

Master's thesis (YAMK)

Master of Engineering, Industrial Quality Management

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Implementing the Cost of Poor Quality

– Production quality cost



Master's Thesis | Abstract

Turku University of Applied Sciences

Industrial Quality Management

2025 | 61

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Implementing the Cost of Poor Quality

- Production quality cost

The thesis was carried out in collaboration with the company as a development project, with the aim of identifying loss factors occurring in production and preparing a cost estimate based on these. The production loss in the company was measured in time units, which provided the baseline data for calculating quality costs. The loss included production errors, repair installations, and scrapping costs. The goal of this work was to identify and calculate the average quality cost of various losses, which can be utilized in the future, for example, as an initiative for development projects.

The research was conducted as a case study in production. Interviews were also conducted in a different factory where they had implemented a system to determine the cost of poor quality. The aim of the interviews was to gather as much information as possible. As part of the research, data was collected from the information system, and average cost estimates were determined. This led to the development of a fixed formula to calculate the quality costs of various loss factors in monetary terms.

The company's future goal is to create a metric based on the collected data and set values, from which cost estimates of loss factors occurring in production can be reported.

Keywords:

Quality cost, Data collection, Production loss, Loss factors

Opinnäytetyö (YAMK) | Tiivistelmä

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Gemb Harkela

Implementing Cost of Poor Quality

- Production quality costs

Opinnäytetyö toteutettiin yhteistyössä yrityksen kanssa kehittämistyönä, jossa tavoitteena oli selvittää tuotannossa tapahtuvia hukatekijöitä ja laatia näiden pohjalta kustannusarvion aiheutuneesta hukasta. Tuotannon aikainen hukka yrityksessä mitattiin aikayksikössä, josta saatiin pohjatiedot laatukustannuksien laskentaan. Hukkaan sisältyi tuotannon aikaiset virheasennukset, korjausasennukset sekä romutuskustannukset. Työn tavoitteena oli tunnistaa ja laskea erilaisten häviöiden keskimääräinen laatukustannus, jota voidaan tulevaisuudessa hyödyntää esimerkiksi kehitysprojektien aloitteena.

Tutkimus toteutettiin tapaustutkimuksena tuotannossa. Lisäksi haastatteluja tehtiin toisessa tehtaassa, jossa oli otettu käyttöön järjestelmä huonon laadun kustannusten määrittämiseksi. Haastattelujen tavoitteena oli kerätä mahdollisimman paljon tietoa. Osana tutkimusta kerättiin tietoa tietojärjestelmästä ja määritettiin keskimääräisiä kustannusarvioita. Tämän pohjalta kehitettiin kiinteä kaava, jolla voidaan laskea erilaisten häviötekijöiden laatukustannukset rahassa mitattuna. Yrityksen tulevaisuuden tavoitteena on luoda mittari kerätyn datan ja asetettujen arvojen perusteella, jonka avulla voidaan raportoida tuotannossa esiintyvien häviötekijöiden kustannusarvioita.

Asiasanat:

Laatukustannus, Tiedonkeruu, Tuotantohäviö, Häviötekijät

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List of abbreviations (or) symbols

COPQ	Cost of Poor Quality (AIAG, 2012)
SPC	Statistical Process Control (Smith & Hawkins, 2004)
PONC	Proof of No Complexity (AIAG, 2012)
CoQ	Cost of Quality (Hessing, 2020)
ERP	Enterprise Resource Planning (Juran & De Feo, 2010)
PDCA	Plan-Do-Check-Act (Ioppolo et al., 2024)

1 Introduction

The concept of the Cost of Poor Quality (COPQ) is a concept that helps to understand the financial impact of producing substandard products or services. COPQ encompasses all costs incurred due to nonconformity to quality standards, including the costs associated with rectifying defects and failures. These costs can be broadly categorized into internal failure costs, external failure costs, appraisal costs, and prevention costs. (Hessing, 2020).

Understanding COPQ is beneficial for organizations as it highlights the areas where quality improvements can lead to significant cost savings. By investing in prevention and appraisal activities, organizations can reduce internal and external failure costs, thereby enhancing overall profitability and customer satisfaction (AIAG, 2012, p.15).

In this thesis the focus is on the costs that are created on internal failures. Internal failure includes costs of rework, scrap and analysis on the failure. This thesis is a part of development project in collaboration with Supplier Sourcing development team. Some of used calculation values were determined in collaboration (Syrjänpää, 2024).

This development project initially started when we realized that our indicators lacked a clear, visual, and precise quality cost value. Usually, quality costs were calculated on a case-by-case basis when deemed necessary. Based on this need, we were able to clearly define and focus the initial stages of the development project, which led to an interesting thesis project for myself. I proposed the thesis and development initiative to my supervisor, aiming to create something beneficial for our company. At the same time, I felt that this would help enhance our understanding of quality costs. Personally, I was the initiator and creator of the development project, as I was genuinely interested in exploring the topic further and challenging myself to create a monetary estimate of our quality deviations.

1.1 Internal and external failures

Internal failure costs arise from defects identified before the product reaches the customer. These include costs related to rework, scrap, and failure analysis.

External failure costs are incurred when defects are discovered after the product has been delivered to the customer, such as warranty claims, repairs, and loss of goodwill. (AIAG, 2012).

1.2 Appraisal and prevention costs

Appraisal costs are associated with activities aimed at measuring and monitoring quality to ensure conformance to specifications. These include inspection, testing, and quality audits. Prevention costs are incurred to prevent defects from occurring in the first place, such as costs related to quality planning, training, and process improvement. (AIAG, 2012).

1.3 Categories of Cost of Poor Quality

In quality management, the costs associated with ensuring and maintaining product quality are typically divided into four main categories: internal failure costs, external failure costs, appraisal costs, and prevention costs. Internal failure costs arise from defects identified before the product reaches the customer and include activities such as rework, where faulty products are corrected, scrap, which involves the disposal of unusable items, and failure analysis aimed at determining the root causes of defects. (Chopra & Garg, 2011)

External failure costs, on the other hand, occur after the product has been delivered and may include warranty claims, returns and repairs, as well as the loss of goodwill caused by customer dissatisfaction and damage to the company's reputation. Appraisal costs are related to the detection of defects before delivery and involve inspection and testing, quality audits, and supplier

rating processes, all designed to ensure compliance with quality standards. Prevention costs represent proactive measures taken to avoid defects altogether, such as quality planning, employee training, and process improvement efforts intended to enhance efficiency and reduce errors. (Chopra & Garg, 2011). Understanding and analyzing these categories is essential for improving quality performance, optimizing production processes, and reducing total quality-related costs.

Internal failure costs:

Rework: Costs incurred to correct defects before the product reaches the customer.

Scrap: Costs associated with defective products that cannot be repaired or used.

Failure Analysis: Expenses related to identifying the root causes of defects.

External failure costs:

Warranty Claims: Costs for repairing or replacing defective products after they have been delivered to the customer.

Returns and Repairs: Expenses for handling returned products and performing necessary repairs.

Loss of Goodwill: Financial impact due to damaged reputation and customer dissatisfaction.

Appraisal Costs:

Inspection and Testing: Costs for activities that ensure products meet quality standards.

Quality Audits: Expenses related to systematic reviews of quality processes.

Supplier Rating: Costs for evaluating and approving suppliers.

Prevention Costs:

Quality Planning: Costs for developing processes that prevent defects.

Training: Expenses for educating employees on quality standards and practices.

Process Improvement: Investments in activities aimed at enhancing process efficiency and reducing defects.

2 Quality in production

Production quality, also known as manufacturing quality, is a fundamental aspect of the manufacturing process that determines the degree to which a product meets its design specifications and customer expectations. High production quality is essential for ensuring customer satisfaction, operational efficiency, and overall business success. (Schroeder et al., 2005). This comprehensive overview explores the key factors influencing production quality, the benefits of maintaining high production quality, and strategies for continuous improvement (Smith & Hawkins, 2004).

2.1 Key factors influencing production quality

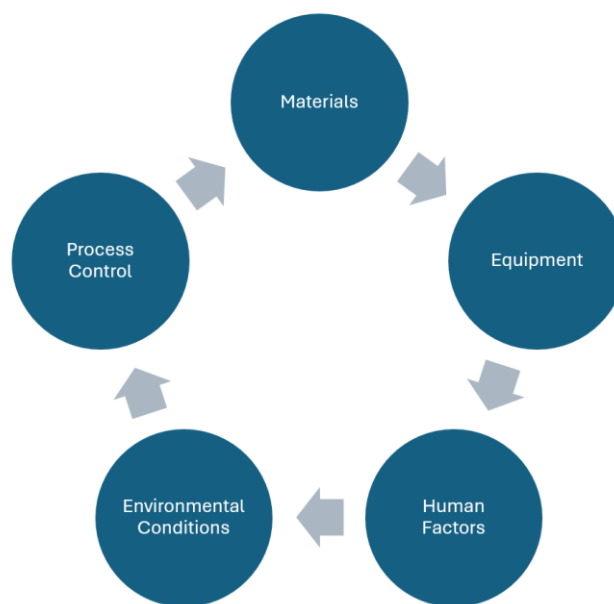


Figure 1. Key factors of production quality. Based on:(Smith & Hawkins, 2004, p 7)

Materials:

The quality of raw materials used in production has an impact on the final product's quality. High-quality materials lead to more reliable and durable

products, while substandard materials can result in defects and failures. Ensuring a consistent supply of high-quality materials is crucial for maintaining production quality. (Colledani et al., 2014)

Equipment's:

Advanced and well-maintained equipment according to quality management system helps achieve precision and consistency in manufacturing processes. Regular maintenance, calibration, and upgrades of machinery help prevent defects and minimize downtime. Investing in state-of-the-art equipment can enhance production capabilities and improve product quality. (Colledani et al., 2014).

Human Factors:

Skilled and well-trained personnel play's role in maintaining high production quality. Human errors can be minimized through continuous training, adherence to standardized procedures, and fostering a culture of quality awareness. Employee engagement and motivation are also critical for ensuring that quality standards are consistently met. (Wiendahl et al., 2005)

Environmental Conditions:

The production environment, including factors such as temperature, humidity, and cleanliness, can influence product quality. Controlled environments help maintain consistency and reduce the risk of contamination. Implementing environmental controls and monitoring systems is essential for ensuring optimal production conditions. (Georgoulas et al., n.d.)

Process Control:

Robust process control measures, such as statistical process control (SPC) and real-time monitoring, are essential for identifying and correcting deviations from quality standards promptly. Implementing process control techniques helps maintain consistency, reduce variability, and improve overall production quality. (Colledani et al., 2014).

2.2 Creating a Culture of Quality

The concept of quality has evolved over time, reflecting changes in societal values, technological advancements, and industrial practices. The journey of quality can be traced back to ancient civilizations, where craftsmanship and attention to detail were paramount. The history of quality reflects a continuous journey of improvement and adaptation, driven by the quest for excellence and the changing needs of society. (Sahay, 2015). As we move forward, the principles of quality will continue to evolve, shaping the future of industries and organizations worldwide (Juran & De Feo, 2010).

Achieving long-term success and maintaining competitive advantage is an aim for organizations. A culture of quality ensures that every employee, from top management to frontline workers, is committed to delivering high-quality products and services. (Schroeder et al., 2005). This comprehensive overview explores the key elements of building a culture of quality, the benefits it offers, and strategies for fostering and sustaining such a culture. By focusing on key elements such as leadership commitment, employee engagement, continuous training, clear communication, customer focus, and process improvement, organizations can foster and sustain a culture of quality (AIAG, 2012).

The benefits of a culture of quality include enhanced customer satisfaction, improved operational efficiency, increased employee morale, cost savings, and competitive advantage. Continuous investment in quality initiatives and a commitment to excellence are essential for driving long-term growth and success. (Juran & De Feo, 2010).

2.3 Quality Spectrum

The ideology of the Quality Spectrum is to graphically explain that for every action in any organization there is an impact. It helps organizations understand and manage the different levels of quality within their products, services, and

processes. It contains a range of subsequent steps, from basic compliance to excellence, and provides a structured approach to continuous improvement. (AIAG, 2012).

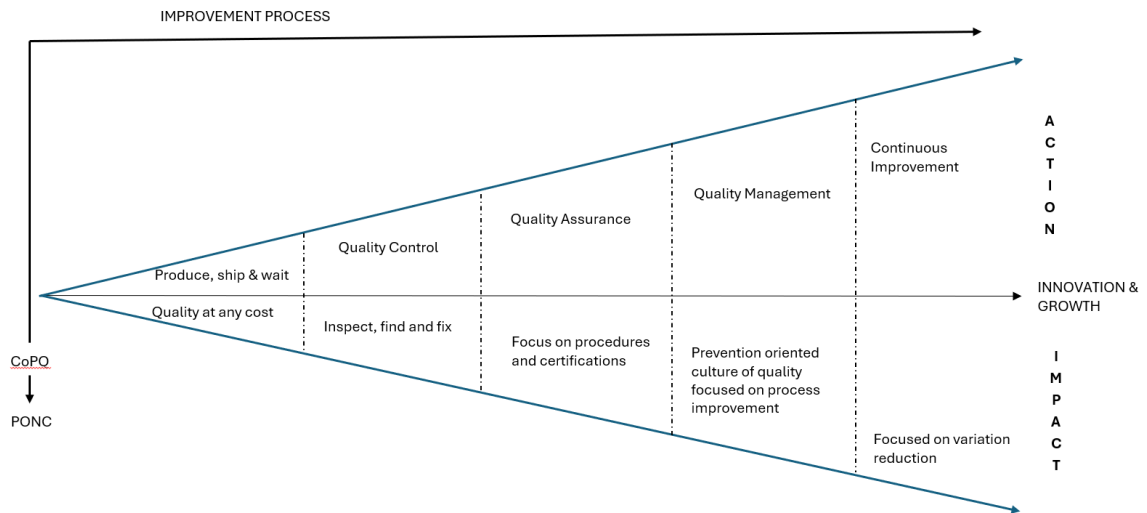


Figure 2. The Quality Spectrum subsequent steps. Based on: (AIAG, 2012)

Identification of a problem occurs when something is not happening that should be or when something is happening when it should not be. As seen in Figure 2. Each subsequent step to improve has an impact therefore as an organization they move more and more to the right on the Spectrum where their COPQ is reduced. (Dale & Smith, 1997). The left side of the Spectrum is where the company may receive a complaint, reacting with whatever it takes to correct the problem, it creates a culture of “quality at any cost” (AIAG, 2012).

3 Costs in Quality

As mentioned in the first chapter of this thesis, internal and external failures impact differently in quality costs. The categories determine the input of a certain action needed. Appraisal and preventive costs are costs associated with inspection that deficiencies are discovered before customers are affected. (Mahmood et al., 2014).

When discovering deficiencies, it avoids major failure costs later and it helps develop more effective and efficient inspection methods. There is always a quality cost in some form at any stage of production, the main goal is to avoid excessive costs (Juran & De Feo, 2010, p 161).

The Cost of Quality (CoQ) is a framework that helps organizations understand the financial impact of ensuring quality in their products and services. It is divided into four main categories as shown in the Figure 3: prevention costs, appraisal costs, internal failure costs and external failure costs. Each category represents different aspects of quality-related expenses. (Hessing, 2020).

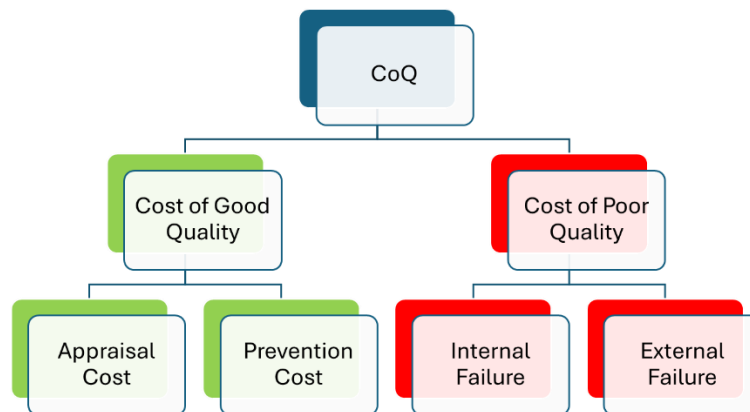


Figure 3. Categories of Cost of Quality. Based on: (Hessing, 2020)

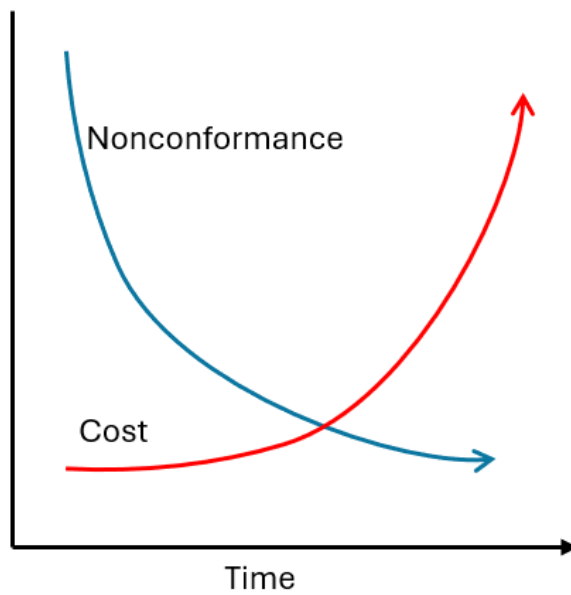


Figure 4. Appraisal cost affection to Quality Culture. Based on: (AIAG, 2012)

As seen in the appraisal Figure 4. The costs take a leap when the nonconformance level drops. This is due to the companies action towards finding causes of the poor quality of the product. (Shubhangan & Darshak, 2016). The cost of appraisal focuses on the discovery of defect rather than the prevention of defects. Appraisal costs are related to testing, measuring and auditing (Hessing, 2020).

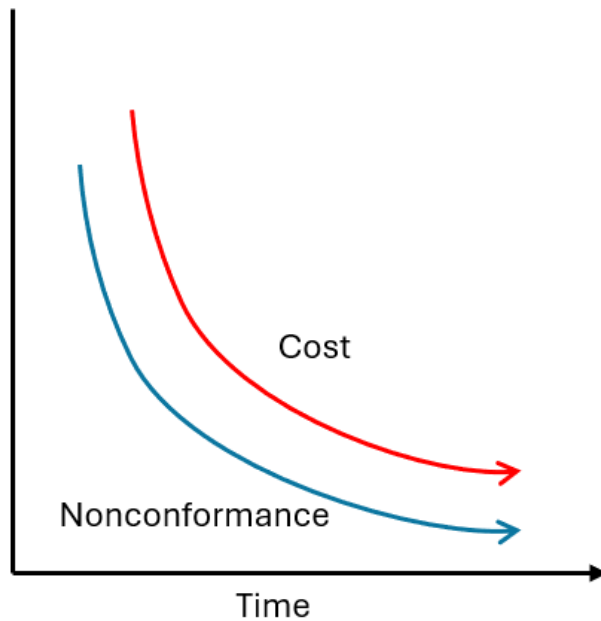


Figure 5. Preventive cost affection to Quality Culture. Based on: (AIAG, 2012)

As per Figure 5. The costs of Preventive cost are those activities that are specially designed to prevent poor quality of products. These actions such as quality planning, trainings, audits, supplier evaluations and research work, are considered as the efforts to ensure or minimize the risks for failures to occur in the first place (Juran & De Feo, 2010, p 163).

3.1 Hidden and obvious Costs of Quality

In other words, '*invisible cost*' is used to indicate the failure costs that are not discovered during the production (Juran & De Feo, 2010). Hidden quality costs refer to the indirect expenses that arise from quality issues but are not immediately apparent in financial records. These costs can include lost productivity, increased rework, customer dissatisfaction, and damage to the company's reputation. (Shubhangan & Darshak, 2016).

Most commonly measured failure costs in manufacturing companies are the obvious costs of poor quality. These obvious failures are the ones that are most visible and measure during the product lines, such as scrap, rework and

warranty. Mentioned failures are considered as internal failures. Failure costs are occurring prior to shipment of the product. (Naidu, 2006).

3.1.1 The Iceberg Analogy in Quality Management

The iceberg analogy is a used metaphor in quality management to illustrate the concept of hidden costs associated with poor quality. As illustrated in the Figure 6. the analogy helps organizations understand that the obvious costs of poor quality are only a small section of the total costs, with the majority being hidden beneath the surface (Dogaru & Zaharia, 2019).

Visible costs are those that are easily identifiable and measurable. These costs are often the focus of obvious quality management efforts and include defect costs, which are expenses related to the examination and testing of products to ensure they meet quality standards (Khadim et al., 2023). Rework costs are incurred to correct defects in products or processes, while scrap involve costs associated with handling and resolving issues with the product that cannot be used in production and are scrapped with a cost.

Hidden costs are less obvious and these costs include lost sales and reputation, as poor quality can lead to a decline in customer trust and loyalty, resulting in lost sales and damage to the organization's reputation (Khadim et al., 2023). Excess inventory is another hidden cost, as defective products contribute to unsellable inventory, which requires storage and maintenance, leading to additional costs. Investigations, fines, and legal fees are also part of hidden costs, as they involve expenses associated with regulatory fines, legal fees, and investigations into quality issues (ETQ Organization, 2019) .

The iceberg analogy serves effectively in quality management and requires a comprehensive approach that considers both visible and hidden costs. Organizations that focus on the visible costs may miss opportunities to address the underlying issues that contribute to poor quality. By recognizing and mitigating hidden costs, organizations can achieve better quality outcomes and enhance their overall performance. (Dogaru & Zaharia, 2019).

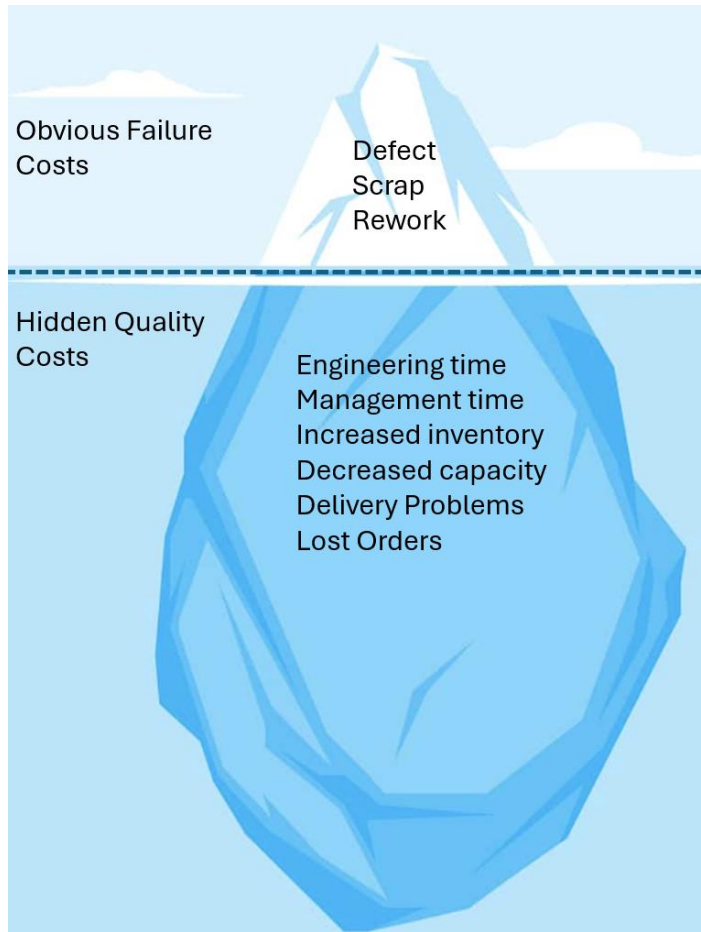


Figure 6. The Iceberg Analogy. Based on: (Khadim et al., 2023).

4 Research and Development Methods

This chapter focuses on how the data was collected for this thesis. The schedule of the project as seen in Figure 7 was flexible and did not interfere with production nor personal scheduling. This thesis progressed according to spiral model referenced from “*Research development activities: perspectives on the development process, inclusion and information production*” by Toikko et al. (2009). This process entailed regularly evaluating the need for adjustments and identifying any enhancements required to reach the desired result. The spiral model is illustrated in Figure 8.

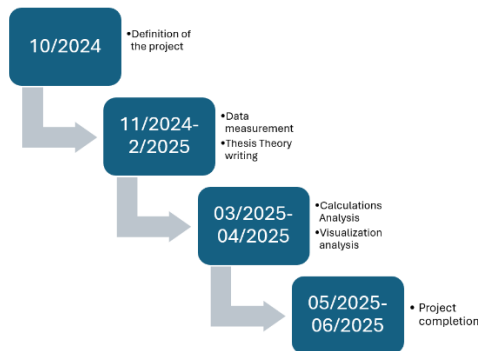


Figure 7. Thesis and project schedule

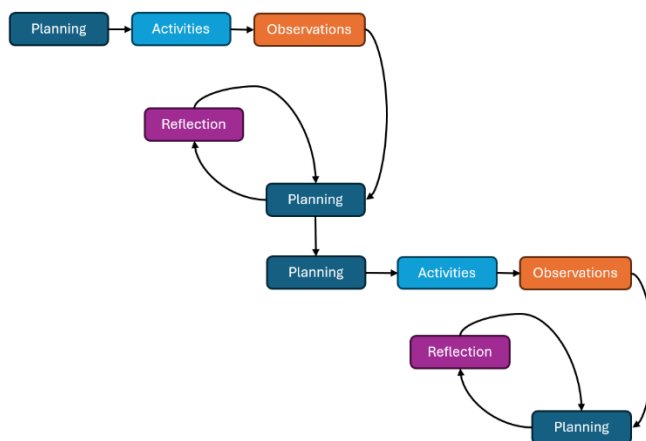


Figure 8. Thesis process spiral model. Based on: (Lewin, 1948, as cited in Toikko et al. 2009).

4.1 Thesis scope

The main focus of the thesis or project is to determine the costs of the obvious failure costs, which are included in the category of Internal failure costs shown in Figure 3. At this point, we are aware that some of the data are not available to reach through ERP system.

A dedicated path will be built into the ERP system to collect the necessary data. The repair time used was desired to be shown in hours. Each repair case should be identified based on the product, so that the data would be as clear and unambiguous as possible, while still containing all the required information. The path to ERP system will be developed in collaboration with the production system experts.

In production, at this time we have two manufacturing lines, each line consisting of 10 working areas. Each area has a specified work type and materials and at the of the line the product is done. Line illustrated in Figure 9. Other manufacturing places are called 'cells', which does not operate as a line process. Production areas in total are 22 cells and two production lines.



Figure 9. Line areas described

4.2 Research plan and Data collection

At first, for the project it was necessary to find out what data can we get from ERP system. This action determined the approach on what we need to identify through interviews and what is needed to define or measured manually.

Initially started to highlight key points when rework is performed, defect part has occurred and why the part/component is being scrapped. Key points to be able to measure obvious costs are listed below.

Rework

Loss time (the time lost when not performing valuable work).

Rework assembly (the time lost doing rework on machine, including delays and working overtime).

Defect part

Time loss on investigation (is the defected part repairable).

Time loss on repair.

New replacement part from stock.

If not repairable → Scrap.

Scrapping

Components/parts are scrapped (all parts that cannot be repaired and are not claimable to supplier).

From the obvious failure costs, only scrapping part can be excluded from the calculation analysis due to it is a fix cost from its value. The process during scrapping involving other functions are minimal due to its automated process and fix costs. These values are available directly from ERP system and are reported by finance department.

4.3 Research and existing database

The study was limited to line production areas, because produced product in a line consisted of all areas separately compared to a cell manufacturing place. The calculations can be adjusted to a cell manufacturing area based on the data gained from the line production. The planned sample quantity was approximately **50**.

As the project focuses on internal failure happening in production, one of colleagues project focuses on internal failures involving suppliers (Syrjämpää, 2024). Therefore, the determined values on hours, costs and averages must be the same.

4.3.1 Production

As mentioned in chapter 4.1, production areas in total are 22 cells and two production lines consisting of 10 areas per line. This is the maximum capacity at the moment of production. There is a possibility to increase or decrease the number of cells. All data involving manufacturing the product are digitalized. The data runs through ERP system.

Every work phase is pre-planned, and all the needed materials are scheduled according to the phase need. These are automatically collected and brought to production areas by logistics. The logistics operates via ERP system, as mentioned above all phases are pre-planned therefore the logistics does not need to for additional information what is needed, when and where.

4.3.2 Immediate changes to collect data

For production the first initiative was to create a path to ERP system to collect spend time for any deviation on a specific product. This path will allow production workers to operate without interference and for data collection aspect it will be automatically collected in ERP system. This path is foreseen to

have a possibility to enhance the data collection inputs such as dividing quantity of worker per cases. With this information we can again investigate and determine cost values more specifically.

Defected part, when needed for a new part from stock, in the working phase in ERP system, demanded the reason why this is called again. Therefore, the reason for double collecting is explained. The investigations throughout are reported and collected by Quality Controllers.

4.3.3 Internal failure cost equations

Internal failure costs refer to the expenses incurred to correct defects or nonconformities before a product or service is delivered to the customer. These costs arise from problems detected during internal quality control processes and do not reach the external customer but still impact the company's efficiency and profitability. (Mahmood et al., 2014). Cost formula is based on chapter 4.2 list, where identified the possible measurable points in process. Internal failure costs are calculated as shown in Equation 1 and 2.

$$\text{Total Cost} = \text{Total repair time (h)} \times \text{Overhead costs €}$$

Equation 1. Calculation of Total Costs. Based on: (ETQ Organization, 2019)

This Equation 1. calculates the cumulative cost of internal failures by multiplying the total hours spent on repairs with the standard overhead cost rate. It offers a broad understanding of how much internal quality issues are costing the company over a given period.

$$\text{Avg. Cost per case} = \frac{\text{Total repair time (h)}}{\text{Total repair cases}} \times \text{Overhead costs €}$$

Equation 2. Average Cost per Case. Based on: (ETQ Organization, 2019)

Formula of Equation 2. provides the mean cost of a single repair case by dividing the total repair time by the number of repair cases and multiplying the

result by the overhead rate. It helps in identifying us how costly individual failures are on average, offering our quality team a valuable insight for root cause analysis and improvement prioritization.

5 Findings

Original data measurement schedule was planned from November 2024 to February 2025. Due to political situation and collective labor agreement negotiations these led to a strikes across multiple sectors, including ours which affected. Addition to this, there were also lay offs which limited the data collection and whole work.

The decision was made to collect data until the end of April 2025 and if the gathered data proves insufficient, retrospective data collection may be conducted to include relevant information from earlier periods. By the end of April, the amount of data was under target value and it consisted few product types which were seen not sufficient enough to continue. Data collection was expanded to earlier periods, in a way that there are enough data and different types of machines. The data was selected to begin from June 2024.

Based on situation and obtained results, we can state that measurement phase decisions were accomplished and the study was excellent. In total the data of repairs during production was collected from 156 cases and five different product which we can call machines. Seven cases were excluded from the research because they were individual cases of different machines.

Another research was conducted with same periodic measurement from June 2024 until April 2025. These were the cases that consist the measurement on repair time after production of the machine. The data for these types of repair was in total 46 cases with multiple machine types. Each machine has at least 5 cases. This measurement was not planned nor a part of the research scope. The decision to add these types of repair cost among the thesis instantly was agreed on within Quality Department.

In total the data was collected from two different situations. The first data collection was collected during the production of the machines. During the production if there was some mistake or some repair required the repair time was collected to designated work to have a data of repair time. Prices, names

and type of repairs are modified due to confidentiality. The second data was collected after the production of machine. This indicates that the data or repair time has been created when the machine was ready but after testing the machines required repair.

5.1 Repair hours during production

The data from repairs during production was separated into individual machine types. Total amount of cases was 156 pieces, and these cases were divided into individual machine type as shown in Figure 10. One case represents one machine, in this case the Machine 1 represents the type of machine and the amount of cases of that machine type represents how many machines of that type has been produced during the measurement period. If the case has a zero value, 0 hours spent on repair, it is still considered as a case.

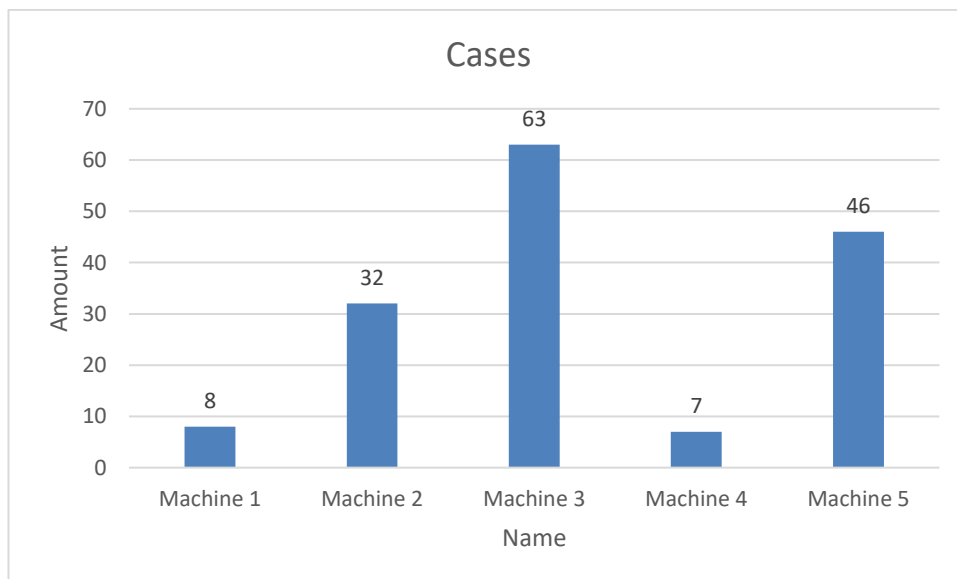


Figure 10. Case amount per machine type

From these cases we could calculate the total repair hours of each machine and also the average repair hour per case. As seen in Figure 10 the amount of repairs are measured in quantity it does not define whole picture of the one particular case nor the used repaired time.

When calculating the total amount of repair time during the production and the average used repaired time per case, we are able to justify and more precisely target our areas of focus for example to initiate continues improvement to that machine. The total repair hours of machine and the average repair hour per machine are shown in Figure 11.

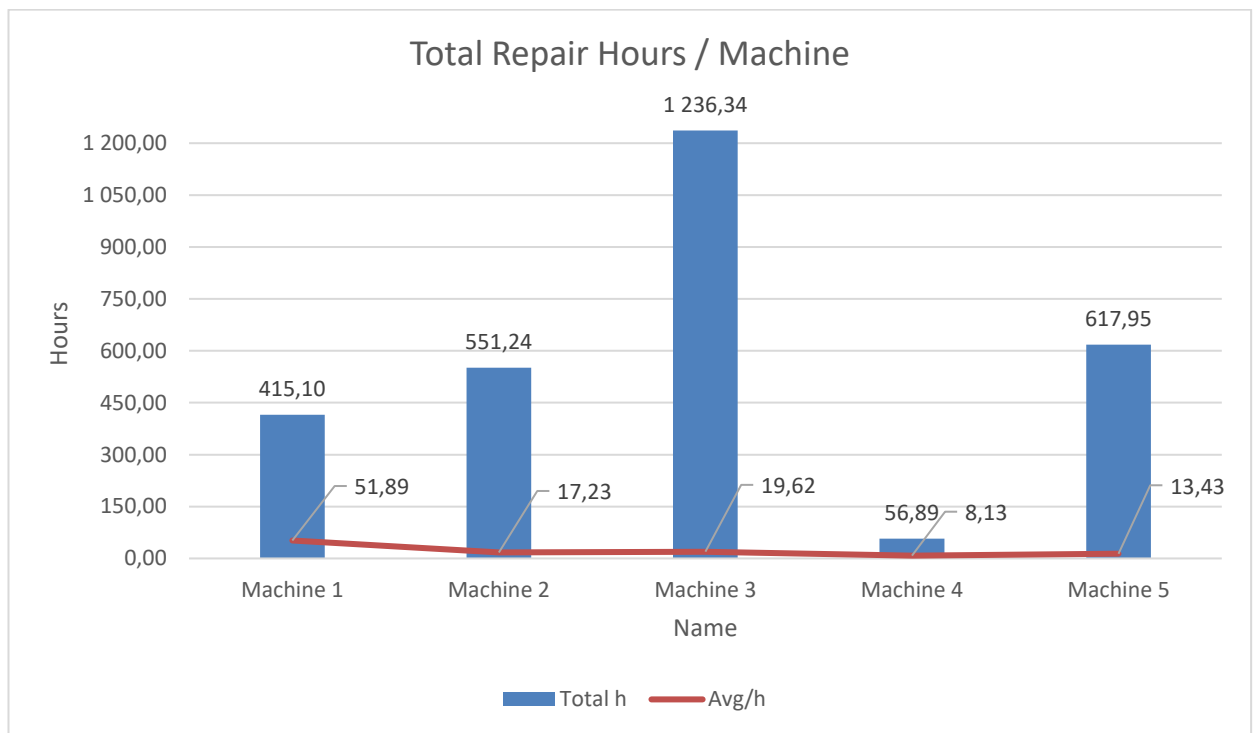


Figure 11. Total Repair Hours per machine and average hour per case

As seen in Figure 10, the Machine 1 type products were produced 8 pieces, within those 8 there was in total 415 hour spent on repair time during the production of all 8 products as seen in Figure 11. The average used repair hour for this type of machine was nearly 52 hours.

Compared to Machine type 3 which owns the most cases and the most repair time used, the average used repair hours per case in this type is under 20 hours. With this knowledge, we can evaluate the significance of the focus to where should we concentrate on continuous improvement or to analyze more.

Name	Total repair hour	Total cases	Avg/h
Machine 1	415,10	8	51,89
Machine 2	551,24	32	17,23
Machine 3	1236,34	63	19,62
Machine 4	56,89	7	8,13
Machine 5	617,95	46	13,43
Total	2 877,52	156	18,45

Figure 12. Machine types repair time during production

In Figure 12 are calculated and listed the total repair time of each machine types and the average repair hour per case of machine type. With this research we have calculated the average repair time of one case, which is 18,45 hours this equals to 18 hours and 27 minutes. Classification of machines from the most repair time used in type is shown in Figure 13.

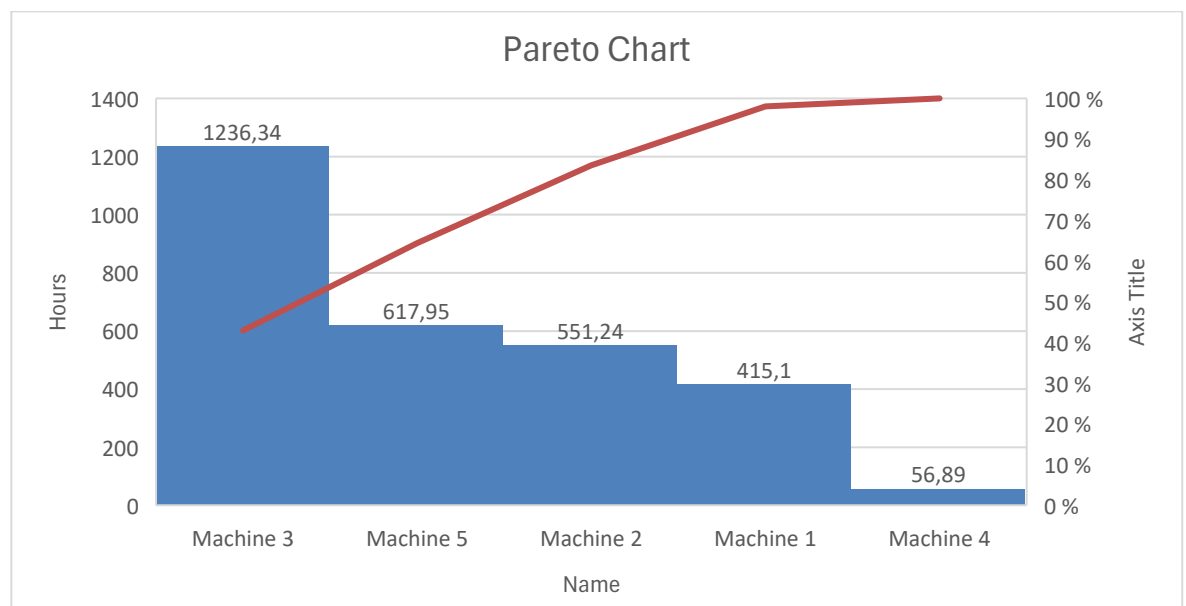


Figure 13. Pareto chart of Total Repair hours during production

5.2 Total Repair Hours per machine type in production

In the following chapters are shown the measurements or data form each machine type. The data is from each case that has occurred in that specific machine type.

5.2.1 Total Repair Hours of Machine 1 type

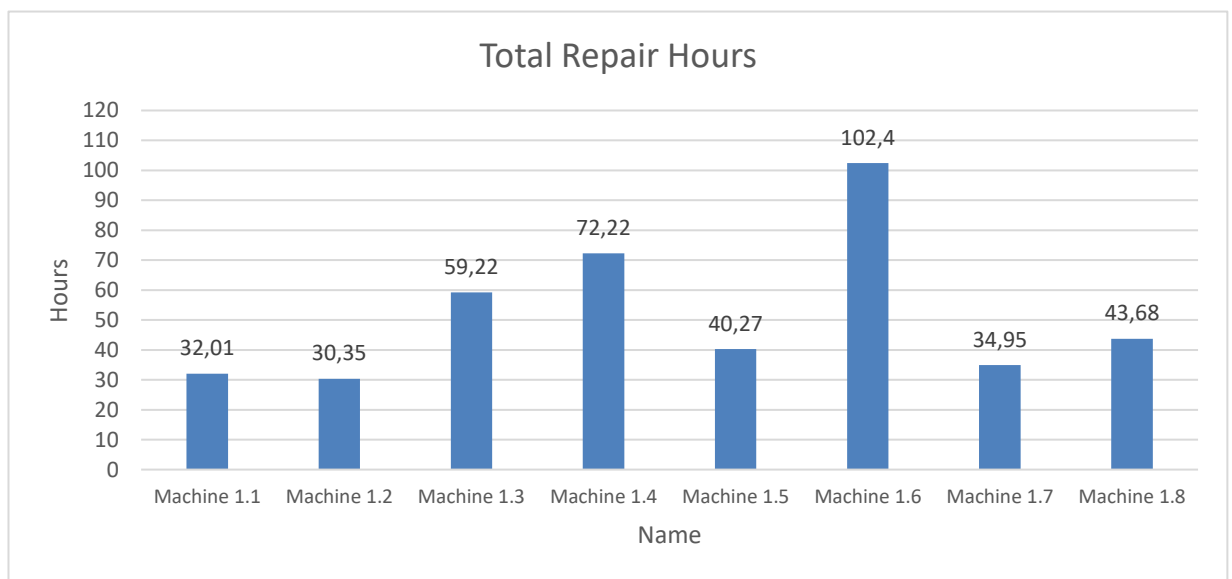


Figure 14. Total repair hours per case of Machine 1

5.2.2 Total Repair Hours of Machine 2 type

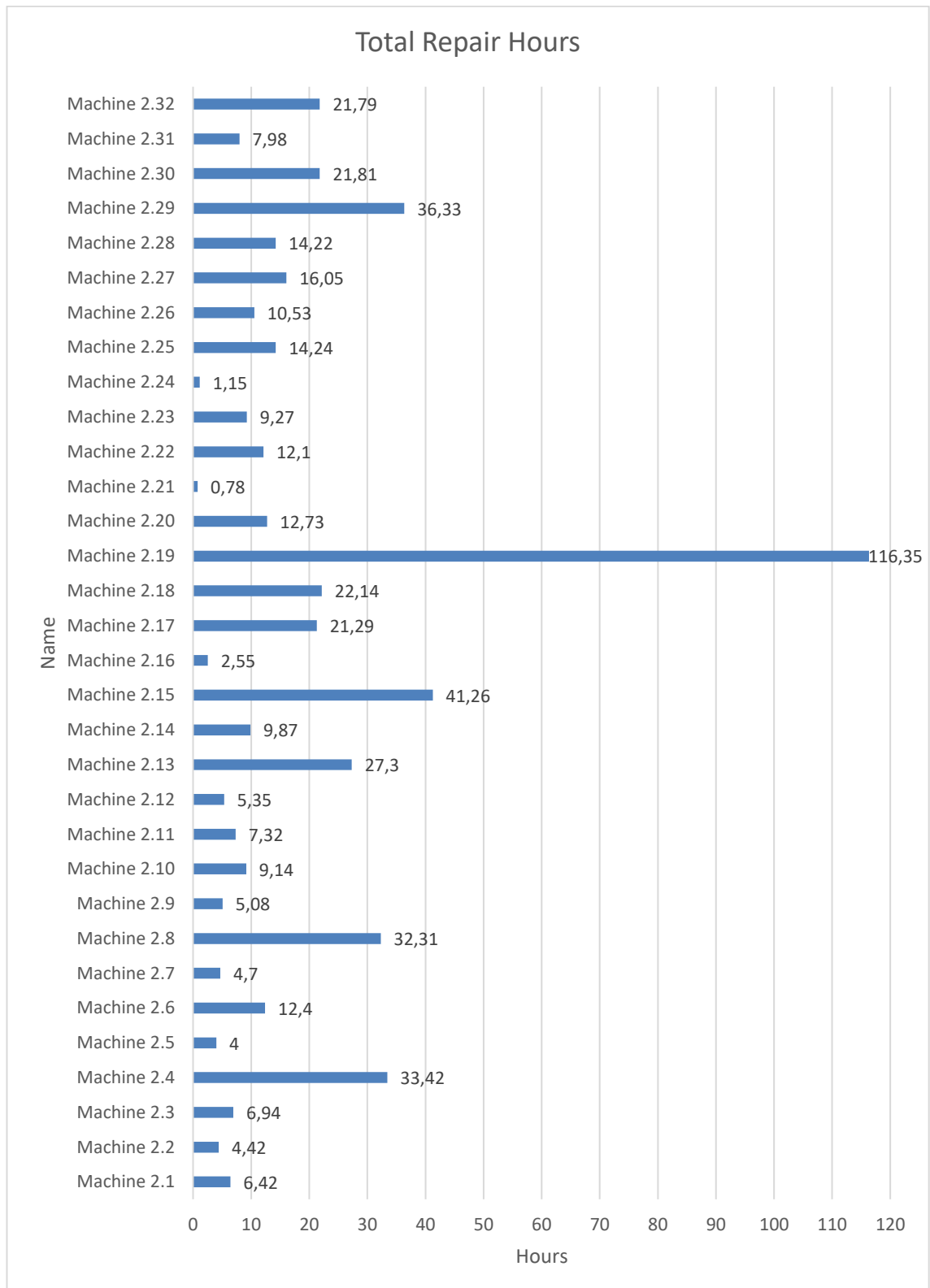


Figure 15. Total repair hours per case of Machine 2

5.2.3 Total Repair Hours of Machine 3 type

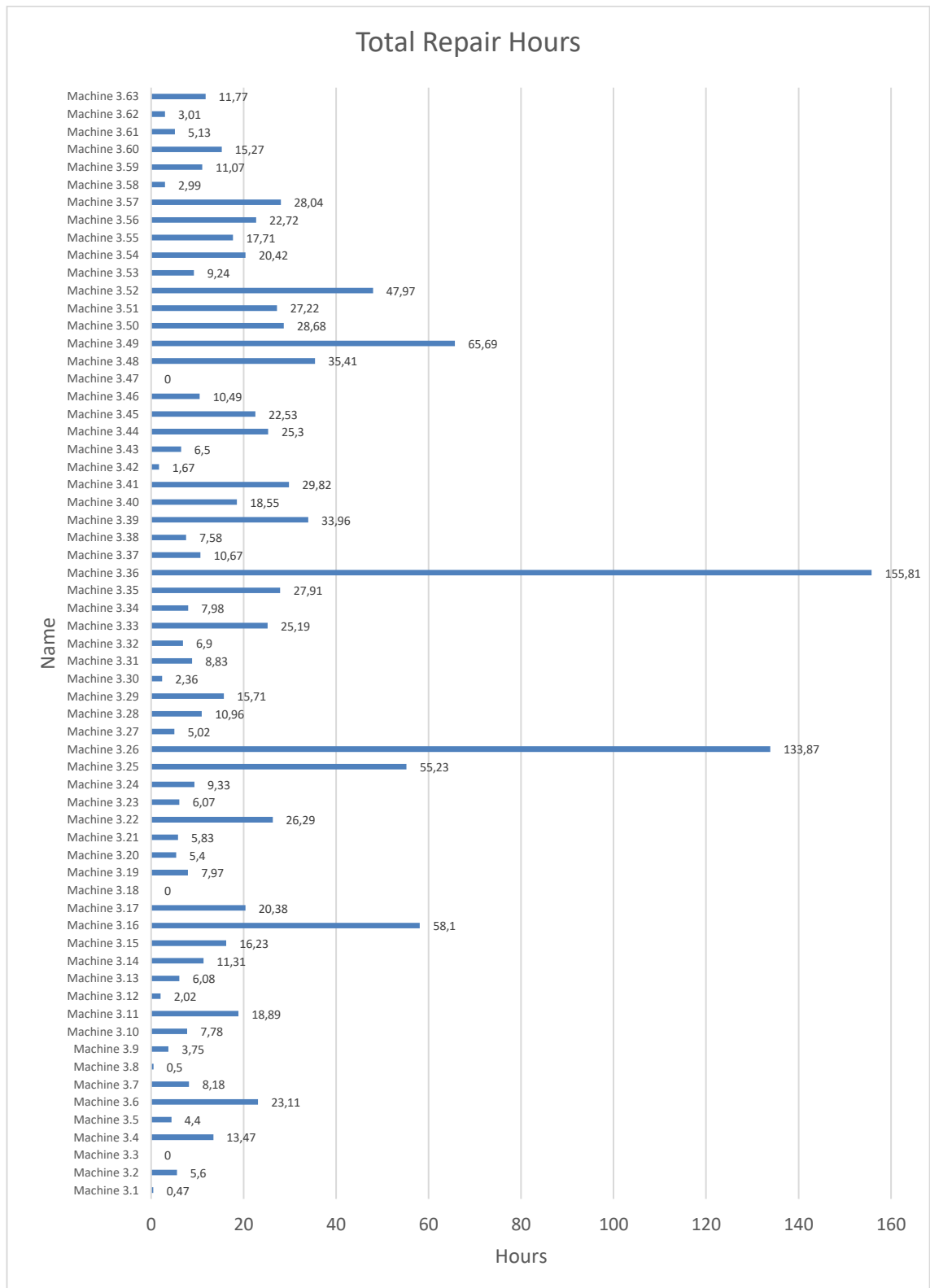


Figure 16. Total repair hours per case of Machine 3

5.2.4 Total Repair Hours of Machine 4 type

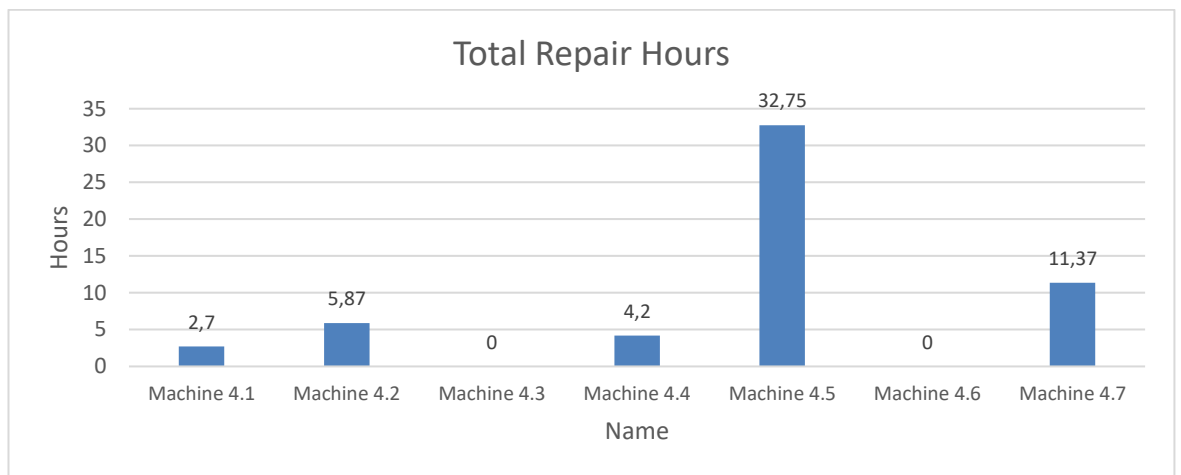


Figure 17. Total repair hours per case of Machine 4

5.2.5 Total Repair Hours of Machine 5 type

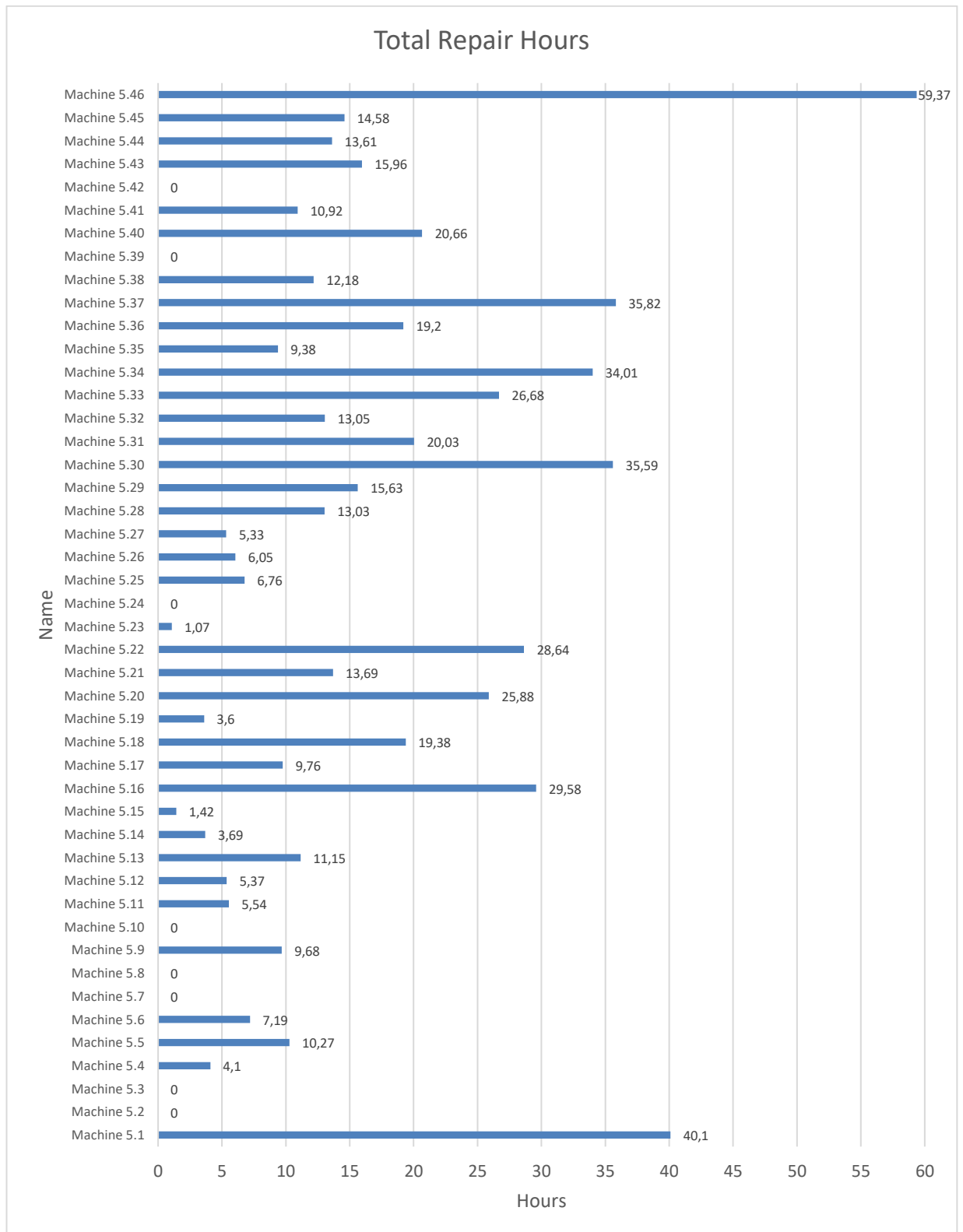


Figure 18. Total repair hours per case of Machine 5

5.3 Repair hours on post production

Produced machined undergoes a specific process which is equivalent to product audition. In the audition process, the machine is thoroughly inspected against work instructions, assembly guidelines, and the operational model standard. The process output is a report of observations to take into account for repair.

The ideology of this process is to monitor the factory's functions to secure we are meeting our customer requirements and fulfilling our guidelines and operational model standard requirements. The total was of 46 pieces of data collected. When it occurred that we can expand the measurement area in this development work, we did not think twice. The information of post production repair time are as needed as during.

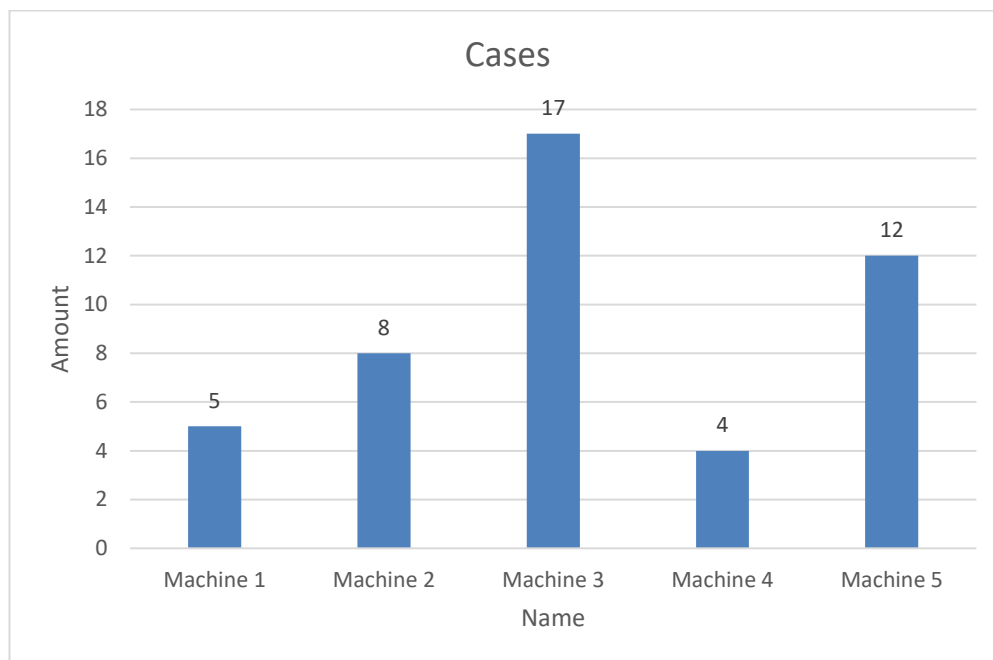


Figure 19. Total cases on ready machines

The data of cases between during production and on ready machines differs in a way that in the ready machines cases there are no zero values cases. In this process the case is an input for a repair need which leads to opening a work case for the repairs and the output is a repair case.

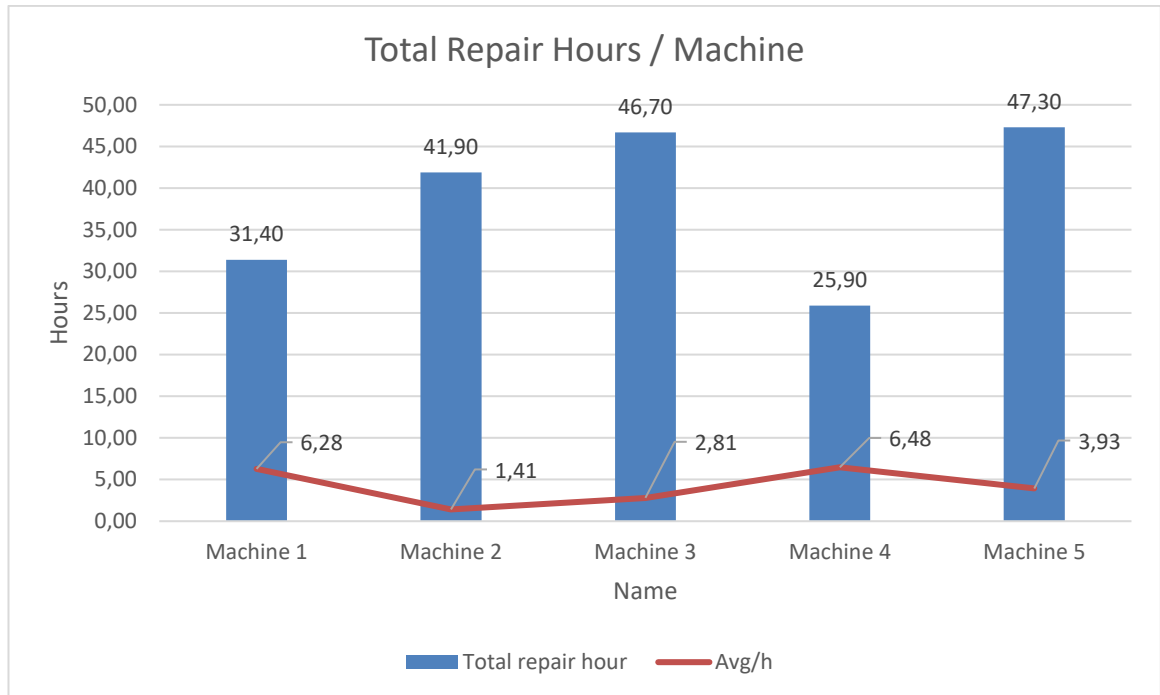


Figure 20. Total repair hours per machine and average hour per case

As shown in Figure 20 the total repair hours per machine, in Machine 1 type the total repair time is almost 32 hours from 5 created repair cases. And a average repair time from one case is just over 6 hours.

Name	Total repair hour	Total cases	Avg/h
Machine 1	31,40	5	6,28
Machine 2	41,90	8	1,41
Machine 3	46,70	17	2,81
Machine 4	25,90	4	6,48
Machine 5	47,30	12	3,93
Total	193,20	46	4,20

Figure 21. Machine types repair time on ready products.

In total 46 cases the total repair time was 193,10 hours this equals to 193 hours and 6 minutes. With these calculations the average repair time of one case is 4,20 hours this equals 4 hours and 12 minutes. In the classification chart in Figure 22 we can identify that top three machine types continued to be the most repaired after manufacturing.

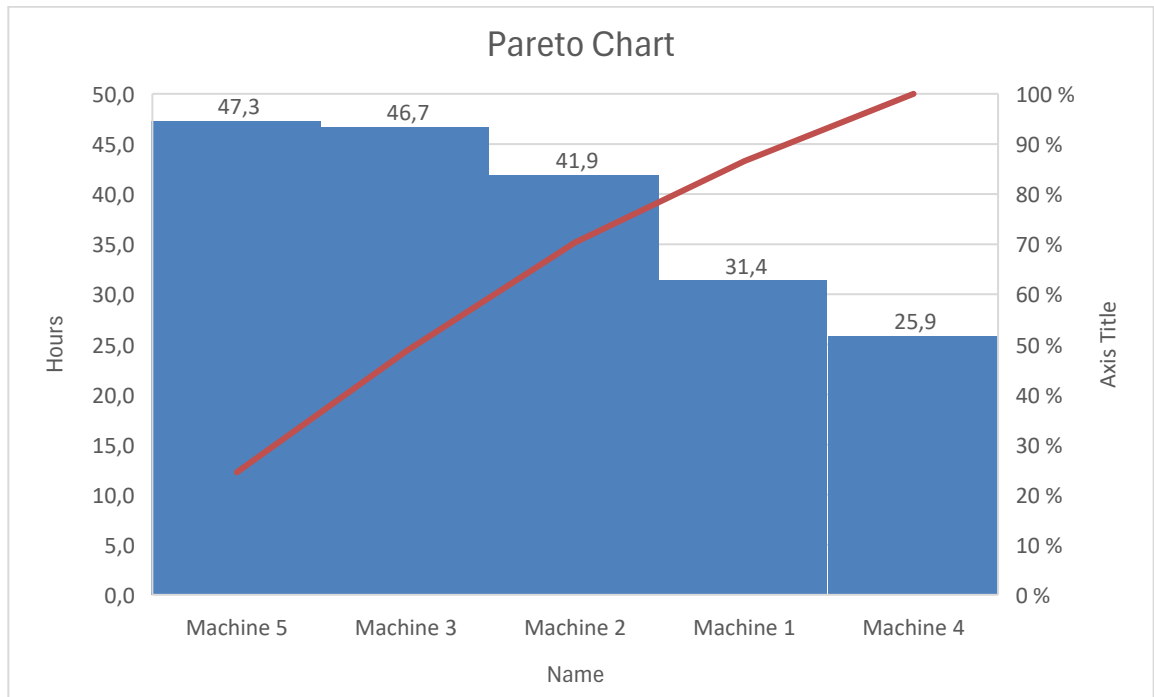


Figure 22. Pareto chart of Total Repair Hours on ready products

5.4 Total Repair Hours per machine type after manufacturing

In the following chapters are shown the measurements or data form each machine type. The data is from each case that has occurred in that specific machine type. The data is collected after the product or machine has been produced.

5.4.1 Total Repair Hours of finished Machine 1 type

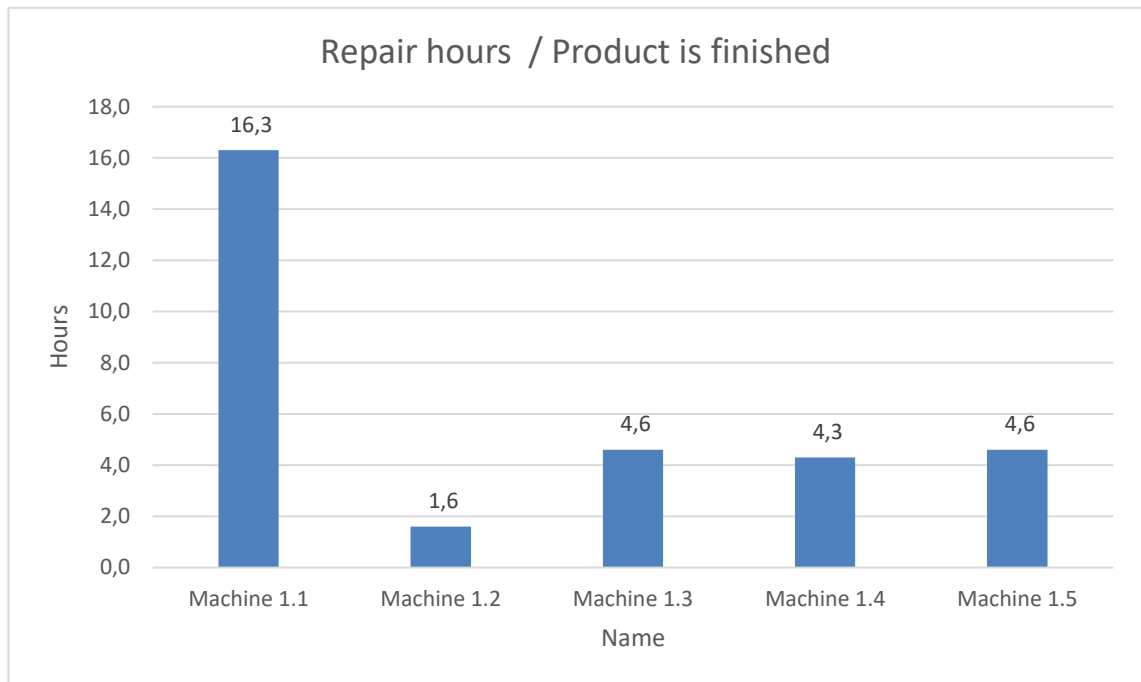


Figure 23. Total repair hours per case of finished Machine 1 types

5.4.2 Total Repair Hours of finished Machine 2 type

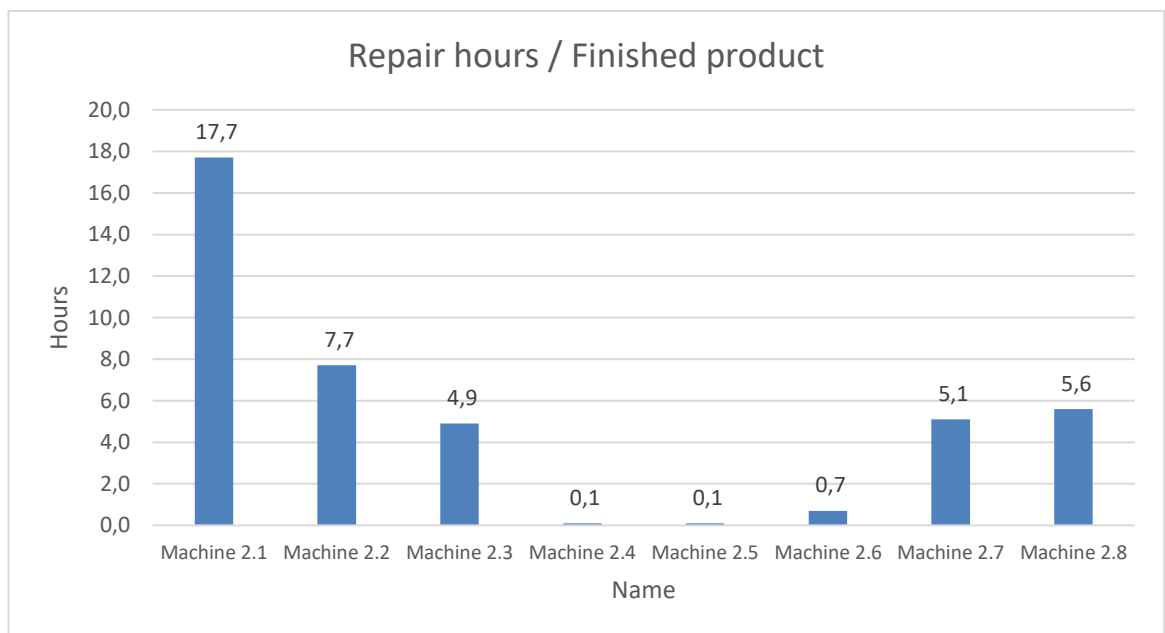


Figure 24. Total repair hours per case of finished Machine 2 types

5.4.3 Total Repair Hours of finished Machine 3 type

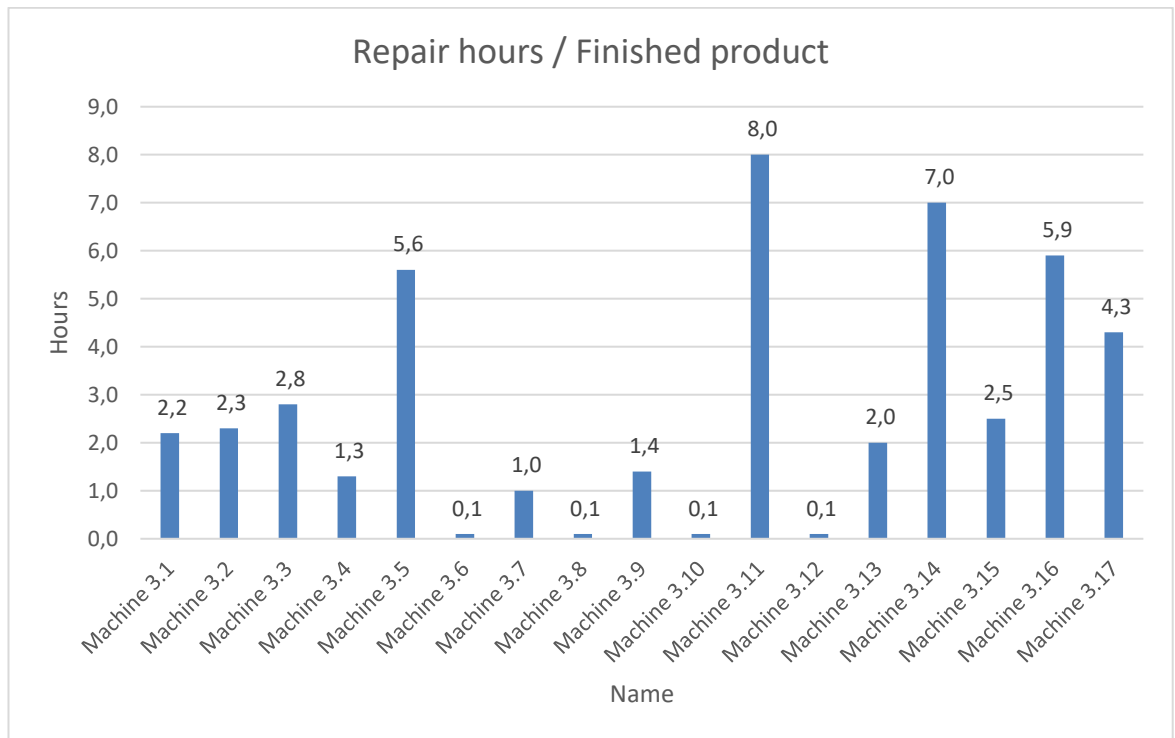


Figure 25. Total repair hours per case of finished Machine 3 types

5.4.4 Total Repair Hours of finished Machine 4 type

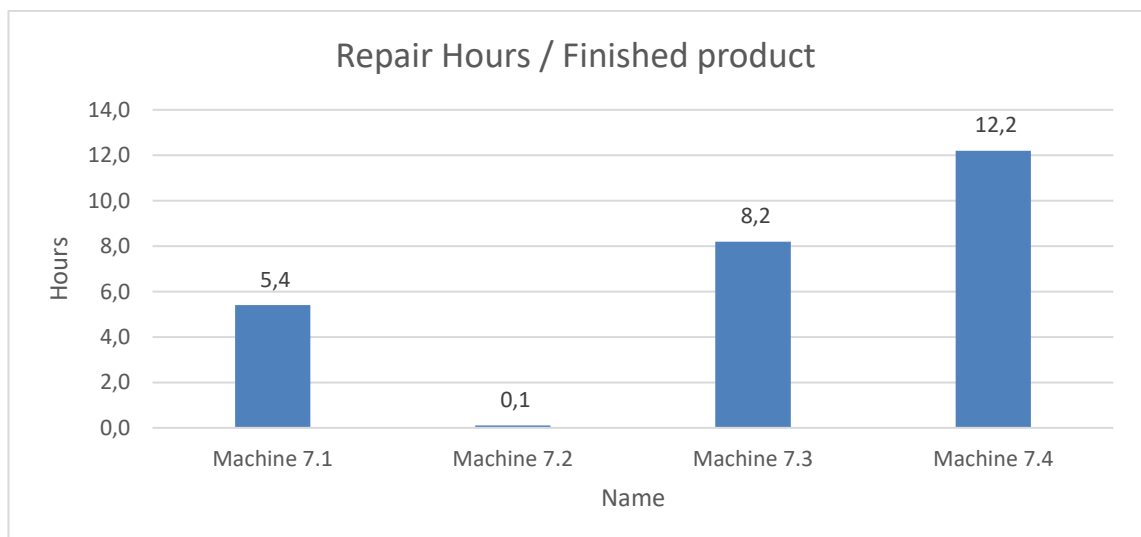


Figure 26. Total repair hours per case of finished Machine 4 types

5.4.5 Total Repair Hours of finished Machine 5 type

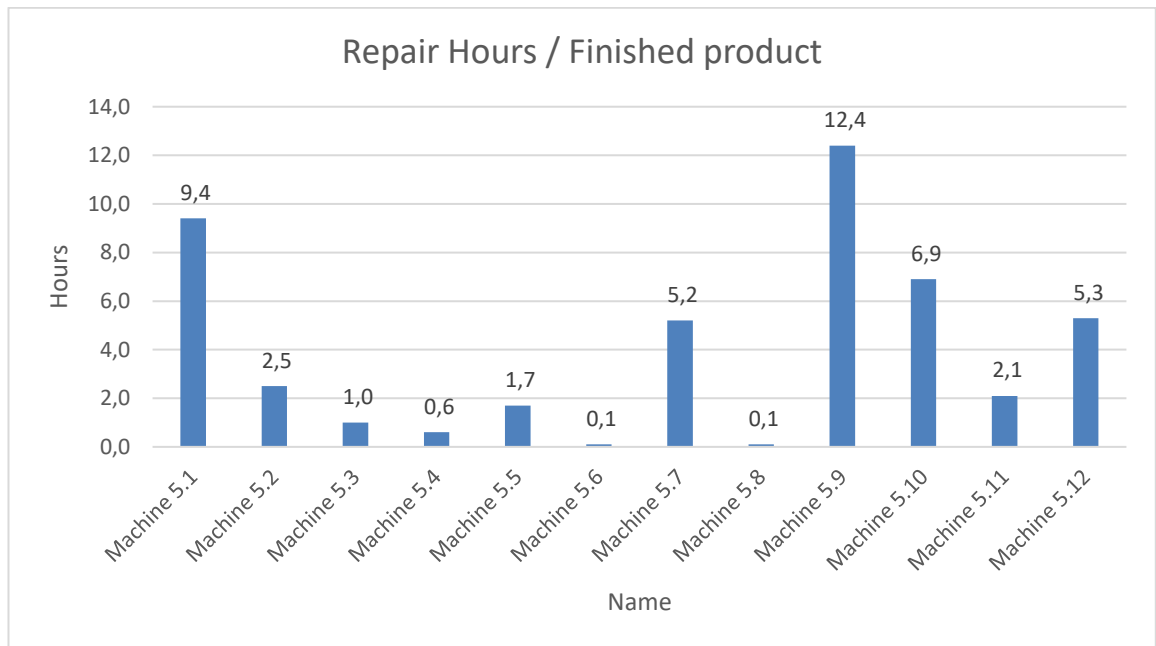


Figure 27. Total repair hours per case of finished Machine 5 types

5.5 Results of measurements

With these given results during production and on finished product we were able to reach the point where we could calculate and determine the costs on repairs so the costs of poor quality in the production.

The results are automatically collected from our ERP system where we can in the future utilize it more efficiently and create indicators which can be beneficial to all functions. The indicator and in cost of poor quality challenges has been taken into account by interviewing another factory where the COPQ indicator has been created earlier.

Some critical values of the cost of poor quality calculations has been agreed within the company. The values used in calculations such as overhead cost value is determined retroactively. Overhead value fluctuates during the month but stabilizes or becomes reliable by month-end when all the cost are taken into account. The cost of poor quality value must be calculated after ending or

locking the previous production month. This means that cost of poor quality of month January can be locked and it is more trustworthy when calculated in February. (Sadkowsi & Jedynak, 2022).

5.6 Cost of repairs

Table 2 illustrates the formula which is used to calculate the general cost of repair on average of one case. The overhead cost as mentioned in previous chapter is fluctuating as everyday therefore on these examples the used overhead cost is 60 €. In the Table 1 is calculated the example data of Machine 3 of finished products and on Table 2 is for during the production repairs.

Table 1. Average cost for one case on finished products

Origin of costs	Price €
$Total\ Cost = Total\ repair\ time\ (h) - 46,70 \times Overhead\ costs\ € - 60€$	2802 €
$Avg.\ Cost\ per\ case = \frac{Repair\ time\ per\ case\ (h) - 46,70}{Total\ repair\ cases - 17} \times Overhead\ costs\ € - 60€$	164,82
$Overtime\ work \times x€$	0
$= Average\ (Avg.)\ cost\ per\ case\ €$	164,82

The overtime work must be taken into account, it will increase the costs. During the measurement period there was not any overtime work done for these repairs in the both measurement fields.

For Machine 3 cost calculations the average cost of poor quality per case is 164,82 €.

Table 2. Average cost for one case on during production repairs

Origin of costs	Price €
$Total Cost = Total\ repair\ time\ (h) - 1236,34 \times Overhead\ costs\ € - 60€$	74 180 €
$Avg.\ Cost\ per\ case = \frac{Total\ repair\ time\ (h) - 1236,34}{Total\ repair\ cases - 60} \times Overhead\ costs\ € - 60€$	1 177,47 €
$Overtime\ work \times x€$	0
$= Average\ (Avg.)\ cost\ per\ case\ €$	1 177,47 €

For Machine 3 cost calculations the average cost of poor quality per case is 1177,47 € during production repairs. Although the figure may appear large, it is important to consider that the data has been collected over a period of ten months. And the overhead value is just for calculation and it is not the correct value.

In the future the overhead value can be valued more accurately. In the Appendix 1 and Appendix 2 are listed in table the whole data calculations consisting repair time and cost of poor quality.

5.7 Cost of scrapping

The cost of scrapping is indicated by the financial department. All the scrapping is done digitally via ERP system. The physical scrapping is performed by a third party service provider.

In this study there was no need to intervene on the process at any time. Although during the measurement period together with the finance department we located two areas where we can develop a better understanding of scrapping and reporting the scrapping monthly values. These actions were taken by finance department.

In the Figure 28 is shown monthly values of scrapping process of 10 month period. The monetary cost is presented in millions.

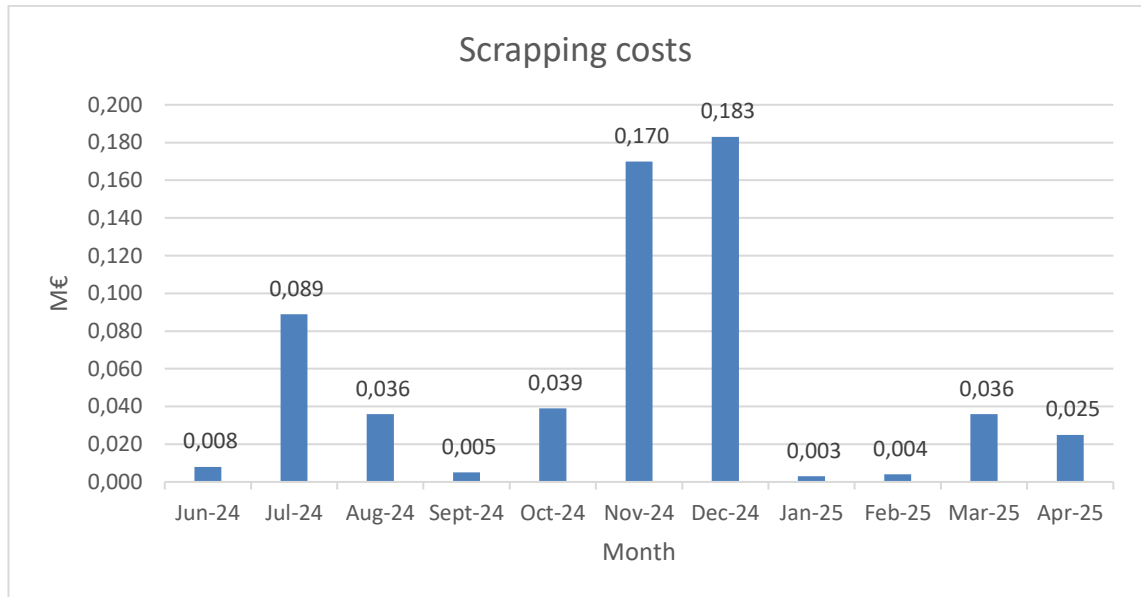


Figure 28. Monthly scrapping values

6 Cost of Poor Quality interview

During the measurement period the opportunity came to interview another factory quality management department for their COPQ indicator. The interview was performed in two sections. The first part was on theoretical point of view and consisted of basic questions what failures they collect, what values they use and how they collect the data.

The second part of interview was focused on practical point of view. In the second part of interview the questions was directed to the peers that are on key role of this process, how are they collecting the data, what are the important steps of the process and how the indicator is used on management level.

For the interviews I chose to use semi-structured interviews as a qualitative research method. There was a set of open-ended questions in advance prepared, but I also allowed room for the conversation to flow naturally and for new topics to come up based on the interviewee's responses and during COPQ indicator illustration. This approach gave me the flexibility to explore important insights in more depth while still ensuring that I covered the key themes relevant to my research. (Bearman, 2019).

I found the conversational style helpful in building trust and encouraging participants to share their experiences more openly. Although the interviews took time to conduct and analyze, they provided rich, detailed information that supported the objectives of my thesis.

6.1 Findings of the interviews

On the first part of the interview the quality management of the factory had assembled the peers who are in key roles of COPQ indicator. The failures that they collect were thought on bigger scale. When a failure occurs the case is created in ERP-system. In that particular case all functions or employee's that are involved somehow to the case collects the work they do. For example a

quality employee creates a case and he starts to work around that case, the consumed time started already when the case was created.

The values that they used to calculate Cost of Poor Quality were the same as those traditionally associated with quality cost frameworks: labor time, material losses, rework hours, and indirect impacts such as downtime or customer dissatisfaction. What was notable in this factory's approach was the systemic integration of these values into their ERP system. The moment a failure is identified and a case is created, the ERP begins tracking all related activities in real-time. (Nestell & Olson, 2017). This aligns closely with the theoretical model of real-time quality intelligence, where information flow and data capture are embedded directly into operational processes (Juran & De Feo, 2010).

This process not only provides transparency but also reinforces accountability across functions. As each stakeholder documents their contribution to resolving the issue whether through investigation, correction, or preventive action a holistic picture of the incident's cost begins to form. From a theoretical viewpoint, this reflects the process-oriented perspective of quality management, wherein the cost is not isolated to the point of failure but distributed across the value chain. (Shubhangan & Darshak, 2016).

The second part of the interview the approach supports the Juran Trilogy model (Juran & De Feo, 2010), particularly the concepts of quality control and quality improvement. When the factory tracks and aggregates COPQ data over time, patterns of recurring issues can be identified, forming the basis for preventive strategies. In this sense, the COPQ is not only a retrospective metric but also a predictive indicator, signaling where resources should be allocated to reduce future losses.

For instance, when a quality employee initiates a case, their time is tracked from the moment of entry. As other departments become involved whether through root cause analysis, corrective action, or communication with suppliers or customers their contributions are likewise logged and time-stamped. This practical method ensures that every cost-driving activity is captured, not based

on estimates or assumptions, but through direct data input. Consequently, the factory obtains a granular view of the true financial burden posed by quality failures.

Factory's COPQ methodology illustrates the theoretical principle of feedback loops in quality systems. The captured data informs future decision-making, reinforcing Deming's PDCA cycle. The continuous feedback from ERP system tracked cases provides empirical evidence to justify investments in training, process redesign, or equipment upgrades all of which contribute to lowering the overall COPQ (Ioppolo et al., 2024).

The practical benefits of this COPQ model are tangible. Firstly, it provides visibility into where quality breakdowns occur most frequently, allowing for targeted interventions. Secondly, it serves as a motivational tool: when employees are aware that inefficiencies are being systematically recorded and analyzed, there is a natural incentive to minimize preventable failures. (Anderson et al., 1994). Thirdly, it facilitates data driven and decision making, where resource allocation for training, equipment upgrades, or process redesign can be justified with empirical evidence (Ioppolo et al., 2024).

In conclusion, the factory's implementation of COPQ monitoring is a robust example of how theoretical quality concepts particularly the principles behind Deming's PDCA and systemic thinking are transformed into actionable practice. It illustrates that when quality management is embedded into the operational fabric of an organization, COPQ becomes not only a performance metric but a strategic lever for continuous improvement and sustained competitiveness. (Anderson et al., 1994).

6.2 Analysis of the interviews

The interview findings provides a comprehensive overview of the factory's methodology for monitoring the COPQ, highlighting a well structured system integrated within the ERP environment. On the surface, the factory demonstrates a theoretically sound approach that aligns with established quality

management frameworks such as the Juran Trilogy and Deming's PDCA cycle. (Anderson et al., 1994). The process involves real-time tracking of failures, transparent documentation of corrective efforts, and data-informed feedback loops intended to support continuous improvement (Juran & De Feo, 2010).

However, upon closer analysis, a discrepancy emerges between the potential of the tools employed and the effectiveness of their actual use. While the ERP system offers advanced functionalities for capturing quality related costs, there is insufficient evidence that the organization is utilizing these tools to their full strategic advantage. The analysis of the interviews accurately identifies a critical shortcoming: although the infrastructure is in place, the factory's application of the COPQ indicator lacks the precision and consistency required to fully capitalize on its benefits. (Ioppolo et al., 2024).

One of the primary concerns is the ambiguity of the values used in COPQ calculations. While the text states that traditional quality cost components labor time, material losses, rework hours, and indirect impacts are tracked, it does not provide clarity on how these values are standardized, validated, or aggregated across different cases. This ambiguity raises concerns about data reliability and comparability. Without a clear methodology for quantifying and interpreting these values, the COPQ metric risks being more symbolic than actionable. (Mahmood et al., 2014).

Moreover, there is no direct indication that the COPQ data is actively used in strategic decision making or performance evaluation. Although the ERP system enables repair time collection and cross functional input, the actual use of this data appears reactive rather than proactive. (Shubhangan & Darshak, 2016). For example, while preventive strategies are mentioned, it is unclear whether these are systematically derived from trend analysis or merely anecdotal. This suggests that the factory may be collecting data without effectively transforming it into actionable knowledge, a common issue in underutilized quality systems.

While the factory demonstrates technical capability and theoretical awareness regarding COPQ tracking, its implementation suffers from operational gaps. The

tools are present, but the execution lacks rigor. The values remain vaguely defined, and the potential for strategic insight is underexploited. This disconnect limits the impact of what could otherwise be a powerful mechanism for quality improvement and cost optimization.(Anderson et al., 1994). To fully realize the benefits of COPQ monitoring, the organization must enhance value definition protocols, enforce consistent data capture practices, and ensure that the outputs are actively used to drive decision-making and continuous improvement.

7 Results and conclusions

This chapter presents a summary of the development project's objectives, the extent to which they were achieved, and reflections on the overall research process. The topic was selected in response to a specific need identified by the Quality department of the company, as the COPQ had not previously been measured within their operations.

At the start of the research, there were immediate limitations, which were both political and related to the collective labor agreement. These did not help collect the adequate amount of data for work. Luckily there was a possibility to reach data from ERP system with the help of colleagues. This data was not collectable at first, but with collaboration we could achieve the designated coding to collect the used repaired hours with backlog. This was very useful from day one, and with these data it was possible to calculate total recorded repairs during production and post production.

An evaluation of the total recorded repair hours during production across five machines reveals notable disparities in maintenance demand and equipment reliability. The percentages, calculated from the cumulative repair hours (**2,877.52 hours**), reflect the proportion of repair time each machine accounted during the production.

Machine 3 represents the highest share of repair activity, accounting for **42.97 %** of total repair hours. This figure indicates a significant concentration of maintenance needs on a single asset. From a quality and reliability standpoint, this level of repair exposure makes Machine 3 a candidate for root cause analysis, preventive maintenance intervention, or even process redesign to mitigate recurring failures. Machine 5 and Machine 2 contributed **21.48 %** and **19.16 %** of the total repair hours, respectively. While not as critical as Machine 3, the repair frequency for these machines remains substantial and may indicate medium-risk maintenance profiles.

Machine 1 accounted for **14.43%** of total repair time. This lower percentage suggests relatively stable performance, although it still warrants routine monitoring to prevent escalation. In contrast, Machine 4 registered only **1.98%** of total repair hours, making it the least problematic in terms of maintenance burden.

The analysis of post production repair hours across five machines provides insight into the distribution of quality related inefficiencies within the production process. The dataset, comprising a total of **193,20** repair hours, indicates varying levels of reliability and performance post production.

Machine 5 accounted for the highest proportion of post-production repair hours at **24,48 %**, followed closely by Machine 3, which contributed **24.17%**. The proximity of these two values suggests that these machines may be subject to similar operational stressors, systemic design limitations, or process weaknesses that manifest only after production has concluded.

Machine 2 contributed **21,69 %** to the total repair hours, positioning it as a moderately significant source of post production issues. While less critical than Machines 5 and 3, its contribution is still substantial and may represent process variability. Machine 1 and Machine 4 registered **16,25 %** and **13,41 %**, of the total post production repair hours. These lower figures suggest relatively higher process stability or that any issues are more easily detectable and preventable during production.

However, even with these lower percentages, these machines should not be overlooked. Continuous monitoring and data collection can ensure their performance remains consistent and that emerging trends are identified before they escalate. In Figure 29 and 30 pie charts representing the percentage contributions of each machine from both repair areas.

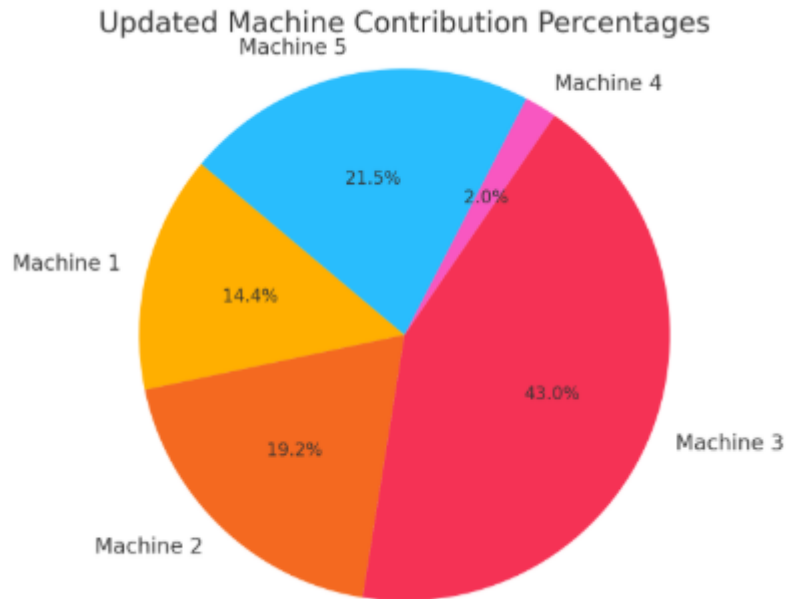


Figure 29. Percentages during production

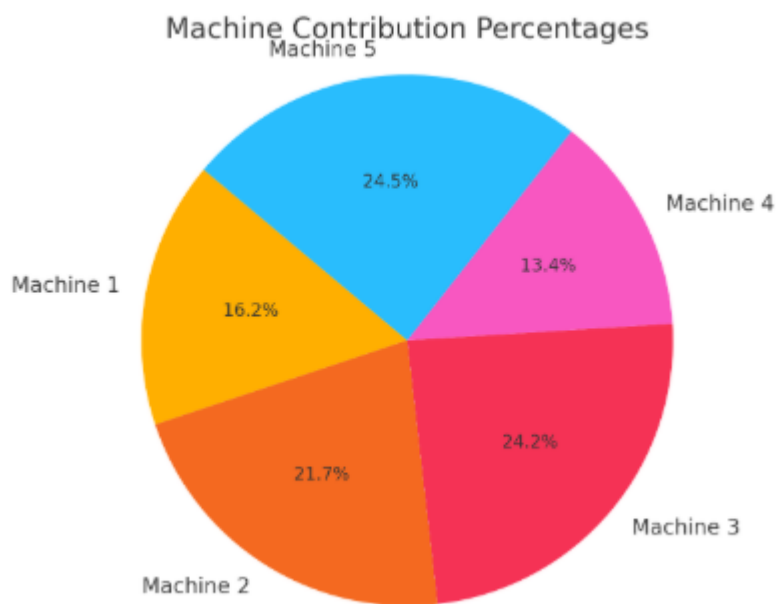


Figure 30. Percentages post production

The most valuable and the most effective findings were the interviews in other factory regarding COPQ. The two performed interviews gave us knowledge and understanding on COPQ indicator but also beneficial information on what to exclude from the indicator due to its complexity. Although the factory

demonstrates theoretical knowledge and technical capability, operational gaps hinder effective COPQ monitoring. There is a clear need for improved protocols in value definition, data capture consistency, and the active use of outputs to support decision-making and continuous improvement.

Based on the identified limitations and operational challenges in applying the COPQ indicator effectively, this development project will not adopt a similar indicator for its analysis. Instead, alternative approaches better suited to ensuring data reliability, strategic relevance, and actionable outcomes will be pursued.

Based on this thesis COPQ indicator can be implemented accordingly. The created source in ERP-system ensures that the data is reliable. During data collection we noticed some gaps that could help improving data and those were also fixed during the research. This is project is a part of another project made by my colleague where the aim is to connect our thesis results to create whole COPQ indicator which measures internal failures and failures that are originated from supplier.

In Figure 7, the planned schedule, the thesis is on schedule, nevertheless the challenges faced on data measurement phase. Even though this was not personal fault the situation affected the work timewise. This showed me the importance of the planning of any kind of project. The decision making to gain more data on backlog gave me confidence to aim for completing thesis on planned time.

During the work I used AI for educational path to secure writing. AI was useful in some categories because English is not my native language. The data and the research was done in my native language.

The study and the interviews improved my personal knowledge around COPQ what is efficient and what can be ignored or is not useful to our factory. The was to reach a point that COPQ is possible to implement, now with these studies and data it is plausible to implement that can be beneficial to stakeholders but also to production employees. This study will be shared to all quality related

functions that can gain more information what actions will be taken regarding quality costs.

Also, I would like to thank my colleagues and ERP system specialists who were involved during this study. They helped me to achieve designated data that helped me achieve enough data to work on. Lastly, I would thank my supervisor who gave me a chance to take time on this development project and properly prepare the results and interviews.

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List of repairs during production

	Machine	Start date	End date	Total Hours	Status	Total Cost	Avg.Cost/Case
Machine 1	Machine 1.1	12.08.24	09.10.24	32,01	Done	24 906,00 €	3 113,25 €
	Machine 1.2	19.09.24	29.10.24	30,35	Done		
	Machine 1.3	20.08.24	29.10.24	59,22	Done		
	Machine 1.4	12.09.24	30.10.24	72,22	Done		
	Machine 1.5	31.10.24	04.12.24	40,27	Done		
	Machine 1.6	15.10.24	09.12.24	102,4	Done		
	Machine 1.7	29.11.24	24.02.25	34,95	Done		
	Machine 1.8	04.04.25	25.04.25	43,68	Done		
	Total			415,10			
Machine 2	Machine 2.1	03.09.24	11.09.24	6,42	Done	33 074,40 €	1 033,58 €
	Machine 2.2	10.09.24	30.09.24	4,42	Done		
	Machine 2.3	13.06.24	30.09.24	6,94	Done		
	Machine 2.4	01.10.24	11.10.24	33,42	Done		
	Machine 2.5	15.10.24	15.10.24	4	Done		
	Machine 2.6	02.10.24	16.10.24	12,4	Done		
	Machine 2.7	03.10.24	17.10.24	4,7	Done		
	Machine 2.8	01.10.24	28.10.24	32,31	Done		
	Machine 2.9	17.10.24	29.10.24	5,08	Done		
	Machine 2.10	27.10.24	05.11.24	9,14	Done		
	Machine 2.11	17.10.24	11.11.24	7,32	Done		
	Machine 2.12	08.11.24	12.11.24	5,35	Done		
	Machine 2.13	04.11.24	14.11.24	27,3	Done		
	Machine 2.14	21.11.24	26.11.24	9,87	Done		
	Machine 2.15	13.11.24	01.12.24	41,26	Done		
	Machine 2.16	28.11.24	05.12.24	2,55	Done		
	Machine 2.17	29.11.24	11.12.24	21,29	Done		
	Machine 2.18	14.11.24	12.12.24	22,14	Done		
	Machine 2.19	18.11.24	14.12.24	116,35	Done		
	Machine 2.20	27.11.24	30.12.24	12,73	Done		
	Machine 2.21	11.12.24	14.01.25	0,78	Done		
	Machine 2.22	02.01.25	23.01.25	12,1	Done		
	Machine 2.23	20.12.24	23.01.25	9,27	Done		
	Machine 2.24	16.01.25	24.01.25	1,15	Done		
	Machine 2.25	15.01.25	17.02.25	14,24	Done		
	Machine 2.26	30.01.25	19.02.25	10,53	Done		
	Machine 2.27	28.02.25	10.03.25	16,05	Done		
	Machine 2.28	29.01.25	14.03.25	14,22	Done		
	Machine 2.29	14.03.25	24.03.25	36,33	Done		
	Machine 2.30	12.03.25	28.03.25	21,81	Done		
	Machine 2.31	01.04.25	04.04.25	7,98	Done		
	Machine 2.32	31.03.25	22.04.25	21,79	Done		
Total			551,24				

Machine 3	Machine 3.1	27.08.24	03.09.24	0,47	Done	74 180,40 €	1 177,47 €
	Machine 3.2	23.08.24	03.09.24	5,6	Done		
	Machine 3.3		06.09.24	0	Done		
	Machine 3.4	29.08.24	09.09.24	13,47	Done		
	Machine 3.5	28.08.24	10.09.24	4,4	Done		
	Machine 3.6	27.08.24	16.09.24	23,11	Done		
	Machine 3.7	09.09.24	24.09.24	8,18	Done		
	Machine 3.8	04.09.24	24.09.24	0,5	Done		
	Machine 3.9	04.09.24	24.09.24	3,75	Done		
	Machine 3.10	04.09.24	24.09.24	7,78	Done		
	Machine 3.11	09.09.24	25.09.24	18,89	Done		
	Machine 3.12	06.09.24	25.09.24	2,02	Done		
	Machine 3.13	10.09.24	25.09.24	6,08	Done		
	Machine 3.14	05.09.24	09.10.24	11,31	Done		
	Machine 3.15	04.09.24	10.10.24	16,23	Done		
	Machine 3.16	05.09.24	14.10.24	58,1	Done		
	Machine 3.17	04.09.24	17.10.24	20,38	Done		
	Machine 3.18		23.10.24	0	Done		
	Machine 3.19	04.09.24	28.10.24	7,97	Done		
	Machine 3.20	24.09.24	28.10.24	5,4	Done		
	Machine 3.21	24.09.24	30.10.24	5,83	Done		
	Machine 3.22	22.10.24	31.10.24	26,29	Done		
	Machine 3.23	15.10.24	01.11.24	6,07	Done		
	Machine 3.24	24.10.24	07.11.24	9,33	Done		
	Machine 3.25	28.10.24	08.11.24	55,23	Done		
	Machine 3.26	04.09.24	11.11.24	133,87	Done		
	Machine 3.27	24.10.24	15.11.24	5,02	Done		
	Machine 3.28	12.11.24	19.11.24	10,96	Done		
	Machine 3.29	05.11.24	20.11.24	15,71	Done		
	Machine 3.30	15.11.24	21.11.24	2,36	Done		
	Machine 3.31	06.11.24	26.11.24	8,83	Done		
	Machine 3.32	25.11.24	28.11.24	6,9	Done		
	Machine 3.33	25.11.24	02.12.24	25,19	Done		
	Machine 3.34	20.11.24	02.12.24	7,98	Done		
	Machine 3.35	28.11.24	12.12.24	27,91	Done		
	Machine 3.36	09.11.24	17.12.24	155,81	Done		
	Machine 3.37	13.11.24	18.12.24	10,67	Done		
	Machine 3.38	09.12.24	18.12.24	7,58	Done		
	Machine 3.39	04.12.24	20.12.24	33,96	Done		
	Machine 3.40	29.11.24	30.12.24	18,55	Done		
	Machine 3.41	30.12.24	13.01.25	29,82	Done		
	Machine 3.42	30.12.24	15.01.25	1,67	Done		
	Machine 3.43	11.12.24	22.01.25	6,5	Done		
	Machine 3.44	15.01.25	24.01.25	25,3	Done		
	Machine 3.45	10.01.25	27.01.25	22,53	Done		
	Machine 3.46	10.12.24	04.02.25	10,49	Done		
	Machine 3.47		05.02.25	0	Done		
	Machine 3.48	15.01.25	18.02.25	35,41	Done		
	Machine 3.49	27.01.25	27.02.25	65,69	Done		
	Machine 3.50	22.01.25	03.03.25	28,68	Done		
	Machine 3.51	22.01.25	03.03.25	27,22	Done		
	Machine 3.52	22.01.25	03.03.25	47,97	Done		
	Machine 3.53	29.01.25	19.03.25	9,24	Done		
	Machine 3.54	03.03.25	24.03.25	20,42	Done		
	Machine 3.55	10.03.25	25.03.25	17,71	Done		
	Machine 3.56	17.03.25	01.04.25	22,72	Done		
	Machine 3.57	19.03.25	02.04.25	28,04	Done		
	Machine 3.58	10.04.25	22.04.25	2,99	Done		
	Machine 3.59	04.04.25	23.04.25	11,07	Done		
	Machine 3.60	11.04.25	23.04.25	15,27	Done		
	Machine 3.61	21.04.25	28.04.25	5,13	Done		
	Machine 3.62	10.04.25	28.04.25	3,01	Done		
	Machine 3.63	10.04.25	30.04.25	11,77	Done		
Total			1 236,34				

Machine 4	Machine 4.1	20.08.24	04.09.24	2,7	Done	3 413,40 €	487,63 €
	Machine 4.2	09.09.24	10.09.24	5,87	Done		
	Machine 4.3		12.11.24	0	Done		
	Machine 4.4	01.11.24	22.11.24	4,2	Done		
	Machine 4.5	18.11.24	10.12.24	32,75	Done		
	Machine 4.6		14.04.25	0	Done		
	Machine 4.7	07.04.25	28.04.25	11,37	Done		
	Total			56,89			
Machine 5	Machine 5.1	02.09.24	06.09.24	40,1	Done	37 077,00 €	806,02 €
	Machine 5.2		13.09.24	0	Done		
	Machine 5.3		19.09.24	0	Done		
	Machine 5.4	16.09.24	24.09.24	4,1	Done		
	Machine 5.5	16.09.24	25.09.24	10,27	Done		
	Machine 5.6	13.09.24	30.09.24	7,19	Done		
	Machine 5.7		08.10.24	0	Done		
	Machine 5.8		22.10.24	0	Done		
	Machine 5.9	29.10.24	30.10.24	9,68	Done		
	Machine 5.10		04.11.24	0	Done		
	Machine 5.11	11.11.24	12.11.24	5,54	Done		
	Machine 5.12	19.11.24	20.11.24	5,37	Done		
	Machine 5.13	12.11.24	27.11.24	11,15	Done		
	Machine 5.14	18.11.24	09.12.24	3,69	Done		
	Machine 5.15	15.11.24	11.12.24	1,42	Done		
	Machine 5.16	02.12.24	17.12.24	29,58	Done		
	Machine 5.17	18.11.24	19.12.24	9,76	Done		
	Machine 5.18	28.11.24	31.12.24	19,38	Done		
	Machine 5.19	04.12.24	11.01.25	3,6	Done		
	Machine 5.20	13.12.24	13.01.25	25,88	Done		
	Machine 5.21	30.12.24	14.01.25	13,69	Done		
	Machine 5.22	16.12.24	16.01.25	28,64	Done		
	Machine 5.23	15.01.25	20.01.25	1,07	Done		
	Machine 5.24		21.01.25	0	Done		
	Machine 5.25	14.01.25	23.01.25	6,76	Done		
	Machine 5.26	15.01.25	04.02.25	6,05	Done		
	Machine 5.27	28.01.25	05.02.25	5,33	Done		
	Machine 5.28	21.01.25	06.02.25	13,03	Done		
	Machine 5.29	30.01.25	18.02.25	15,63	Done		
	Machine 5.30	17.01.25	19.02.25	35,59	Done		
	Machine 5.31	21.01.25	06.03.25	20,03	Done		
	Machine 5.32	23.01.25	12.03.25	13,05	Done		
	Machine 5.33	27.01.25	13.03.25	26,68	Done		
	Machine 5.34	18.03.25	24.03.25	34,01	Done		
	Machine 5.35	21.03.25	26.03.25	9,38	Done		
	Machine 5.36	13.03.25	26.03.25	19,2	Done		
	Machine 5.37	20.03.25	27.03.25	35,82	Done		
	Machine 5.38	26.03.25	31.03.25	12,18	Done		
	Machine 5.39		01.04.25	0	Done		
	Machine 5.40	21.03.25	03.04.25	20,66	Done		
	Machine 5.41	19.03.25	04.04.25	10,92	Done		
	Machine 5.42		08.04.25	0	Done		
	Machine 5.43	01.04.25	23.04.25	15,96	Done		
	Machine 5.44	22.04.25	25.04.25	13,61	Done		
	Machine 5.45	16.04.25	02.05.25	14,58	Done		
	Machine 5.46	25.04.25	05.05.25	59,37	Done		
Total			617,95				
Total (All)				2 877,52		172 651,20 €	6 617,94 €

List of repairs on produced machines

	Name	Type	Start date	End Date	Status	Total hours	Total Cost	Avg. Cost/Case
Machine 1	Machine 1.1	Machine 1	17/06/2024	19/06/2024	Done	16,30	1 884,00 €	376,80 €
	Machine 1.2	Machine 1	26/09/2024	27/09/2024	Done	1,60		
	Machine 1.3	Machine 1	25/10/2024	28/10/2024	Done	4,60		
	Machine 1.4	Machine 1	14/11/2024	15/11/2024	Done	4,30		
	Machine 1.5	Machine 1	04/02/2025	05/02/2025	Done	4,60		
	Total				31,40			
Machine 2	Machine 2.1	Machine 2	29/07/2024	05/08/2024	Done	17,70	2 514,00 €	314,25 €
	Machine 2.2	Machine 2	29/07/2024	06/08/2024	Done	7,70		
	Machine 2.3	Machine 2	04/11/2024	06/11/2024	Done	4,90		
	Machine 2.4	Machine 2	07/11/2024	14/11/2024	Done	0,10		
	Machine 2.5	Machine 2	28/11/2024	04/12/2024	Done	0,10		
	Machine 2.6	Machine 2	17/02/2025	17/02/2025	Done	0,70		
	Machine 2.7	Machine 2	25/02/2025	26/02/2025	Done	5,10		
	Machine 2.8	Machine 2	17/04/2025	23/04/2025	Done	5,60		
	Total				41,90			
Machine 3	Machine 3.1	Machine 3	14/06/2024	17/06/2024	Done	2,20	2 802,00 €	164,82 €
	Machine 3.2	Machine 3	02/07/2024	08/07/2024	Done	2,30		
	Machine 3.3	Machine 3	11/07/2024	12/07/2024	Done	2,80		
	Machine 3.4	Machine 3	05/08/2024	12/08/2024	Done	1,30		
	Machine 3.5	Machine 3	23/08/2024	03/09/2024	Done	5,60		
	Machine 3.6	Machine 3	14/10/2024	22/10/2024	Done	0,10		
	Machine 3.7	Machine 3	06/11/2024	06/11/2024	Done	0,10		
	Machine 3.8	Machine 3	06/11/2024	06/11/2024	Done	1,40		
	Machine 3.9	Machine 3	25/10/2024	29/10/2024	Done	1,00		
	Machine 3.10	Machine 3	14/11/2024	14/11/2024	Done	0,10		
	Machine 3.11	Machine 3	20/01/2025	21/01/2025	Done	8,00		
	Machine 3.12	Machine 3	20/01/2025	21/01/2025	Done	0,10		
	Machine 3.13	Machine 3	10/03/2025	10/03/2025	Done	2,00		
	Machine 3.14	Machine 3	24/03/2025	25/03/2025	Done	7,00		
	Machine 3.15	Machine 3	28/03/2025	28/03/2025	Done	2,50		
	Machine 3.16	Machine 3	02/04/2025	04/04/2025	Done	5,90		
	Machine 3.17	Machine 3	22/04/2025	23/04/2025	Done	4,30		
	Total				46,70			
Machine 4	Machine 4.1	Machine 4	24/06/2024	28/06/2024	Done	5,40	1 554,00 €	388,50 €
	Machine 4.2	Machine 4	19/08/2024	19/08/2024	Done	0,10		
	Machine 4.3	Machine 4	17/09/2024	18/09/2024	Done	8,20		
	Machine 4.4	Machine 4	27/11/2024	04/12/2024	Done	12,20		
	Total				25,90			
Machine 5	Machine 5.1	Machine 5	30/07/2024	05/08/2024	Done	9,40	2 838,00 €	236,50 €
	Machine 5.2	Machine 5	24/09/2024	26/09/2024	Done	2,50		
	Machine 5.3	Machine 5	23/10/2024	06/11/2024	Done	1,00		
	Machine 5.4	Machine 5	28/11/2024	02/12/2024	Done	0,60		
	Machine 5.5	Machine 5	09/12/2024	10/12/2024	Done	1,70		
	Machine 5.6	Machine 5	01/01/2025	08/01/2025	Done	5,20		
	Machine 5.7	Machine 5	08/01/2025	08/01/2025	Done	0,10		
	Machine 5.8	Machine 5	20/01/2025	20/01/2025	Done	0,10		
	Machine 5.9	Machine 5	12/03/2025	13/03/2025	Done	12,40		
	Machine 5.10	Machine 5	12/03/2025	14/03/2025	Done	6,90		
	Machine 5.11	Machine 5	28/03/2025	28/03/2025	Done	2,10		
	Machine 5.12	Machine 5	16/04/2025	22/04/2025	Done	5,30		
	Total				47,30			
Total (All)						193,20	11 592,00 €	1 480,87 €