was difficult to find other literature regarding this specific setting. But when instead widening the search and looking for planning, processing time and setup time, better results were found. This illustrates the specific nature of the problem and the relative limited research focus on the issue.

5.2.4 The work sampling

Despite the clear objectives, all the precaution steps taken before and communication done during the work sampling, a negative feeling of being watched, during the work sampling was expressed by the operators. I also really did feel like a mix of a time-study man and a supervisor monitoring the work performance of the operators several times during the sampling. An example of this was when one of the operators observed was going to the toilet and upon return asked if that was recorded. He then got the true reply that "yes" it was recorded as personal time. At another time it was seen that one operator left his station and for a long time stood talking to fellow operators. Upon the return the operator was holding up a wrench and told he had again been "searching for a tool" since that was earlier explained as one of the categories.

5.2.5 Internal validity

The cause and effect correlations were strengthened by using both data and method triangulations. **Method triangulation** by free observations, work sampling and interviews besides the data collection from the ERP system.
Data triangulation by both collecting data from SAP and compare with Pro job. Also by discussing the conclusions from the observations with the planners and foremen.

5.3 Replicability

Can the project and study be repeated with the same result? Without any doubt. Can someone else repeat the study with the same results? This one is much more dubious. Some fortunate events and happenstances have together enabled this project to create the results it has.

First and paramount, the access in the first place and the level of access given. Without the approval and gratitude towards the previously performed project from the company and the good personal contacts with key members of the organization, any access to the organization maybe would have been denied in the first place. Secondly the level of clearance to the SAP system and to the entire production given was also probably a result of this trust from the company. Without this every data collection from SAP system would have to be done by someone else. Then the ideas to automate the workflow would probably never have emerged. Also the almost unrestricted access to the production and possibility to participate in the morning status meetings at the shop floor and being welcome to sit in on planning and quality meetings enabled a crucial holistic view of the company and manufacturing.

Secondly the author's prior knowledge and experience in Excel and a refusal to give in to the problem even though doubts were raised of the method and of the countless numbers of problems encountered in the development. The efforts and time put on the development have been high and were the paramount reason for the delay in finishing the project.

The support from the Wärtsilä supervisor Ellen Lindewall has also been crucial. Regardless of having a tremendous workload she always had time to at least point me in the right direction when questions or problems rose. The fortunate placement in the same room was crucial here. Her work was disturbed by questions a numerous times but without this the problems encountered would never been able to be solved so quickly and the project would not have made it half the way it did.

All in all because of this it is very unlikely that someone else can repeat the project with the same result. It is therefore most likely not replicable.

5.4 Reflections on the development of the VBA-Excel tool

A key driver for crating PACSOT was the author's ambitions too not only create valuable guidelines and recommendations that could just end up in an archive. This was pushing the author to provide the company with a tool to directly cope with the problems at hand. During the progress such a possibility was seen by the use of Excel for an integrated tool be able to get the necessary data, process it to be able to draw conclusions and make follow up but foremost to in a structured way efficiently actually correct the SOTs in the system.

The author's previous experience with Excel in both courses such as Six Sigma but also in previous work experiences was the starting point even though the author only had taken one single programing curse at Chalmers. The alternative would be to just simply recommend the purchasing of a Business Intelligence tool such as for example ClickView but that would need upper management decisions, investment and an implementing project when integrating with the SAP. Besides this it will not be tailored to fully cope with the specific settings at the SBSE and therefore anyway cause a lot of efforts when implementing. Also this was not in line with the author's goal to create and implement an improvement that directly could help the organization.

The development of the PACSOT VBA-tool was the outcome of the authors ongoing struggling with trying to analyze the ERP data and the purpose to create something useful for the company besides only recommendations. It was the result of the ambitious goal to create something that directly could solve some of the problems encountered with trying to measure the performance of the SOTs and correcting the SOTs that were found to be wrong.

However as described by McKay and Wiers (2004) merely to develop a prototype with limited functionality are time consuming, costly and require some level of programing in Visual Basic. In this case with the VBA that is integrated in Excel. The aim of PACSOT however goes beyond the ambitions of merely being a prototype showing what's possible. Due to the big need for the company for a solution it has been focused towards actually being a fully functional tool for correcting the SOT. However since not being a commercial product with a team of experienced developers behind it and tested as a computer program usually is with several Alfa and Beta versions going through a numerous error fixing, debugging and improvement stages. It will suffer from many of the traits of a prototype. Therefore using it, one has to be aware that it is not a commercial and fully tested program. However, if SBSE wish to take immediate action to a decent cost, it is probably still the superior solution.

In this regard the authors strive to try to simplify the operation of the PACSOT was sometimes working in the opposite way. By simplifying the actions required of the user to only press a number of buttons to execute several thousand rows of code risked to cause a situation when the complexity of what the prototype actually archived was not understood. The reception of the tool has passed several phases. From being frowned upon as to complicated and causing older computer to entirely freeze when trying to execute the VBA code to making people thinking the reasons for an error being easily to correct on the theme since ”I only pressed the button”. Because of this, the tool is given its relatively complicated name PACSOT to try to communicate both the complexity and the similarities to a prototype of the tool.

Despite all the problems the tool was starting to be used at the company in November 2015. Firstly the daily follow up functions of PACSOT were used to monitor performance of the operations and the SOT for yesterday's operations. This is a result in itself since no method has existed at all for the company before to archive this in an acceptable way. This will both give information about the performance but also put focus on the problem and probably make the operators more cautious to make incorrect registrations since errors are acted upon. This will also serve as a way to collect data in a structured way of which components the times differ the most and what the operators consider to be a more adequate SOT.

The company is eager to start to use the more advanced functionalities for actually correcting the times before the end of 2015. However the extent of problems encountered when actually starting to use the prototype tool for making real corrections has delayed the start and the plan is currently to start this work in the beginning of 2016. However test corrections done by the author during one single workday enabled the net sum difference error to be decreased with 3663 hours on the historic data. This change from an net sum difference error of 11000 hours to 7700 hours was done by running the process 35 times and correct 35 operation types on different material families. In total this represents a correction of 882 individual operations on individual materials. This represents an improvement of 16,2 percent since the net sum difference error was reduced from 41,9 to 25,7 percent. This was accomplished by starting with the ones with the biggest differences. These are easily sorted out thanks to the built in decision support and real time feedback loop showing the effects of the performed corrections in the tool before they even are uploaded to the ERP system as new master data.

However one has to take into consideration that the big positive effect are of course to be expected sine the new SOT are based on the same historical data. This is the simplest way to measure the new SOT but one has to be aware the effects on future operations are difficult to exactly predict in advance. Also since the logic is that the operations with the most historical error should be corrected first the “decrease” of the error will be more and more difficult to archive due to the endless tail problem.

5.5 Other possible methods

An alternate approach to using historical data as the base for the corrections is to use some kind PTS system, such as MTM. Then how much time one operation should take is calculated.

Several problems however exist with using such an approach at SBSE. Foremost the big variability in products. To calculate all in a sufficient way would take a lot of times due to the amount of different products, sizes and variants. Also the long cycle of the work tasks make it difficult. Since the average confirmed time of an operation are several hours and it takes several multiples of that time to calculate it, the amount of time required for all the calculations would be huge. Of course the result could be extrapolated to other sizes to save time but that would still need to be done for all the operations and materials. Another problem with taking that approach instead of the chosen approach is the purpose of SOT in itself. Should the SOT represent a target for good efficiency in the production or should it reflect the real resources being utilized in the production.

For the first approach using a PTS approach is probably the best solution. However if the goal instead is to reflect the real resources used it is much more dubious.
If for example the SOT by PTS is calculated to be 1,5 hours but in reality the operation average take 3 hours. This will then constantly cause problems in the planning and also making the standard cost for the product to be wrong estimated. To enable planning and to correctly cover the cost the decision was made to make the SOT reflect the real resources utilized for a product. When the SOTs are more correctly displaying the real costs it is also easier to focus improvements projects on the products with the most problems. This focus was decided in cooperation with the Foremen, the production manager, the Production planers and the Business Controller at SBSE. This is the foundation for using the historical data as the base for the corrections.

5.6 Other similar studies

No other studies when trying to set new SOT by regression analysis of historical data and combining the data for different sizes were found. That is partly due to that it is uncommon to only measure the entire operation time. Often it is instead separated in setup times and processing times.

The only other study found when regression analysis was used to calculate processing times was the study from 2015 on harvesters in Maine. In this study size was not used as a parameter but instead only two options like softwood or hardwood. Also for this study the data was captured in a time motion study for a limited period and not like in thesis project when all available historical data was used. The benefit of doing a time study is that the researcher has more control of the data collection. On the other hand it can often only take place for a limited period of time. The context of this project with the big variability in the products, such an approach would not be possible since the data would then be insufficient to be able to draw meaningful conclusions.
The solution to create a VBA Excel tool was suggested by McKay and Wiers (2004). But no other study where this was done to solve a production planning problem in practice was found.

5.7 What could have been done differently, seeds for future studies?

Some of the expressed characteristics of the time reporting system were not verified For example the said way for the program to distribute time and what's happening with this when afterwards correcting one of these operations in SAP. Could have been tested by a Quasi-experiment. One could have "Pretended" working for an operator absent and "manually" clocked the operation with a stopwatch and compared with the SAP times afterwards.

This was only checked by asking the production planner aka SAP specialist how it worked. In some regard this was checked by controlling the time reported in ProJob since it was stored a separate database.

Due to the delamination to only look at the operation time for production orders, the non-order time was not accounted for. However at the same time as registering was not made or sometimes forgot to be ended, it was also explored that some worker had by mistake due to the confusion when starting up the time reporting system, been logged into activities by mistake. For example one worker was by mistake registered on the non-order connected activity supervising for several months before someone noticed.

A suspicion is that several more (but not that long lasting) errors in the historical registered time exist. An indicator for this is the total reported time in ProJob. As a whole for October 2015 3500 hours were registered and 1200 of these were non-order hours. These 1200 hours represent activities not connected to production orders and this numbers seems unreasonably high. One might suspect that something had happened in October such as for example a bigger maintenance stop or something else making all the normal production to stop for a week. None of that was however the case and the share of reported time proved historically to be similar since all the reported times since February 2014 showed a similar relation.

5.8 Implementation of PACSOT

The PACSOT VBA tool had been partly implemented in November 2015 at SBSE. The parts that had started to be used in the operative production planning were the overview and Follow-up on operations (yesterday) every day from Tuesday to Friday. Monday was excluded since the no production did normally take place in the weekend and it is more difficult to remember things several days back before the weekend.

Implementation of the core and most advanced and useful parts of PACSOT has been postponed to the beginning of 2016. The reason was simply that the project had grown too large to fit into the master thesis and this was also the foremost reason to why the master thesis project was finished several months later than planned. It had simply taken very long time to develop the PACSOT solution so in June when a master thesis normally should have been finished the development of PACSOT was not finished and the report only written to a third. It has therefore taken up several more months of work on part-time to finish PACSOT and finishing the report afterwards. In the end a clear crossroad was seen by either continuing and making PACSOT ready for implementation and solve bugs associated with the tool starting to being used in several computers or to finish the Master thesis report. The author therefore asked the company to hold and wait with further implementation until the Master thesis project towards Chalmers was finished and the company agreed to this.

5.9 Automatic registering of times in production by RFID

Since the registering of operations by the operators both create problems and is considered a hassle by the operators a possible solution could be to instead automatically register the arrival and departure of components in the machines. If such equipment is connected to the machines the setup-time could then automatically be separated from the processing time.
The automatic registrations can be done with Radio-frequency identification (RFID) in different levels.

1. Having an RFID label on the "work order" - Reader on the i.e. the table.
2. RFID ship on sling attached to the part - Reader on a hook at the machine.
3. RFID ship attached to the part by adhesive - reader inside machine.
4. Wieldable RFID processing metal parts - reader inside machine.

Level 1 is most simple to implement but level 4 enable possibility for a RFID ship with active measurement of for example temperatures after production during the operation of the ship, however anyway not possible on parts machines at all sides. Level 2 however is the one that would be quite easy to implement but still allow for a high level of automated registrations and prevent mix-up of parts. A possibility is also to in the future to link machine to the registering device and automatically select the correct tooling paths which would decrease the problem with that the wrong program is selected and the part then wrongly machined.

6 Conclusions

In this chapter the conclusions from the project are presented by answering the research questions formulated in the introduction of the report.

1. ***What was the context of the standard operation time within the organization*?** This is explained in the Results section 4.1 The current situation and by the literature review. In short the standard operation time is an important part of being able to correctly calculate the costs for the products in order to take correct commercial strategic and investment decisions in the production. At the time the planning was mostly based on experience but the company strives toward implementing capacity requirement planning and correct standard operation data was then a key prerequisite**.**

2. ***How can the difference between the standard operation times in the ERP system and the real operation times be measured?*** Measuring single or a relatively small number of operations was insufficient and considered way too time consuming. This was due to the product variability and small production volumes of each variant. A method to extract big amounts of data from the ERP system and analyzing it in a structured and standardized way in Excel was developed. PACSOT enabled these measurements to be done efficiently and with a decent statistical significance.

3. ***How large was the actual difference between the standard operation times in the ERP system and the real operation times?*** The analyzed data showed significant variation in the real operation times both within products of similar size, if produced several times, but also between different sizes and different products. Over a one-year period the total net difference sum between the standard operation time and the real operation time was +41 percent. This share represents a cost currently not covered by the SOTs. However 35 percent of the operations were reported as finished with a real time less than the SOT. From a planning standpoint all deviations from the planned time were causing problems and that were represented for the same period by the absolute difference sum of 85 percent. More sums are found in 4.6.2 One-year Totals.

4. ***What actions can be taken in order to systematically reduce the difference?*** Foremost the PACSOT VBA-Excel tool was developed to immediately enable efficient monitoring, follow-up on differences for recently performed operations and finding and correcting incorrect registrations. The tool also provides decision support and a simple and user friendly interface. It enables correcting multiple operations at once with new standard operation times based on historical data, material families filtering criteria and regression analysis. The PACSOT tool was partly implemented at the company in November 2015. Full implementation was planned in the beginning of 2016. Besides this a best practice suggestion for data collection at the shop floor was also suggested as a vision for future investments in the workshop by automatically registering the arrival and departure times in the machines with RFID chips.

References

Below all the sources and references used in the report are stated. They are separated in the sections: Pictures, Wärtsilä corporate info and Bibliographic references.

Pictures

Wärtsilä (2007)
Figure 11: The SBSE manufacturing unit in Arendal (adopted from Wärtsilä, 2007) with in-picture of the four level office section added in 2009 as it appeared in November 2015.
Wärtsilä SBSE Internal. Provided by Magnus Göthberg, Quality Manager SBSE.

Wärtsilä (2015b)
Figure 1: An Oil tankers, a typical application for the SBSE products (Wärtsilä, 2015b)
Picture on boat from Wärtsilä services business whitepaper
http://cdn.wartsila.com/docs/default-source/product-files/seals-bearings/bwp-white-paper-o-sb-seals-bearings-2013.pdf?sfvrsn=6 (2015-11-07 11.02)

Wärtsilä (2015c)
Figure 2: Explanation of the seals and stern tube's relation to the propeller shaft (Wärtsilä, 2015 adapted from *Wärtsilä Seals and Bearings brochure*
http://cdn.wartsila.com/docs/default-source/product-files/seals-bearings/brochure-o-sb-seals-bearings-general.pdf?sfvrsn=4 (2015-07-27 18.30)

Wärtsilä (2015d)
Figure 3: A SQA seal with all components exploded (left) and with a quarter cutouts (right) (Wärtsilä, 2015d)
Wärtsilä SBSE Internal. Provided by Magnus Eliasson, Project & Product Development Engineer SBSE.

NSRC Forrest (2016)
Figure 7 One harvester in Maine (NSRC Forrest, 2016)
Evaluating Use of a Harvester and a Feller-Buncher in 40-Year-Old Forest Stands in Maine. *Northeastern States Research Cooperative (NSRC)*
http://nsrcforest.org/project/evaluating-use-harvester-and-feller-buncher-40-year-old-forest-stands-maine (2016-01-17 20.24)

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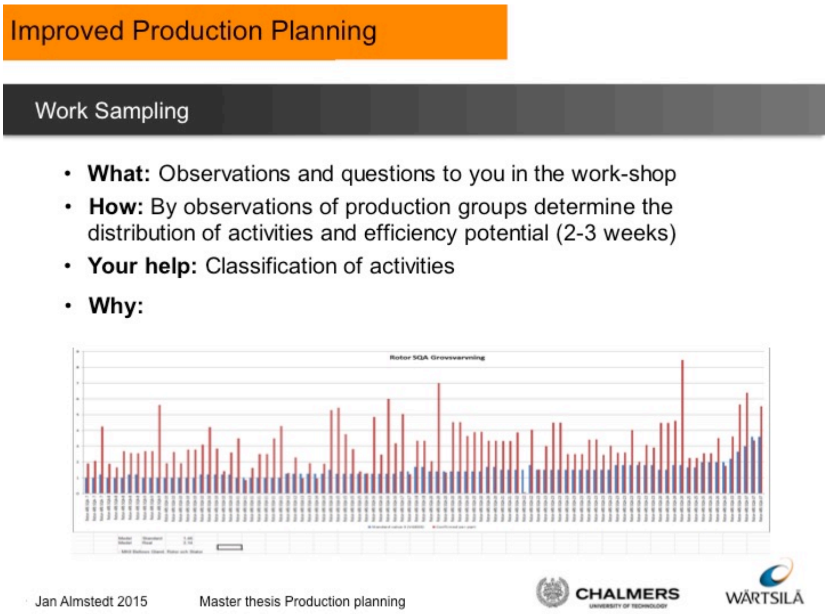
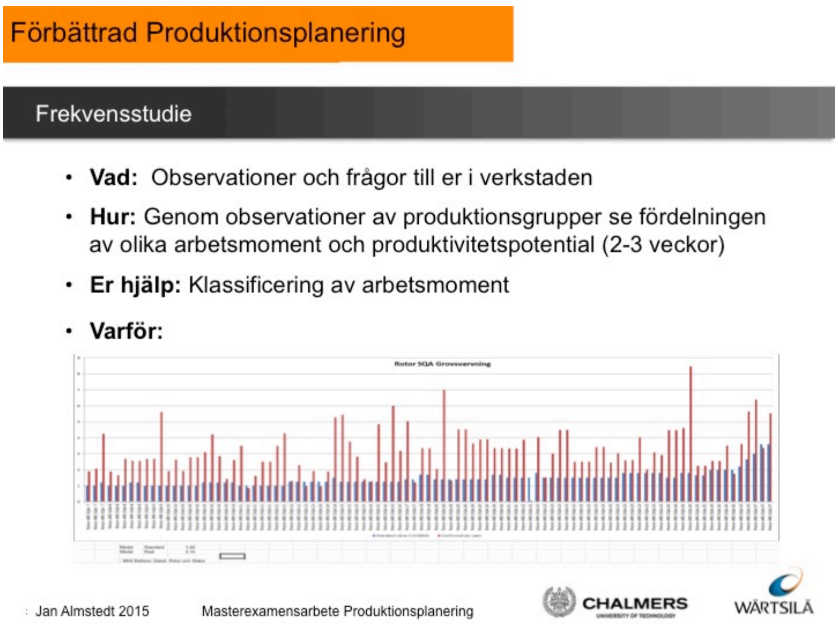
Appendices

Appendix 1 – The Work Sampling Powerpoint

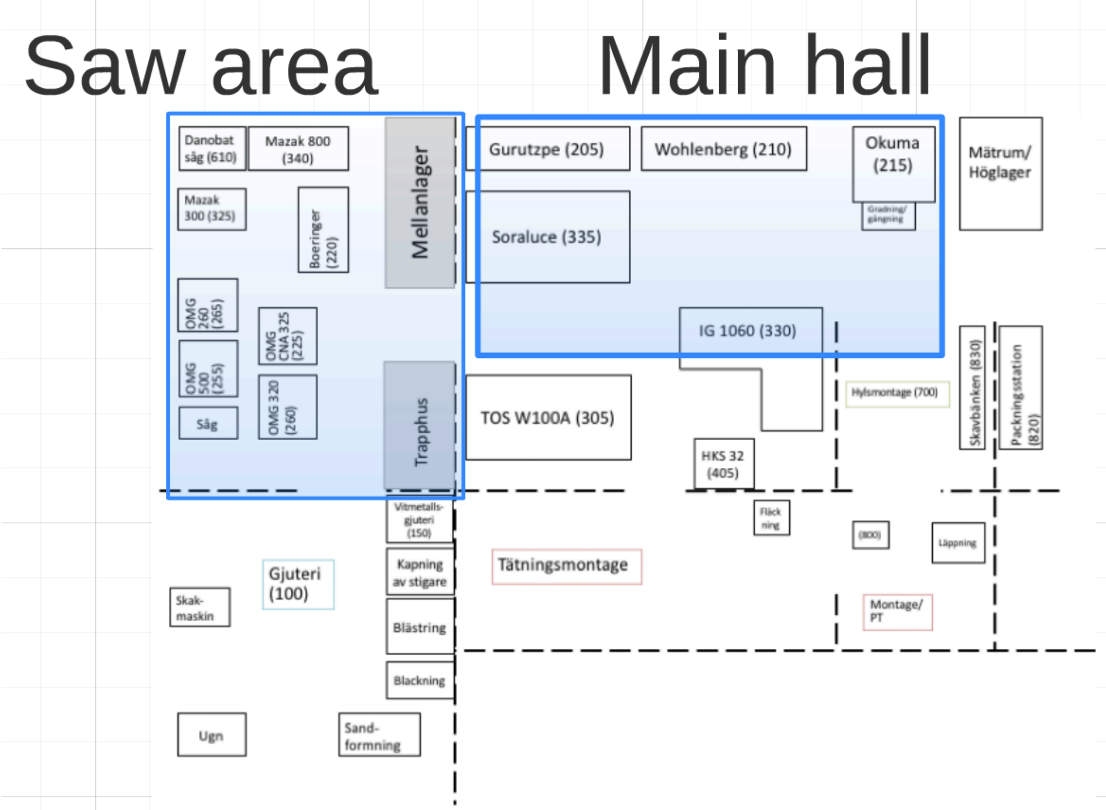
Translated and original PowerPoint slide for explaining the work sampling at speaker's corner.





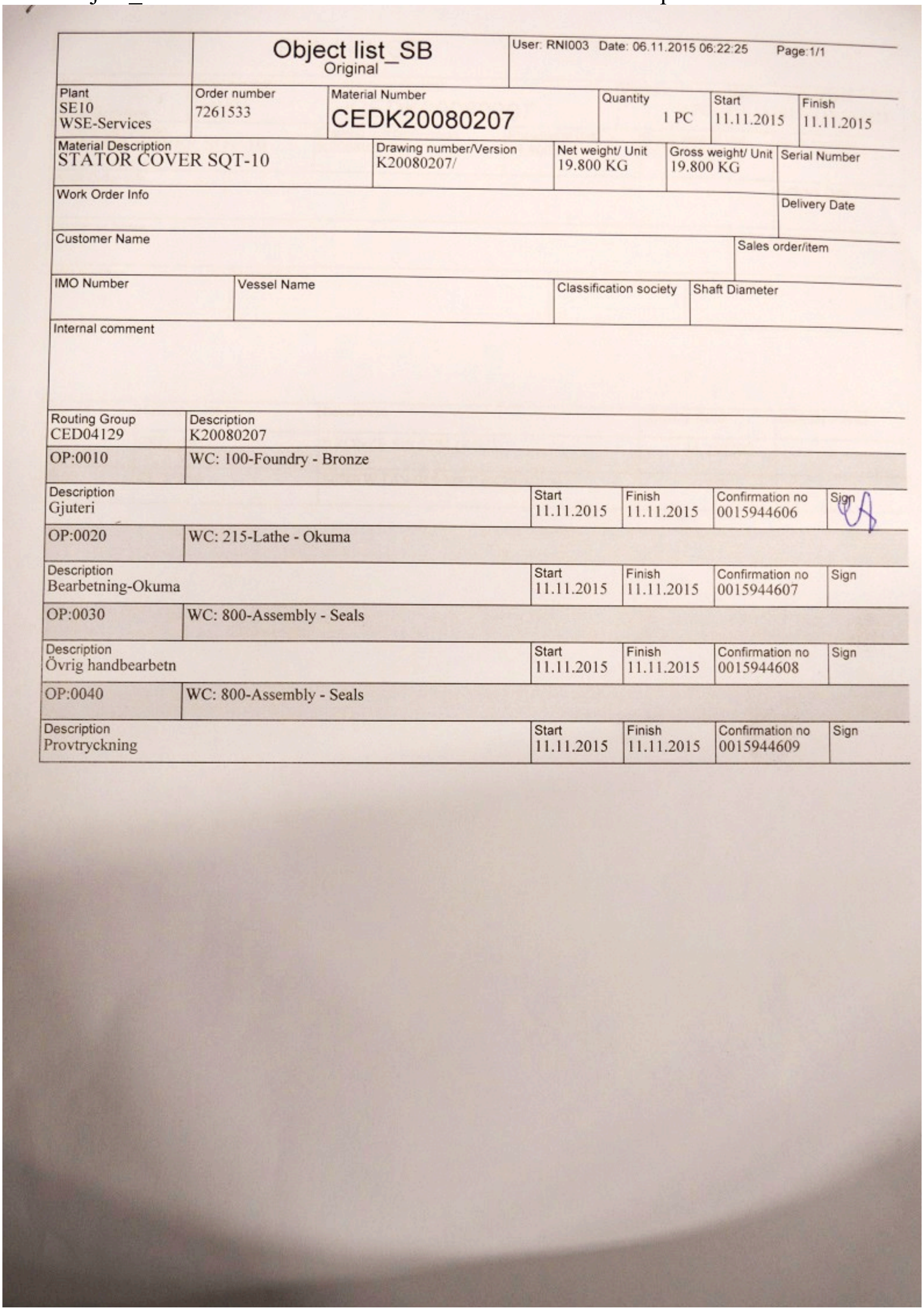
Appendix 2 – Work sampling areas

Shop-floor map of the factory showing the two areas in the work sampling. Original map created by Ellen Lindewall.



Appendix 3 – An Object_list/work order

The “Object_list” or “work order” for a material in the workshop at SBSE.



Object list_SB
Original

User: RNI003 Date: 06.11.2015 06:22:25 Page: 1/1

Plant	Order number	Material Number	Quantity	Start	Finish
SE10 WSE-Services	7261533	CEDK20080207	1 PC	11.11.2015	11.11.2015

Material Description	Drawing number/Version	Net weight/ Unit	Gross weight/ Unit	Serial Number
STATOR COVER SQT-10	K20080207/	19.800 KG	19.800 KG	

Work Order Info	Delivery Date

Customer Name	Sales order/item

IMO Number	Vessel Name	Classification society	Shaft Diameter

Internal comment

Routing Group	Description
CED04129	K20080207
OP:0010	WC: 100-Foundry - Bronze

Description	Start	Finish	Confirmation no	Sign
Gjuteri	11.11.2015	11.11.2015	0015944606	

OP:0020	WC: 215-Lathe - Okuma

Description	Start	Finish	Confirmation no	Sign
Bearbetning-Okuma	11.11.2015	11.11.2015	0015944607	

OP:0030	WC: 800-Assembly - Seals

Description	Start	Finish	Confirmation no	Sign
Övrig handbearbetn	11.11.2015	11.11.2015	0015944608	

OP:0040	WC: 800-Assembly - Seals

Description	Start	Finish	Confirmation no	Sign
Provtryckning	11.11.2015	11.11.2015	0015944609	

Appendix 4 – The graphs for variation in the SQA Stator material family

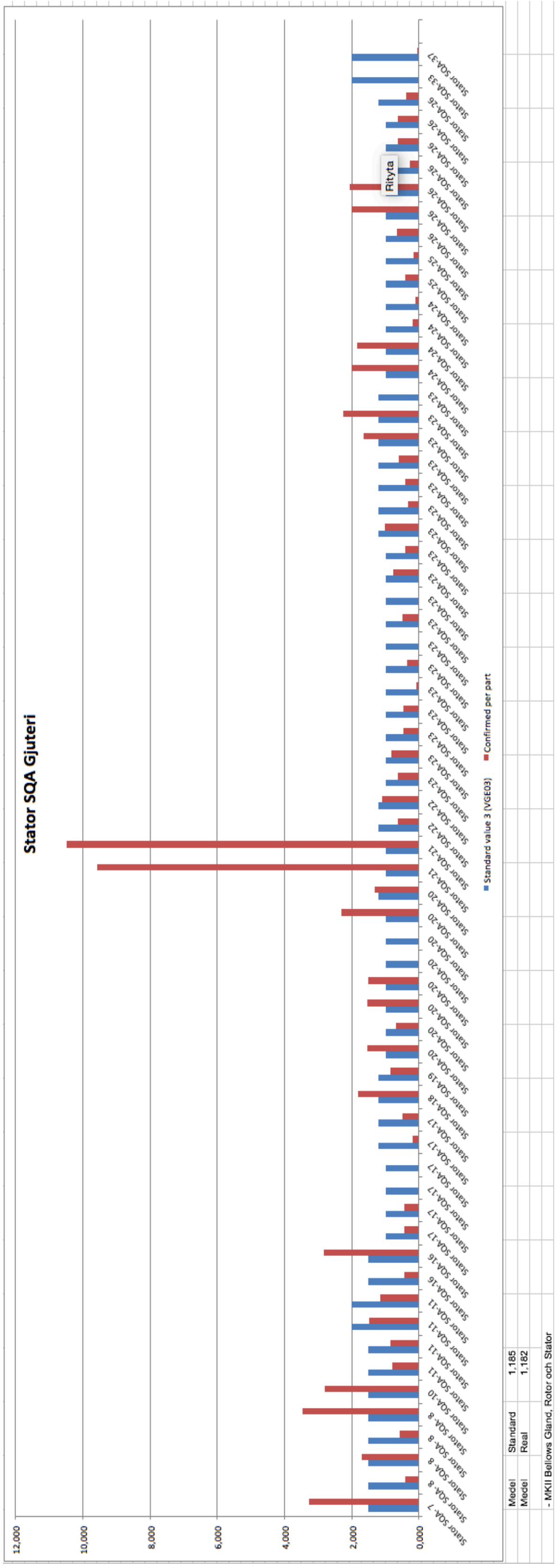


Figure 47 The planned and real operation times for casting in the foundry of the Stator SQA extracted from the SAP the 2015-03-16

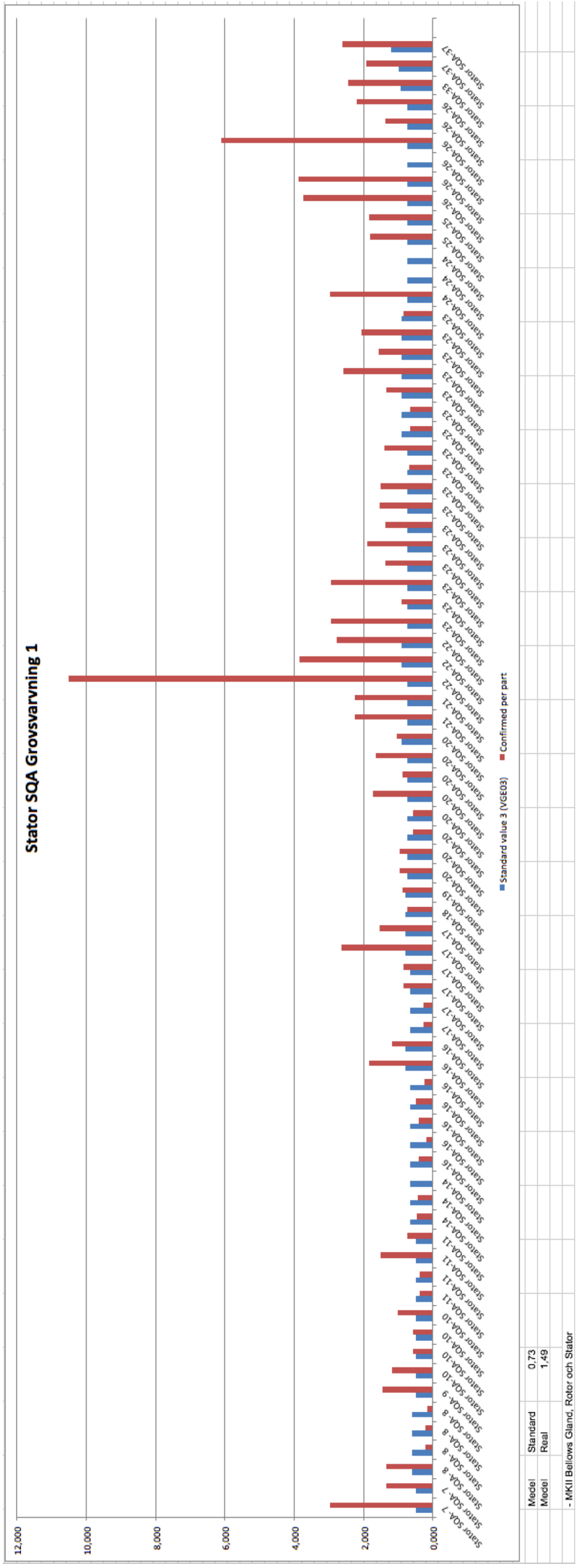


Figure 48 The planned and real operation times for Roughing 1 of the Stator SQA extracted from SAP the 2015-03-16

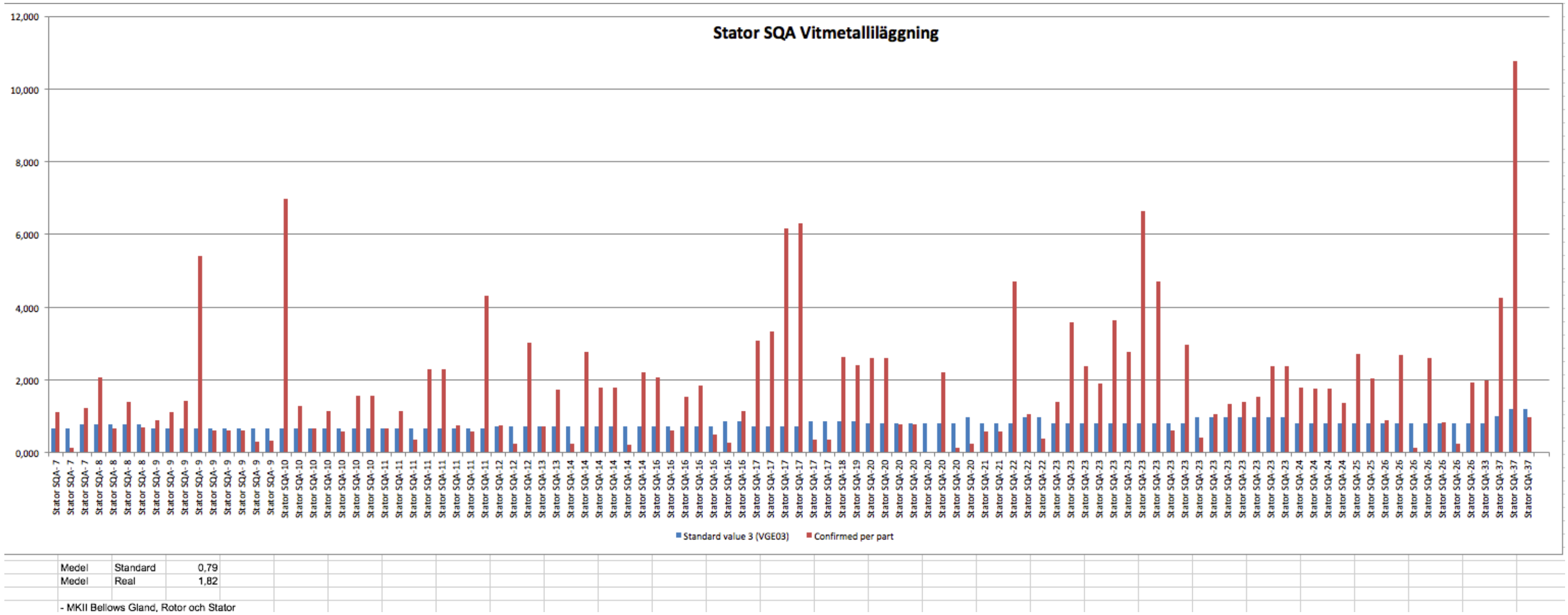


Figure 49 The planned and real operation times for White Metal filling of the Stator SQA extracted from SAP the 2015-03-16

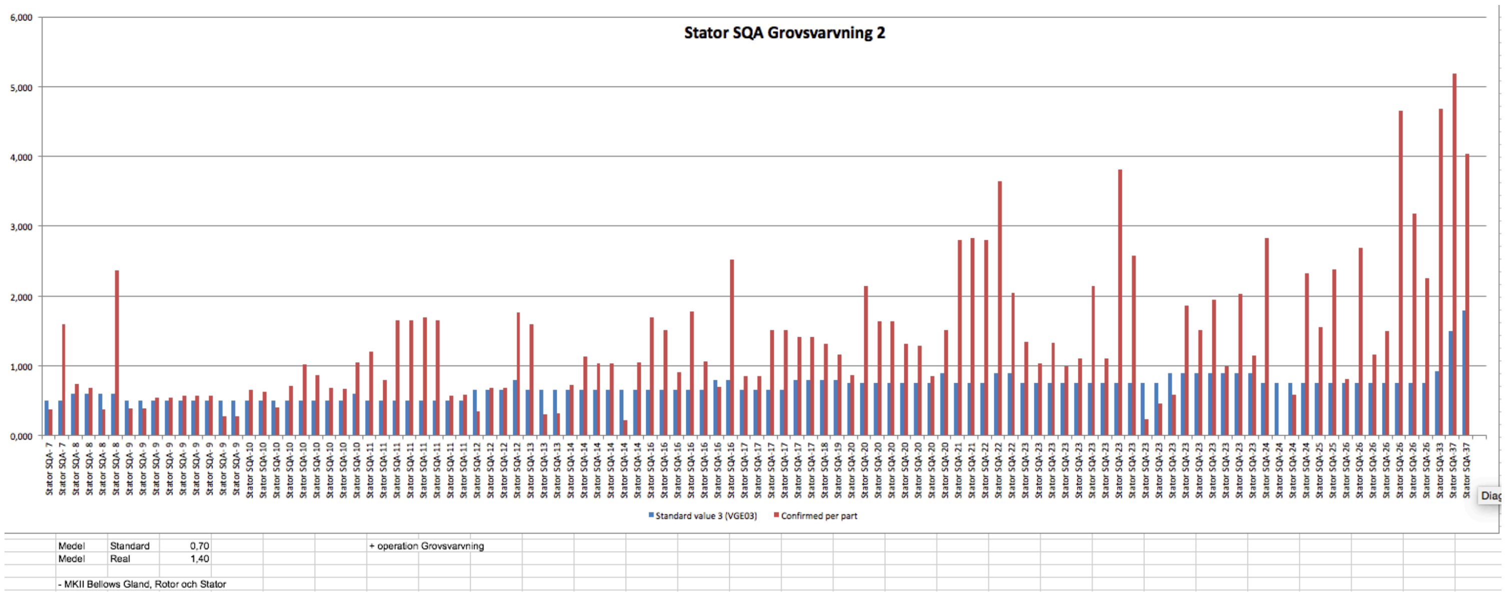
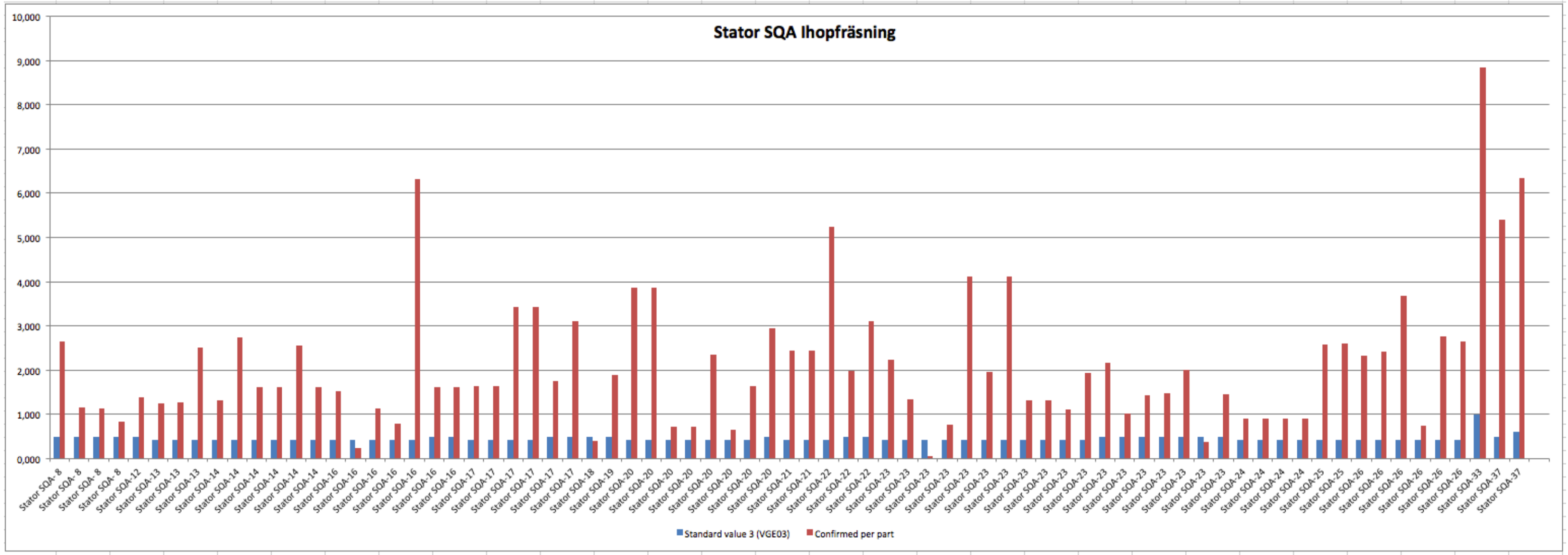


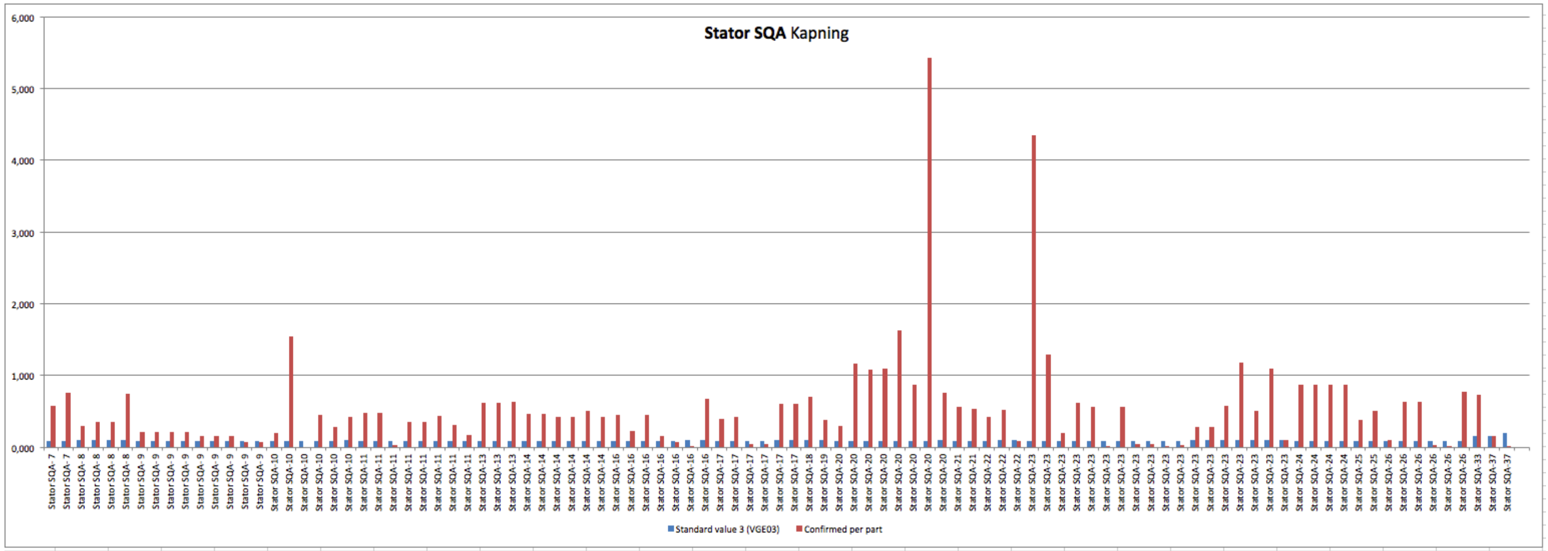
Figure 50 The planned and real operation times for Roughing 2 of the Stator SQA extracted from SAP the 2015-03-16



Medel	Standard	0,45
Medel	Real	2,14

- MKII Bellows Gland, Rotor och Stator

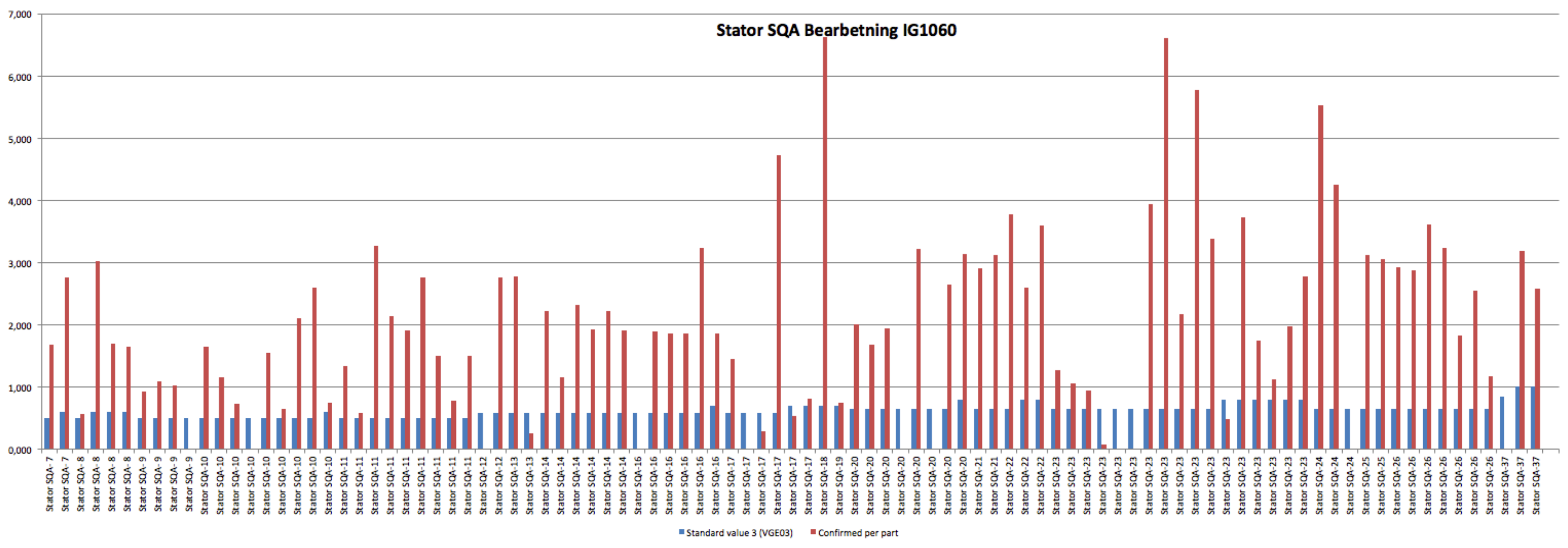
Figure 52 The planned and real operation times for Milling Together of the Stator SQA extracted from SAP the 2015-03-16



Medel	Standard	0,09
Medel	Real	0,54

- MKII Bellows Gland, Rotor och Stator

Figure 51 The planned and real operation times for Cutting of the Stator SQA extracted from SAP the 2015-03-16



Medel	Standard	0,63	37 körs i Okuma o heter Bearbetning
Medel	Real	1,99	
- MKII Bellows Gland, Rotor och Stator			

Figure 53 The planned and real operation times for Processing 1060 of the Stator SQA extracted from SAP the 2015

Appendix 5 – The PACSOT Usage Guide

PACSOT Usage Guide

This document describes the VBA-Macro based PACSOT and the procedures, sheets and macros needed to operate it.

Location of the Excel-file: //SES1001/Engineering/Project/PKON10/Kn20150201/PACSOT 2016-03-10 Prod.xlsm
Location of this Usage guide: //SES1001/Engineering/Project/PKON10/Kn20150201/Analyzing Operations Excel-file Usage-guide.pdf

1 Intro and structure

This Excel-file is a tool for monitoring, analyzing and if required update operation times by generating new master data for upload to SAP. With its VBA-Macros it can be compared to a Business-Intelligence software but tailored to the needs and specific situation at Wärtsilä Product Company Sweden in Arendal (PCSE). The Excel-file and this usage guide was created as a part of a master thesis in improved production planning in 2015.

1.1 This document is structured as follows:

1. Getting started – Explanation of what is required to start working with the file
2. Usage scenarios – the different main functionalities for the file
3. Description of sheets – a more detailed explanation of the different sheets in the file

1.2 In document links

In the text direct links to sections describing features and functions in more detail exist. These are accessed by holding down CTRL while clicking on it) these links are recognized by text marked as ***blue italic and underlined*** like: ***In document links.***

2 Table of contents

3 Getting started

This section provides important prerequisites for being able to start using the Excel-file.

3.1 Enable Macros

Macros have to be enabled in order for the Excel-file to work since it's a VBA Macro workbook with the file extension .xlsm.
When opening the file you can either get a yellow bar in the top of the workbook (see *Figure 53*) or a pop-up window saying "Macros could be dangerous" asking if you want to enable macros or not.

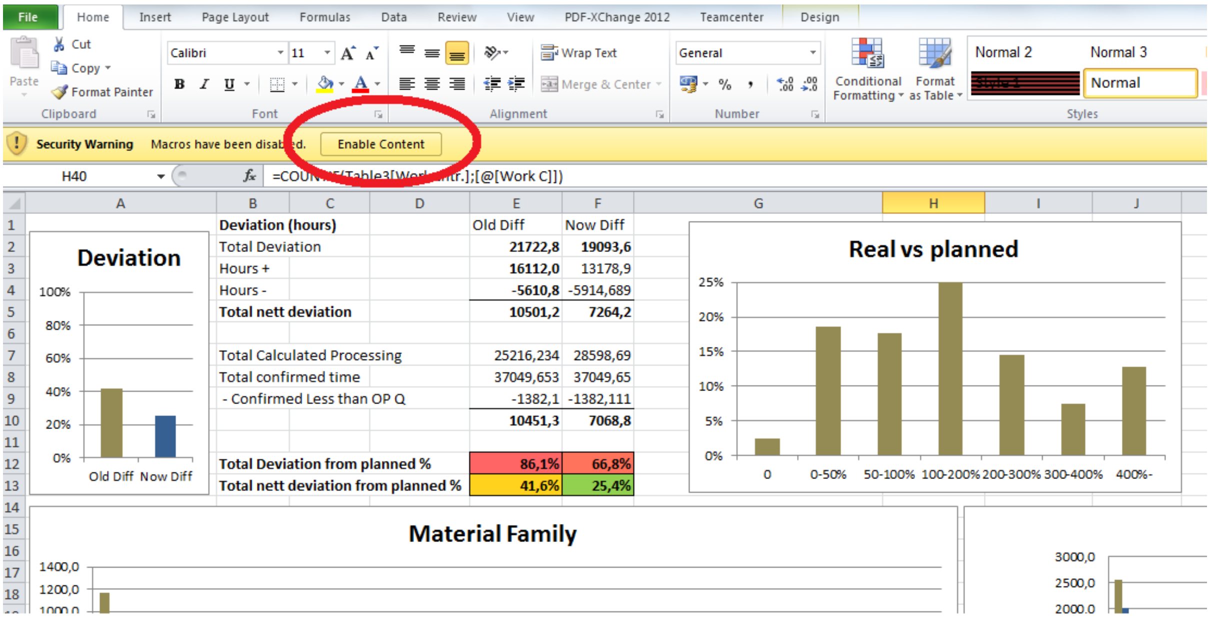


Figure 53 The yellow "Enable content" question bar.

3.2 Disable Scripting pop-up

For importing operation times from SAP a VBS script is used. This VBS script are automatically accessing the COOIS transaction and filtering out the operations for the SE10 plant (PCSE) and exporting it to Excel. This script is generated by the script recorder in SAP itself but is adapted somewhat to function directly from the VBA Macro **Import SAP Data**.

As default a popup (See *Figure 54*) asking if the user will allow the script will show each time the script is run (each time operation times are imported).

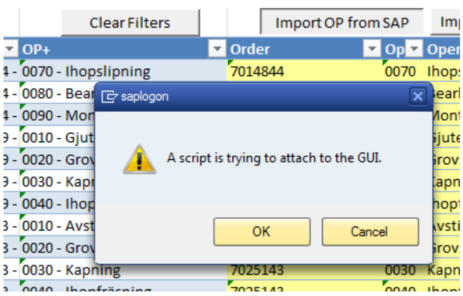


Figure 54 The "A script is trying to attach to the GUI" popup question.

This has to be allowed in order for the import of operations time's data to work. To disable this popup and check that scripting is allowed follow the below instruction Enable scripting and disable popup.

3.2.1 Enable scripting and disable popup

1. Press the button "Customize Local layout" on the start screen when logged into the WE Production (WEP) module. See *Figure 55*. This menu can also be shown by pressing Alt+F12.
2. Press Options.

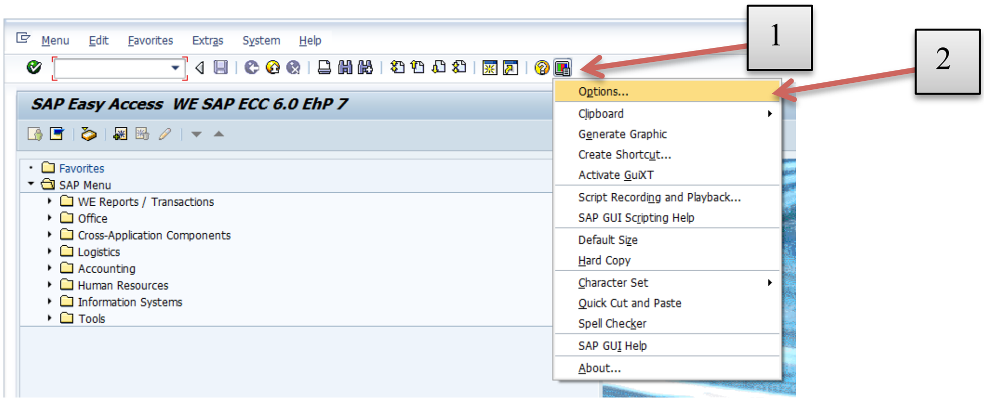


Figure 55 The "Customize Local layout" menu.

The "SAP GUI options – WEP" window will show. See *Figure 56*.

3. Press "Accessibility and scripting"
4. Press "Scripting"

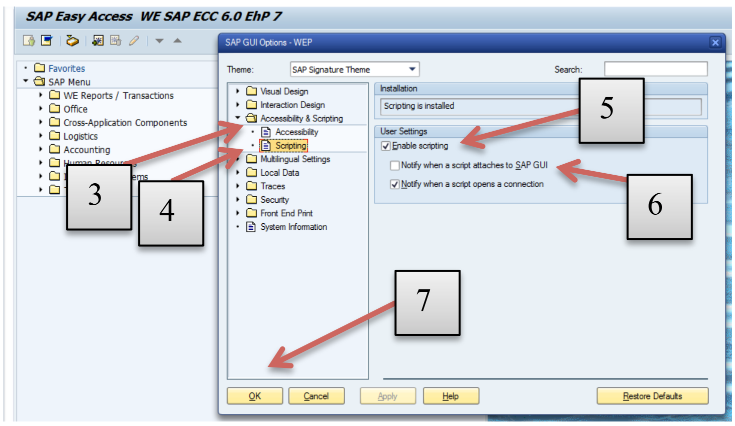


Figure 56 The "SAP GUI options – WEP" window.

5. Ensure the box "Enable Scripting" is marked
6. Unmark the box "Notify when a script attaches to SAP GUI" to disable the above-mentioned pop-up question.
7. Press OK to quit and save the changes.

4 Usage Scenarios

This section explains the main usage scenarios intended for the Excel-file.

4.1 Overview of all Operations

The current total status of all planned vs. real operation times can be viewed in the *All Operations Overview* sheet (see *Figure 57*).

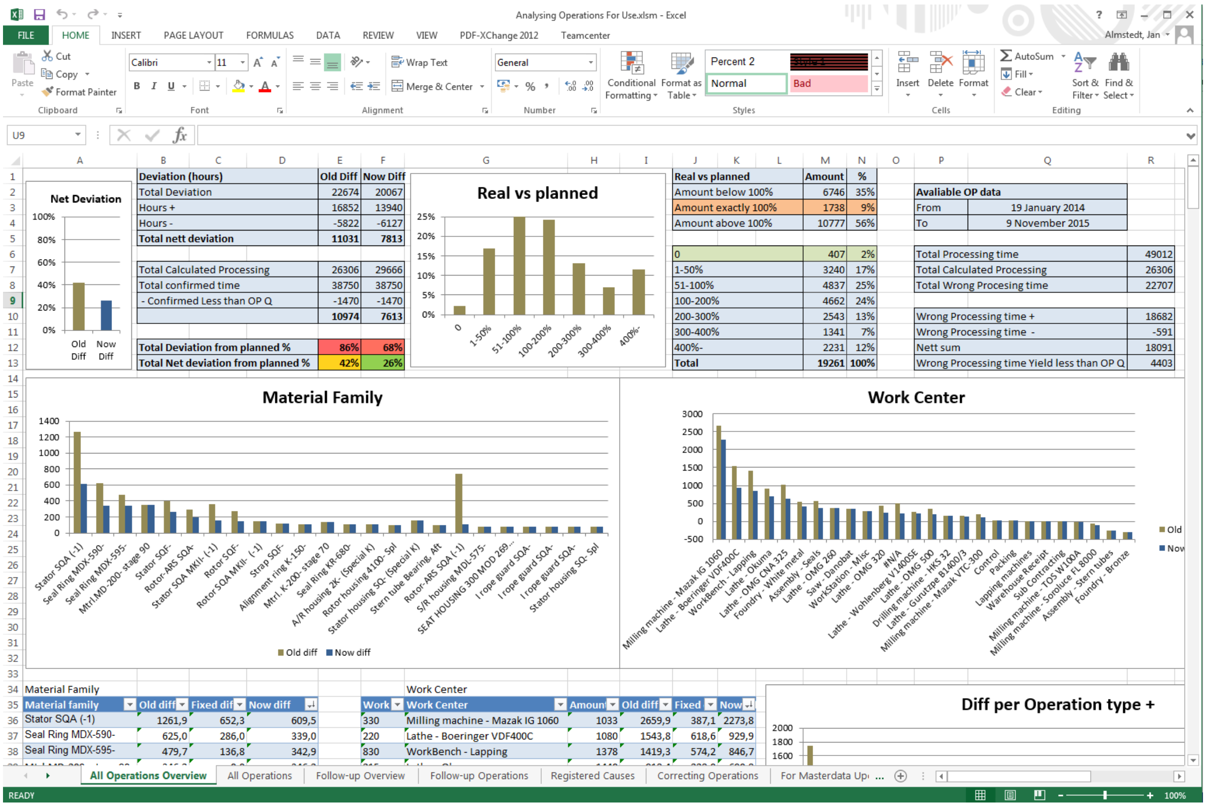


Figure 57 *All Operations Overview* sheet.

To see the current total status, the latest operation times have to be imported from SAP with the button **Import SAP Data** on the *All Operations* sheet (see *Figure 58* Arrow 8).

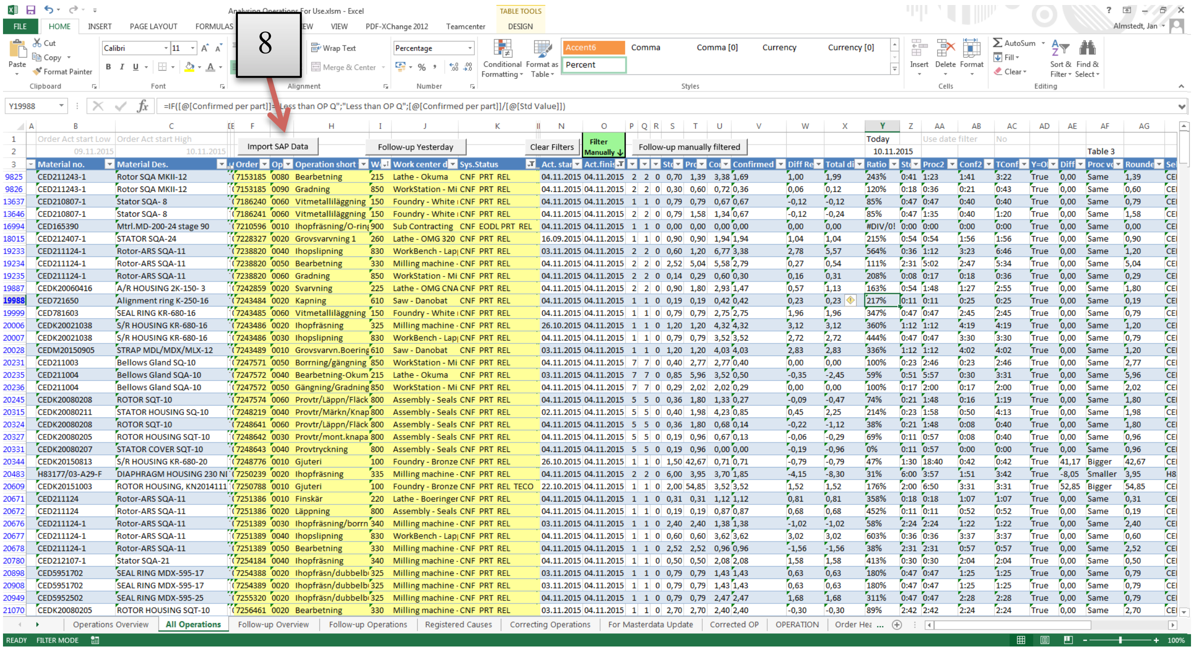


Figure 58 *All Operations* sheet.

4.2 Follow up Operation times for specific period (for example yesterday)

The status of planned vs. real operation times for a selected period can be viewed in the *Follow-up Overview* sheet (see *Figure 59*). All the operations in the selected period outside the limit criteria are shown. New criteria can be set to filter a lesser or bigger amount of operations by changing the High and Low Limit percentage in the "CHOOSE" table for limit criteria (see *Figure 59* Arrow 9).

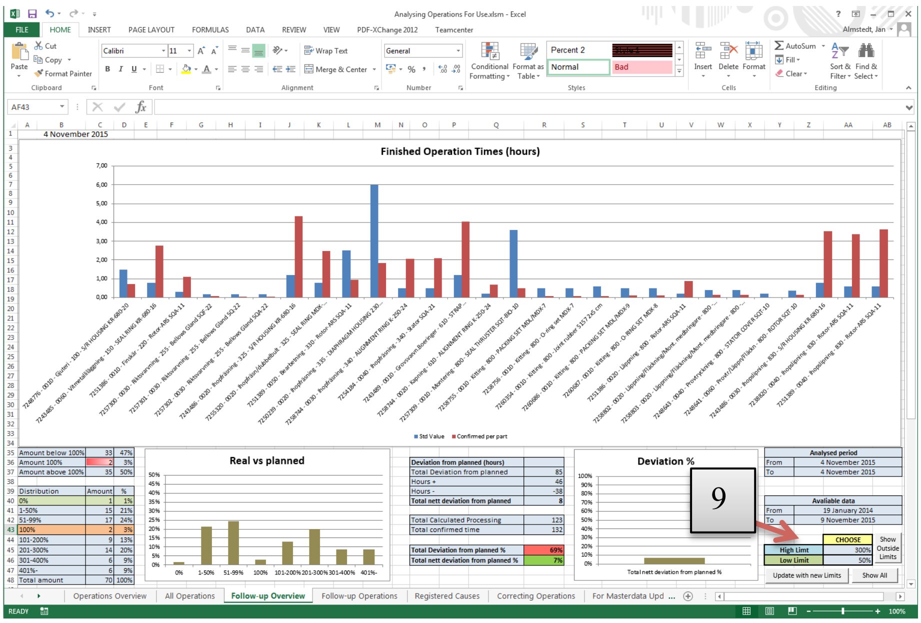


Figure 59 *Follow-up Overview* sheet.

4.2.1 Follow-up yesterday's operations

A specific use for this sheet is to monitor the operations finished yesterday and follow up on deviations from the SAP times.

To show data for a recent period its operation times first has to be imported from SAP with the macro/button **Import SAP Data** on the ***All Operations*** sheet (see ***Figure 60*** Arrow 10). Then to filter yesterday's operations for analyzing simply use the macro/button **Follow-up Yesterday** (see ***Figure 60*** Arrow 11). After the macro is run you will end up on the **Follow-up Overview** sheet (see ***Figure 61***).

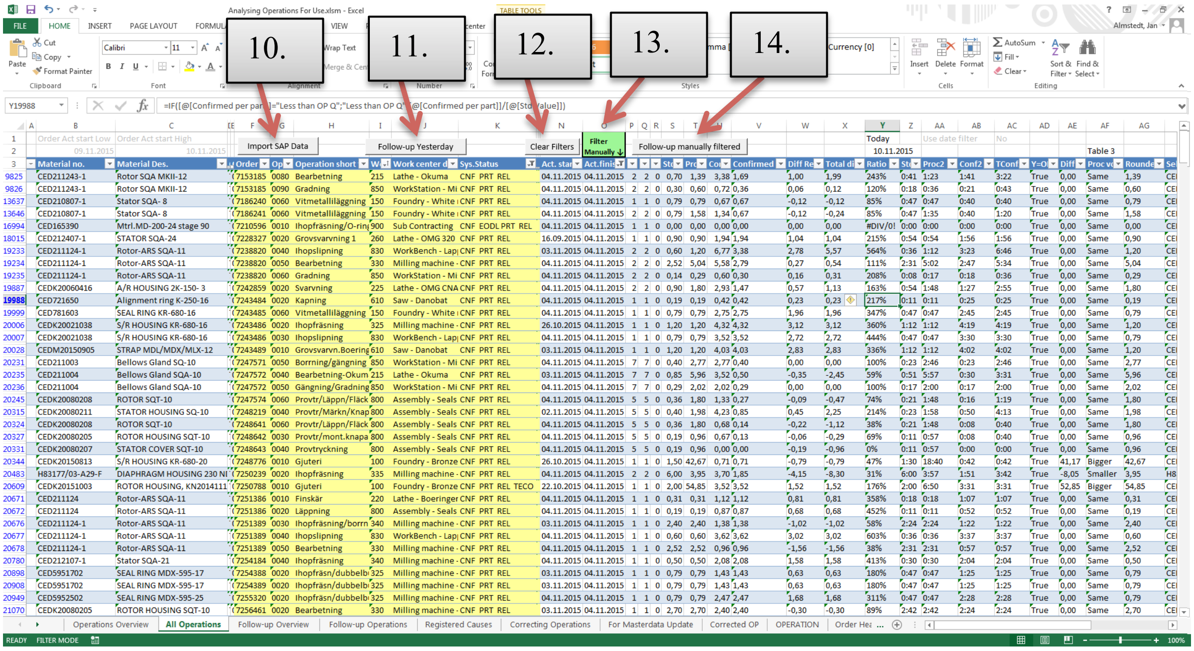


Figure 60 *All Operations* sheet.

4.2.2 Follow-up manually filtered

If another period than yesterday is to be filtered this have to be done by manually filtering out this date or dates on the ***Follow-up Operations*** sheet. Then first press the button **Clear Filters** (see ***Figure 60*** Arrow 12). Then select the dates for the wanted period in the "Act.finish" column with the green box above with the text "Filter Manually ↓" (see ***Figure 60*** Arrow 13). More than one date can be chosen. Then press the button **Follow-up manually filtered** (see ***Figure 60*** Arrow 14). After the macro is run you will end up on the Follow-up Overview sheet (see ***Figure 61***).

4.2.3 Follow up on deviations

To see more details or follow up on the deviations, assign causes and suggest better times the Follow-up Overview sheet can be used (see *Figure 61*). Here all operations meeting the *Limit* (see *Figure 59* Arrow 9) set on sheet Follow-up Overview can be seen for the chosen period. The limit criteria can be seen at the top (see *Figure 61* arrow 15) but only changed on the Follow-up Overview sheet.

Data for the individual operations can be monitored. When for example checking with the responsible operator causes and status for the deviation can be assigned. When registering a cause a suitable category for the deviation has to be selected (see *Figure 61* arrow 20). If the SAP standard time is considered to be wrong a suggestion for a new time can be inserted in the field "New standard" (see *Figure 61* arrow 19). If needed an additional free-text comment may be written in the "Cause (free text…)" column (see *Figure 61* arrow 17).
If one want to see all operations for the selected period regardless of the set *Limit* press the button *Error! Reference source not found.* (see *Figure 61* arrow 21). To again only show the ones outside the *Limit* press the button **Show outside Limits** (see *Figure 61* arrow 22).

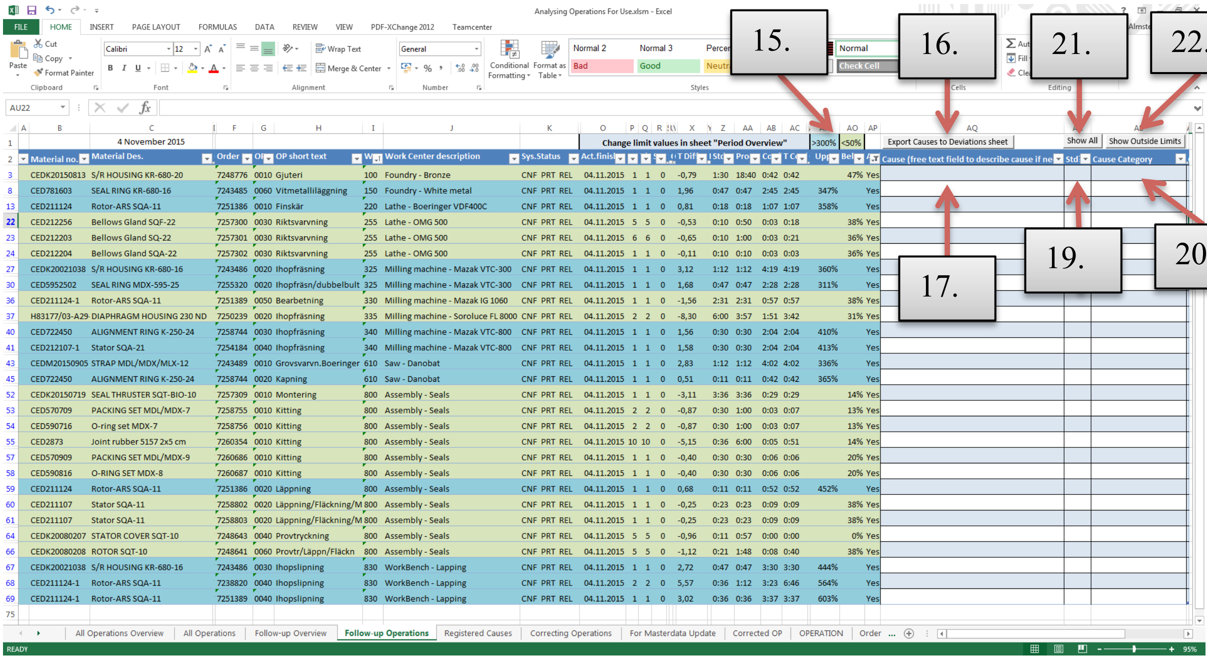


Figure 61 *Follow-up Operations* sheet.

4.2.4 Export deviations

After all found causes are written in they can be exported to the Registered Causes sheet for saving and overview together with earlier reported causes (see *Figure 62*). To do this press the button **Export Causes to Deviations sheet** (see *Figure 61* arrow 16).

4.2.5 Monitor causes

At the Registered Causes sheet all the exported causes can be monitored. Numerous possibilities for analyzing exist on this page. The total distribution for the cause categories are shown in the Graph "Causes from follow up" (see *Figure 62* arrow 21). Different filtering can be done in all the columns and for example only show the deviations for a specific: material, operation or work center (see *Figure 62* arrow 22).

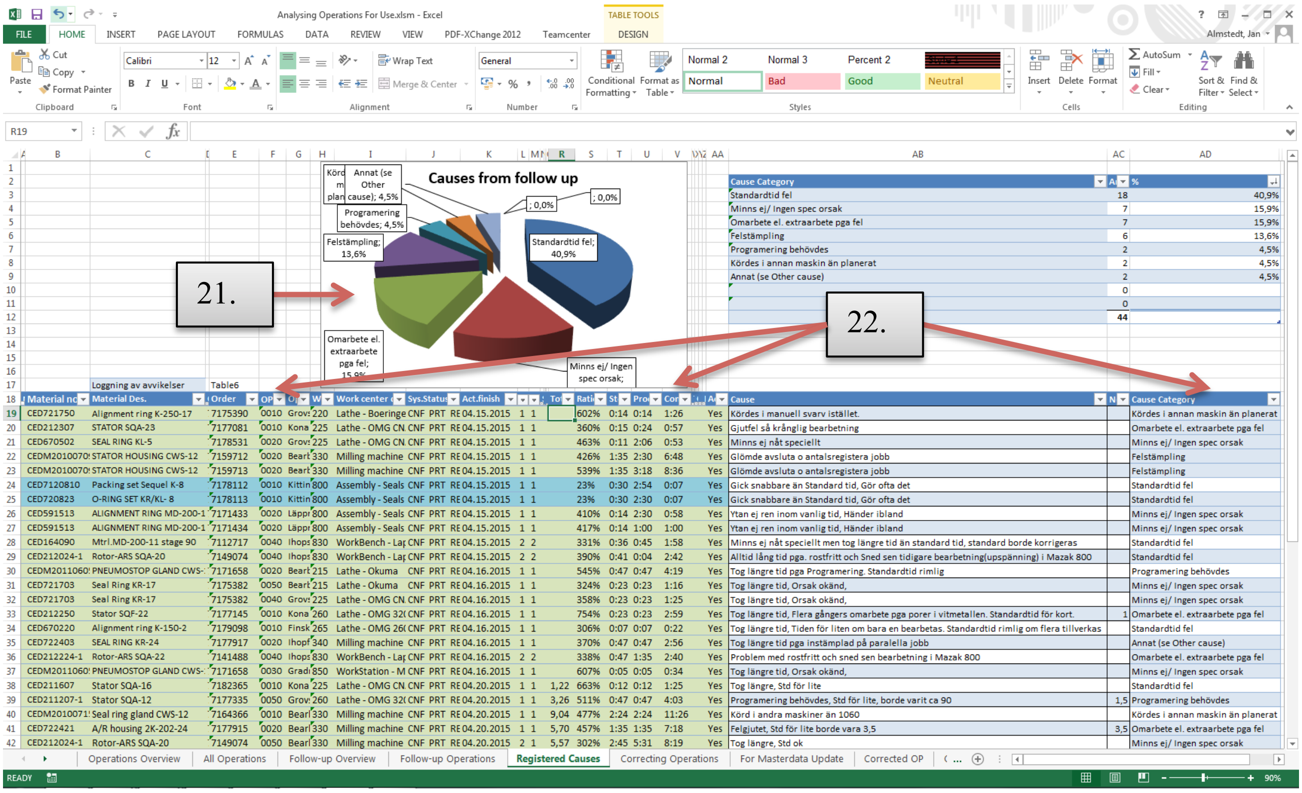


Figure 62 **Registered Causes** sheet.

4.3 Analyzing and correcting a Material Family

To analyze and if needed generate new operation times for a specific operation for a material family use the ***Correcting Operations*** sheet. A material family is defined as a material in different sizes with a similar material number structure to enable to filter out the material. An example is Stator SQA with the material number CED21??07-1 where "??" represent the size. The (-1) describe that it is a material that usually is produced against stock without the last operation that is not carried out until a customer order and the material. Then it gets the similar the material number CED21??07 but without the (-1).

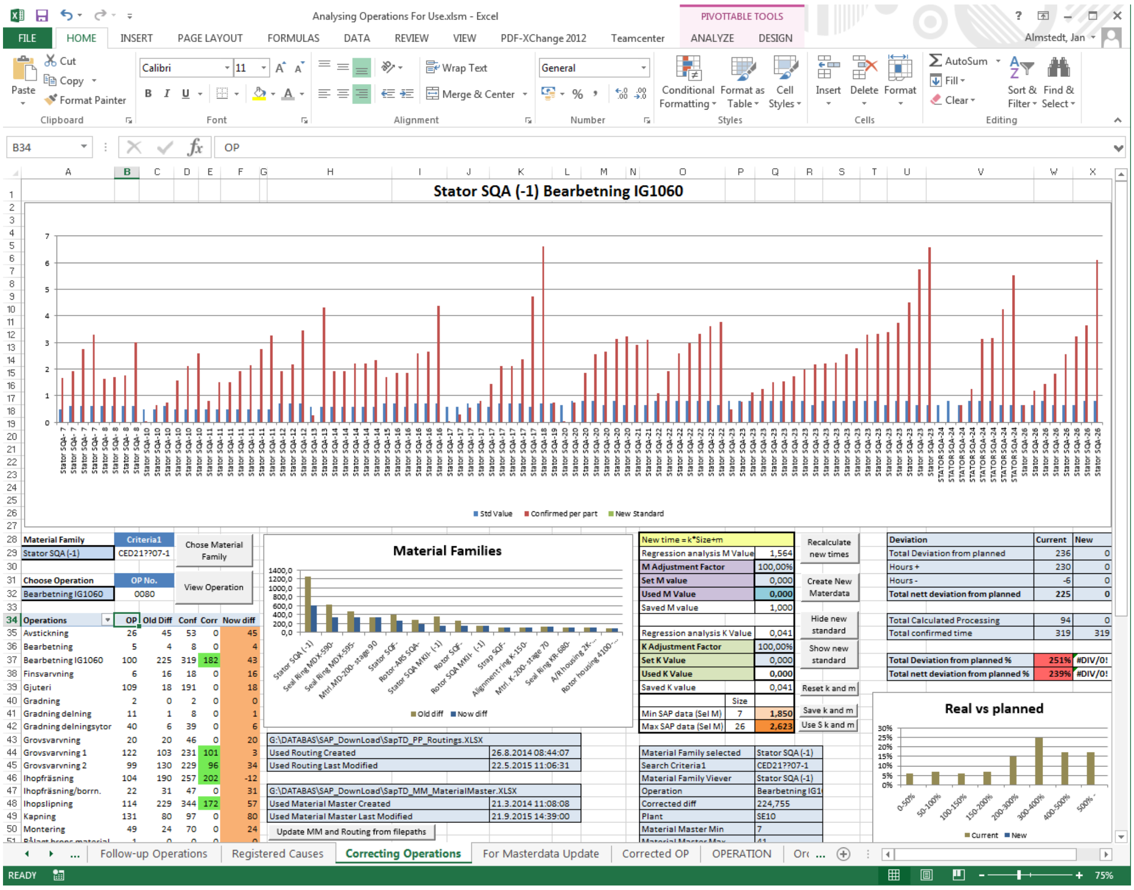


Figure 63 *Correcting Operations* sheet.

The sheet show a graph illustrating both the old diff and the now diff for the material families with the highest now diff. A material family can be selected in the dropdown list and then the button **Chose Material family** should be pressed. Then details about the different operations for the selected material family are viewed at the pivot table below. An operation can then be selected based on which operation that have the highest "Now diff" and then press the button **View Operation**.
The operation times for the selected operation are shown in the top graph and all the calculations on the sheet are updated so the status of the selected operation can be analyzed. A suggestion for new standard operation times is also generated with regression analysis and also displayed in the graph trying to find the linear expression best representing the real operation times. The formula is Y=kx+m where Y is the planned time and X is the size. The k and m values are created in the regression analysis. These values can then either be adjusted or entirely replaced by the user.
The status of the operation if these new standard operation times would have been used is also shown. The net deviation for both the old and new standard operation times is shown. The new standard operation
If new master data is to be created the button **Create New Master data** should be used. New master data is then generated on the sheet For Masterdata Update.

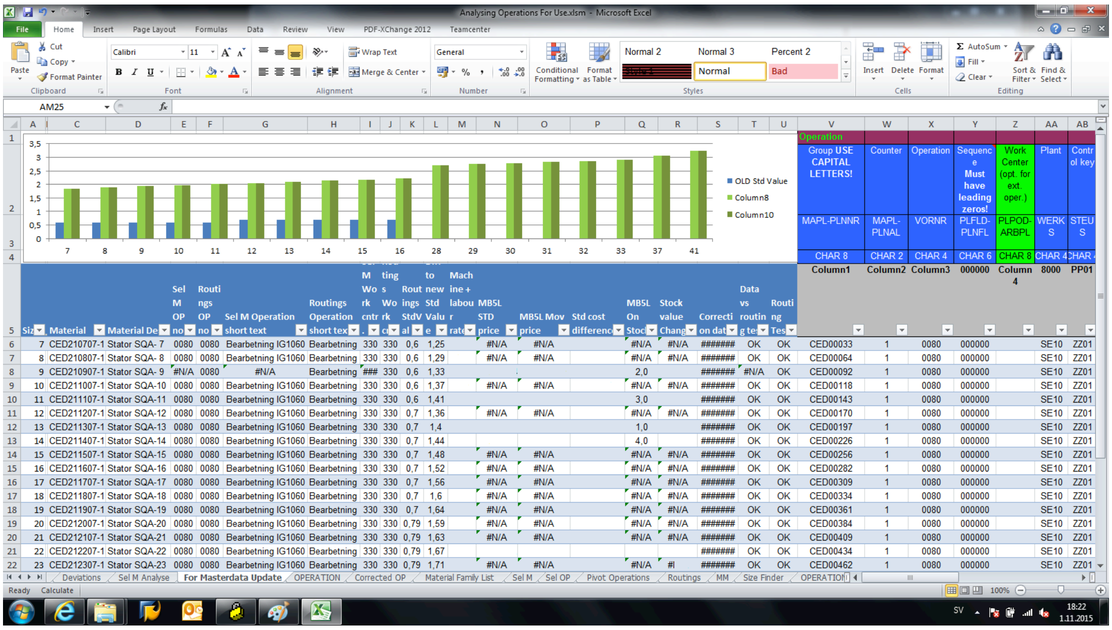


Figure 64 For Masterdata Update sheet left.

Here all the sizes available in the Current material master are displayed.
On the sheet For Masterdata Update a graph showing the old standard times and the new times is displayed. Test is also done to check so the routing is matching. If not the rows representing these sizes have to be removed in order to proceed. When potential problematic size rows are removed the button **Confirm and Copy New Master data** can be used.

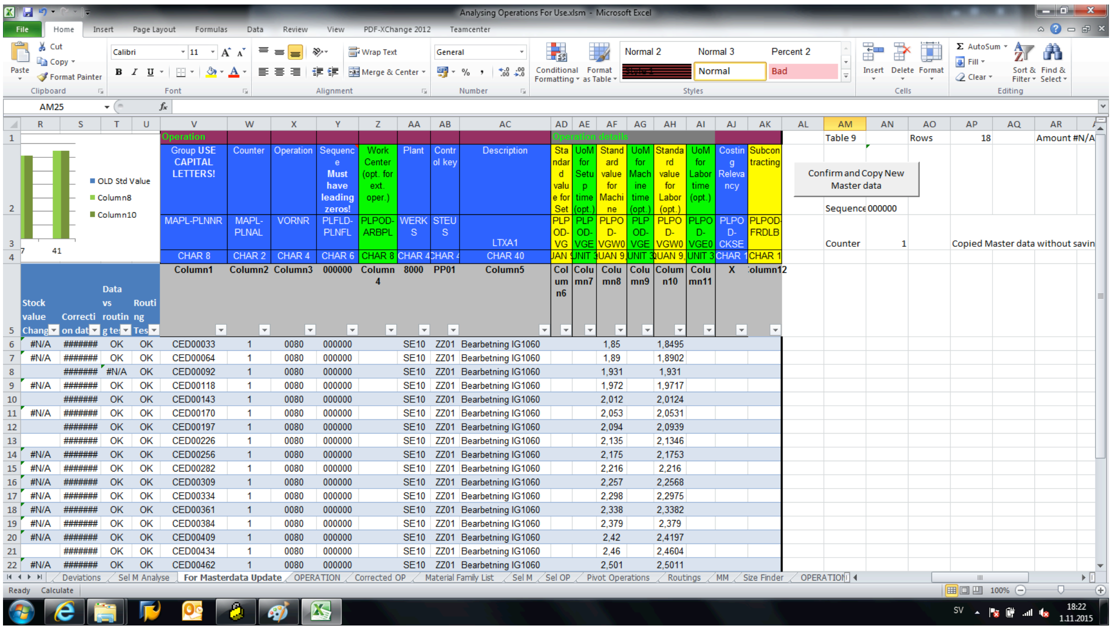


Figure 65 For Masterdata Update sheet right.

Now the new master data is copied as values to the OPERATION sheet and converted to the correct format. This sheet can then be saved as a separate excel file by using the button **Export Master Data Sheet "OPERATION" for upload to SAP**.

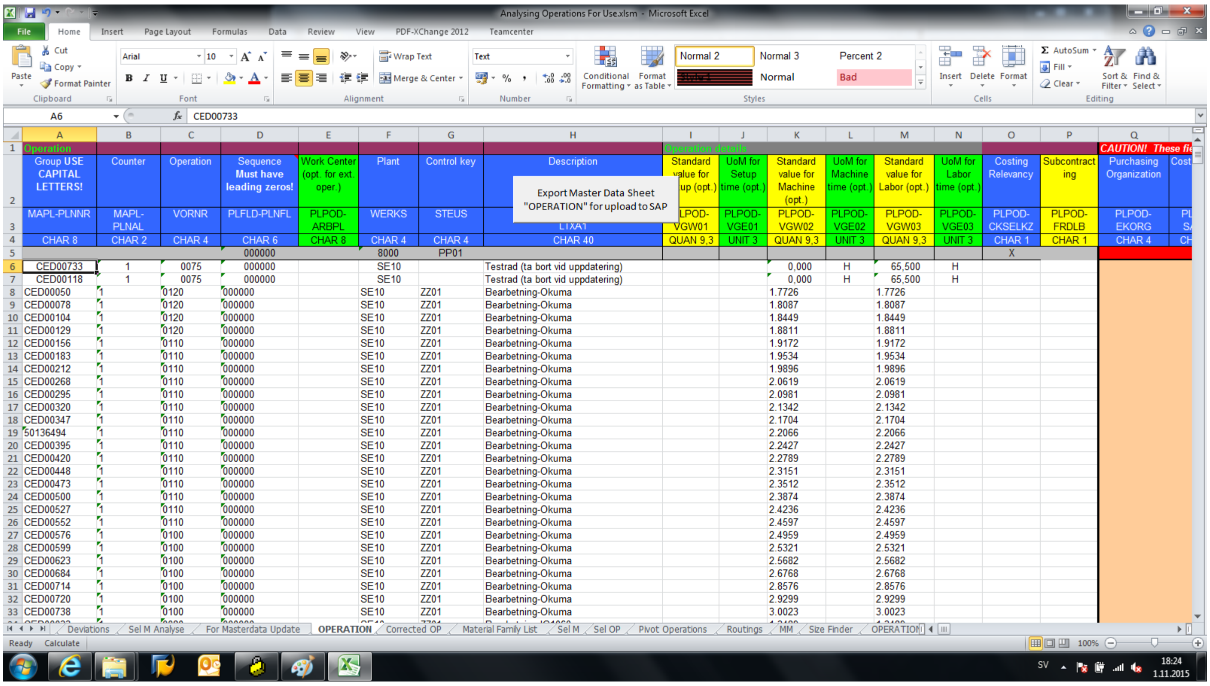


Figure 66 OPERATION sheet.

When new standard operation times are created on the OPERATION sheet all records of the correction and all the correction operations are being stored on the sheet Corrected OP.

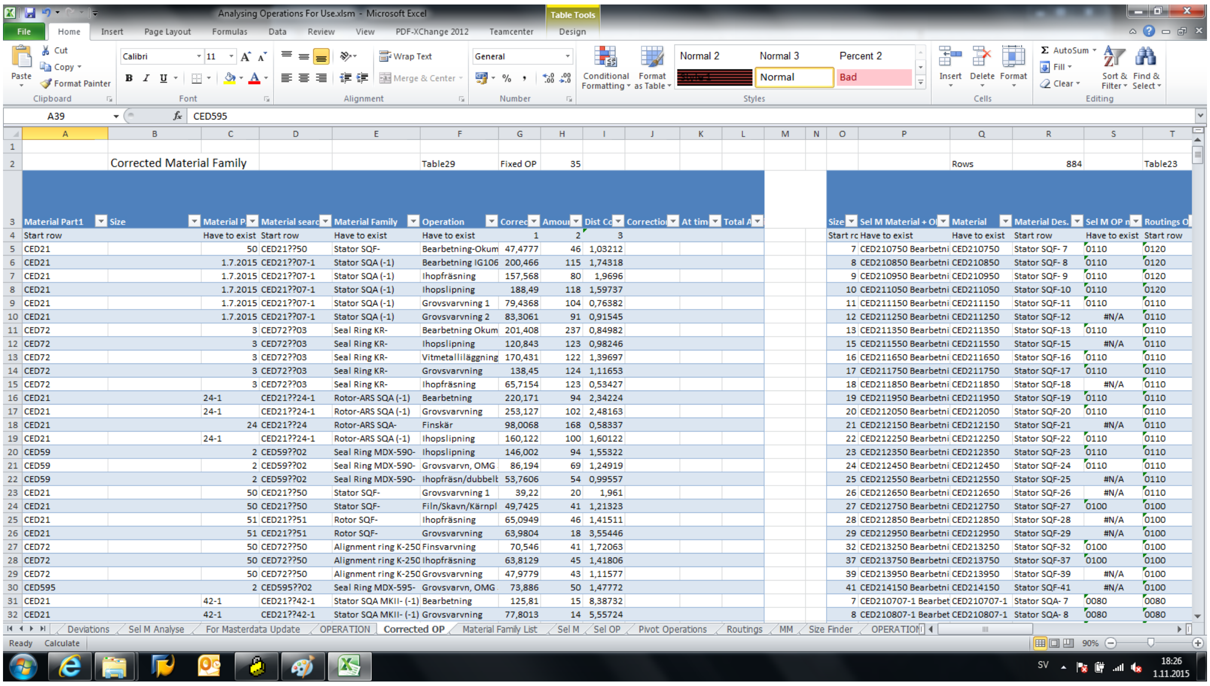


Figure 67 Corrected OP sheet.

5 Description of sheets

This section describes the sheet in the Excel file, both the visible and hidden ones.

5.1 Visible

5.1.1 All Operations

Shows Imported SAP data. Automatic update from SAP possible with the macro **Filter yesterday**. Selection to period analyze possible. Either for yesterday's data with Macro "filter yesterday" or for a manually selected period by "Filter chosen period. This sheet is the master source for all rest of the data and analysis. OP data from SAP is directly imported here. Info from Confirmations is shown by a linked formula. Have many analyzing functions directly build into the sheet. For example diff between standard and confirmed time and calculated processing to deal with the "Random Wrong processing time error" It also have a direct feedback loop showing the new time if the operation already have been adjusted with the Excel file.

5.1.2 All Operations Overview

Shows a both direct and indirect overview of status of all operations in the OP sheet. Indirect since some data first is processed in different sheets such as "Material Family list"

5.1.3 Follow-up Overview

This sheet is similar to the OP overview a sheet showing the status of operations. The difference is that it is created in order to be able to analyze a specific period and most suitable on day of operations. The main application is analyzing yesterday's operation times since a button and automatic macro for this exists. Another period can be set for example if one wants to look at Friday's times on Monday or if the entire last week should be analyzed. However the graph will only be useful for approximately the amount of times corresponding to one day. But if one chose all existing times can be analyzed here. The operations shown is the ones automatically imported and filtered in the sheet "Follow-up Operations"

This sheet also contains the limit criteria for the interval of operation times that should be filtered out in the "Follow-up Operations" sheet and consequently also shown on the "Follow-up overview sheet"

5.1.3.1 Limit criteria

The upper limit means that all operations with a ratio of confirmed time/standard time above this will be filtered out. The lower limit means that all the operations with a ratio of confirmed time/standard time below this will be filtered out. From start these limits are set to lower =50% and upper 300%.

This criterion is used to select whish operations that should be selected for action and selected and marked in the sheet Follow-up Operations. The idea is to set this limits to generate an amount of operations meaningful and possible to track. At the time of the thesis when big errors were seen these limits were set to High=300% and Low=50%. This generated for example for a day with 88 finished operations 9 above 300% and 7 below 50%. When the operation times are starting to get better this interval can hopefully be reduced to e.g. 75% and 150% without generating a high number of operations meeting the criteria.

5.1.4 Follow-up Operations

The list on this sheet is supposed to be used to follow up on yesterday's operation times. It displays the operations exported from OP by either the button and macros "filter yesterday" or "filter chosen period". The list has all the operations for the selected period but only the operations meeting the Limit criteria selected on the sheet "Period overview" is shown.

This list is supposed to be printed out and used for asking the operators for caused for the incoherence with the SAP standard operation times. When finished this information should be filed in the list on the "Sel period again" then by pressing the button "register causes" all the data is stored to the sheet "Deviations" that allow and overview. For how to operate it see 4.2 Follow up Operation times for specific period (for example yesterday)

5.1.5 Registered Causes

Here all the registered deviations can be monitored and future analyzed and filtered.

5.1.6 Correcting Operations

This is the sheet for actually improving the coherence between the SAP standard operation times and the real operation times by in a structured and statistical way analyze and adjust the SAP standard operation times based on weighted information about the real operation times in SAP from sheet OP.

For how to operate it see 4.3 Analyzing and correcting a Material Family.

For the analyzing, information from a number of sources and sheets are used.

The output is that the generated are new standard operation times that are exported with the button and macro "Create new master data" to the sheet "For Masterdata Update".

5.1.7 For Masterdata Update

On this sheet a check is run against the Material master sheet to check how many sizes of the chosen material family that exist. Times are generated for all the sizes of the material families in the material master. A check is also done with the current routing file to ensure that the selected operation have the same number and name. If any mismatches are found these rows have to be manually removed in order to proceed. A check is also run against the MB5L sheet to show the impact of the change on the stock Value. A prerequisite for this is that the data on the sheet MB5L sheet are updated. To the right the master data about to be created is shown but in forms of formulas. When ready press the button "Confirm and Copy New Master data" in order to export the data as values to the sheet "OPERATION". If error exists, a popup describing the problem will show. If no error messages show up the creation of new master data was successful. Information about the adjusted operations is then also automatically written to the sheet "Corrected OP"

5.1.8 OPERATION

This sheet shows the generated Master data in a form ready to be updated to SAP. In order to export the sheet press the button at the top "Export the Master Data Sheet "Operation" for Upload to SAP" this sheet will be exported to a new workbook and the user will be able to choose the location to save it to.

5.1.9 Corrected OP

This sheet shows a list with both the updated Material families to the left where the corrected amount of time is shown and also the effects on the stock value. To the right each individual operation corrected is listed. This list is used to know which operations that already are "fixed" and is the source for the information shown as corrected diff.

5.1.10 Material Family list

This sheet is showing the list of different families. This list has been manually created in order to be able to filter out a specific material family with the Material number. Not all material is covered by this list. The problem is that material families with such unique combinations of material codes exist. The "tail" problem. But the list covers 88,8% of all operations and 91,5% of the total diff.

5.1.11 Sel OP

This sheet is used for generating the data on the "Sel M Analyse" sheet. When selecting a Material Family in the dropdown list on the "Sel M Analyze" and pressing the button/macro "Chose material Family" these operations are filters in the "OP" sheet and pasted to the "Sel OP" sheet. From this sheet the pivot table shown in the "Sel M Analyze" sheet displaying all operations for the chosen material is generated.

5.1.12 Sel M

This sheet is used for generating the data on the "Sel M Analyze" sheet. When selecting an operation in the dropdown list on the "Sel M Analyze" and pressing the button/macro "View operation" that operation are filtered in the sheet " Sel OP" sheet and pasted to the "Sel M" sheet. The data in the table is the source for the Graph the numbers for comparison on the "Sel M Analyze" sheet

5.1.13 Pivot Operations

This sheet is used to generate the list of operations on the sheet "OP overview". Source is "OP".

5.1.14 Routings

This sheet shows the current Routings in SAP. This sheet is not directly updated from SAP but instead from a file.

5.1.15 MM

The abbreviation stands for Material Master. This sheet shows the current Material Master in SAP. This sheet is not directly updated from SAP but instead from a file.

5.2 Size Finder

This sheet is used to generate new master data on the "For Masterdata Update". At the same time a Material Family is selected on the "Sel M Analyze" sheet" all the available sizes of that material family is filtered from the Material Master, copied and pasted on this sheet. This allow min and max size to be showed directly on the sheet "Sel M Analyze" and for generating the list of materials on the "For Masterdata Update"

5.3 OPERATION Original

Shall be removed in final version. No use other than acting as reference during the creation of the file.

5.4 Dev Lists

Full name: Deviation lists. Table 7 and 8 are used to generate the dropdown lists for available options when reporting deviations for a period (e.g. yesterday's operations" on the "Sel Period" sheet. Table 3022. Usage unknown. Have to check if can be removed.

5.5 Conf

Full name: Confirmations. This sheet is used to generate the names and Material since only Order number and Group are available form OP. Can Material master or Routing be used instead? Would save an extraction point from SAP.
Both group and Material are available in Routings but not Material name.
Material and Material name connection available in MM.

5.5.1 Diff based on OP

A lots of selection summaries. Used for generating data in the Master Thesis report. Probably not operationally used somewhere. Investigate and if not used it should be removed.

5.5.2 On stock

The data on this sheet is used to calculate the effects on the stock value from changing the master data. The data comes from the SAP transaction MB5L and is drawn from the G/L Accounts 1300000, 1310000, 1320000. This sheet has to be manually updated.

5.5.3 Table list

This sheet show a list of at whish sheet a specific table can be found. For example "Table 5" is located on the sheet "Sel M".

5.6 On stock

Contains the current stock level imported by the MB5L file

5.7 Revision history

Explains the corrections done to the file in new versions.