Investment alternatives and operational changes in the production of perforating punches

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Abstract

This report identifies and investigates possible investment alternatives and operational improvements to the production of perforating punches. The analysis is conducted for a leading Swedish manufacturer in the industry. First, an analysis of the company and its customers is performed, followed by a study of the current production capabilities. Based on this investigation, key investments opportunities are identified and analyzed. Finally, possible managerial and operational changes are addressed and discussed.

The findings highlight the link between investments and operational management, and how they are interdependent. Specifically, the report identifies the importance of lead times in this industry, and proceeds to propose both investments and managerial changes which would improve these lead times. A total of four investments are analyzed, which significantly impact lead times, product quality, production capacity and production cost. Three of these investments are found to be advisable, whilst one requires further investigations. Finally, changes to corporate management and operations management are discussed. The proposed changes include an increase in production volume, the implementation of the 5S methodology and the strategic change of focusing on increased sales volumes.

Keywords: Investment analysis, production management, production optimization, operations management, perforating punch.

Resumen

Este informe identifica e investiga posibles inversiones y mejoras operacionales en la producción de boquillas de perforar. El análisis tiene lugar en una empresa sueca con reconocimiento internacional en la industria. Primero, se analizan la empresa y sus clientes para permitir el estudio de la producción, luego se identifican y analizan posibles inversiones y cambios a la gestión operacional. Por último, se proponen y discuten cambios operacionales y estratégicos.

Los resultados resaltan la interdependencia entre inversiones y la gestión operacional de la producción. Específicamente, este informe identifica la importancia del plazo de entrega al cliente en esta compañía, y propone inversiones y cambios operacionales que puedan tener impacto al plazo de entrega al cliente. En total se proponen cuatro inversiones distintas, y cada una tiene un efecto significativo con el tiempo de producción, la calidad del producto, la capacidad de la producción y el coste de producción. Los resultados recomiendan tres de estas inversiones, mientras se necesita más investigación para una, la inversión en una máquina de producción. Finalmente, se proponen y discuten cambios estratégicos y operacionales a la producción, incluyendo el aumento en volumen de producción, la implementación de la metodología 5S y el enfoque estratégico en el aumento de los volúmenes vendidos.

Palabras clave: Análisis de inversión, gestión de producción, optimización de producción, gestión operacional, boquilla de perforar.

Sammanfattning

Denna rapport identifierar och analyserar investeringsmöjligheter samt produktionsoperationella förändringar i produktionen av hålpipor. Studien avser en ledande svensk tillverkare i branschen och påbörjas med en analys av företaget självt samt dess kunder. Därefter undersöks förtegets nuvarande produktionsförmåga, varvid investeringsmöjligheter identifieras och analyseras. Slutligen diskuteras och rekommenderas operationella och strategiska förändringar.

Studien belyser länken mellan investeringar samt operationella och strategiska beslut. Exempelvis belyses vikten av ledtider inom branschen, vilket leder till rekommendationer av både investeringar och operationella förändringar. Totalt analyseras fyra olika investeringsmöjligheter, vilka har en signifikant påverkan på ledtider, produktkvalitet, produktionskapacitet och produktionskostnad. Tre av dessa investeringsmöjligheter rekommenderas i rapporten medan en kräver ytterligare analys. Slutligen diskuteras operationella och strategiska förändringar. Exempelvis rekommenderas större produktionsvolymer, implementation av 5S-metoden och ett strategiskt fokus på ökad försäljning.

Nyckelord: Investeringsanalys, produktionsoptimering, hålpipa.

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Daniel Jacobsson

Contents

1. Introduction

1.1. Background

The market for industrial goods is getting evermore international, subjecting suppliers to increased levels of competition. For production facilities located in the western hemisphere, this generally implies competition with low-cost alternatives. As a result, manufacturers often need to cut costs and/or focus on the quality of the products and services in order to remain attractive on the market[1].

Meanwhile, production equipment and technology are rapidly improving, thus requiring production companies to continuously update and improve their production capabilities. Investment in new equipment is necessary but is generally costly and require integration with existing equipment. Therefore, careful analysis of the production process and economic situation of the company is necessary in order to identify the best investment alternatives.

Gerdins Cutting Technology AB (Gerdins) is a leading supplier of cutting dies and perforating punches (punches) in the Nordic region. They have a long history of producing tools for the shoe-manufacturing and printing industries and have a strong customer focus. At Gerdins, quality, lead times and flexibility are regarded as very important in relation to the customers. In the present market conditions and for the current production facilities, a need for investment in production and production optimization has been identified. The company also considers changes to it's overall production management.

1.2. Purpose

The purpose of this study is to analyze the current production capabilities at Gerdins Cutting Technology AB, to allow for an effective decision making process. Furthermore, the analysis shall consider different aspects of production optimization, especially with regards to investments in new machinery. Specifically, the report shall shed light on the possible investment in a furnace for heat treatment, a process which is currently performed by a third party. Depending on the analysis of the current production, other investment alternatives may also be considered. The objective is to make these investment options comparable, through the use of the same investment evaluation method, allowing the analysis to serve as a basis for decision making.

This analysis mainly focuses on the economical aspects of identified investment opportunities and the economical aspects of changes to the production management. Nevertheless, lead times and product quality have been identified as important to both the company and its customers. As such, these are also important considerations in the report.

1.3. Problem statement

The report investigates the current production capabilities at Gerdins and consider different investment alternatives and changes to production management. This study shall answer the following research questions:

- Which investment alternatives are worth considering?
- Which effect will these investments have on production cost, product quality and lead times?
- Which investment alternatives are advisable for the company?
- Which changes to corporate and operations management are advisable?

1.4. Focus and delimitation

The report regards possible investments and changes to the production-related management in the punches business area, but does not consider the cutting dies business area.

With regards to the investment alternatives in the punches business area, not all possible investment alternatives are considered. The report investigates the alternatives identified as most urgent and feasible, with a focus on the investment in a hardening furnace. The number of investigated investment alternatives depends on the depth of analysis deemed necessary.

The main focus is on the identification and analysis of investment alternatives, possible changes to production-related management are to be considered secondary. To the extent that managerial changes are considered, these are production-related.

The main considerations, when regarding changes to the production, are economic factors, product quality and lead times. Of these three, the economic factors are deemed most important, followed by the lead times. When performing the analysis, emphasis is put on products and investment alternatives which are of interest to the company. If the company is uninterested in an assessment regarding a certain product group or investment, this option may be disregarded in the report.

1.5. Methodology and outline

The general methodology used in the study corresponds to the outline of the report. Therefore, the methodology is explained chapter-wise below. A verity of different sources are used in the analysis, such as information made available through the Enterprise Resource Planning (ERP)-system, measurements performed by the author and interviews. More information about this can be found below. The questions asked during interviews vary considerably depending on the matter investigated and the expertise of the interviewee. During the study as a whole, all employees in the punches department were interviewed, along with relevant representatives from corporate management. In total, approximately 100 hours of interviews were conducted.

1.5.1. Pre-study

This chapter contains an analysis of the company itself to determine important elements needed for the further study, such as discount rates. It also attempts to evaluate the significance of aspects which are not directly economical, such as lead times. As such, this chapter lays the groundwork for the further analysis. The information used in this chapter is mainly obtained through interviews with key representatives, from goal documents and from information collected by the company. Based on this data, the pre-study was performed by the author.

1.5.2. The production of representative products

In this chapter, the production is analyzed in depth with the purpose of identifying improvement- and investment opportunities. The data sources for this analysis varies and are therefore commented below. The analysis itself is the product of the author. The analysis is performed in the following steps:

1. **General production analysis:** This is an analysis of the product flows within the factory, the capabilities of different machines and the production management. This is only briefly explained in the report. The main sources of information used in this step are interviews and the company ERP-system.
2. **Identifying representative products:** Based on the general production analysis, the products are divided into different categories, and a representative product is chosen for each group. This analysis considers various aspects of the production, such as the properties of the machines used, as well as sales volumes and turnover for different products. A chart describing the production steps is provided for each product group. The product groups and representative products analyzed are described in the chapter.The main sources of information used in this step are interviews and the company ERP-system.
3. **Analysis of representative products:** The representative products are analyzed mainly with regards to production costs and lead times. The economic and lead time models used for this analysis are detailed below.

4. **Possible improvements:** Based on the cost and lead time analysis conducted, potential improvements to the production are identified. If these improvements are of managerial nature, they are evaluated directly in this chapter, by calculating the expected effect of proposed changes. In such case that the possible improvements are related to an investment, this is investigated in chapter 4.

1.5.2.1. The economic model

Both for the analysis of representative products and for the investment evaluations, unit production costs are calculated. This is done using a sophisticated version of the Activity Based Costing model (ABC-model). The ABC-model used is known for being more accurate than traditional costing models[2], as a result of using cost drivers as the basis of allocation.

Firstly, the production is divided into seven different cost center types; material, machining, side drilling, washing, heat treatment, height adjustment and packing. Note that, for some of the cost center types, there are several different cost centers. For example, in the case of machining, this report considers five different cost centers (production groups). For each of these cost centers there are several types of costs. These are typically rent costs, depreciation costs/capital costs, quality rejection costs, machine running costs (such as electricity, maintenance, etc.) and labor costs. Note that these cost types may vary depending on the cost center type.

Thereafter, costs are calculated for each combination of cost center and cost type. Depreciation and capital binding costs for machines are calculated using the annuity method[3], using the actual investment figures. Furthermore, an investment horizon of 40 years is assumed, as this aligns with the historical utilization period for purchased equipment. The discount rate used is commented in chapter 2.2. After calculating all costs, these are allocated to the products based on relevant cost drivers. In the machining stage, for example, the machine setup time and the cycle time are identified as cost drivers. This means that whilst machine running costs are distributed solely based on the cycle time, rent costs are distributed based on both the setup time and the cycle time. In other words, the allocation basis does not only vary between cost centers, but also between different cost types at the same cost center.

In the case of washing, the cost driver used is the number of washes, meaning that each wash corresponds to a given cost. In other words, the washing cost per product is highly dependent on the batch size. Another example of a cost driver is the material cost, which is used as the allocation basis for the cost of bound capital in the material stock. As the company has not previously worked with the ABC-model and the company lacks data of sufficient accuracy for the employment of this model, the author has personally collected much of the necessary data, on which these calculations are based. This includes the timing of production steps, area measurements and numerous interviews where, for example, appropriate allocation bases were established. The calculations, in their entirety, are the product of the author.

The volume dependency of the production costs is addressed at several points in the report. The batch size dependency is already incorporated in the model, through the use of cost drivers. The number of yearly production hours does however also have an effect. For these calculations, consideration is taken to the cost structure. That is, the dependency of costs on the utilization rate, traditionally expressed in terms of fixed and variable costs. For example, rent costs are independent of the production hours whilst labor costs, for example, show a dependency.

For some machines, the labor costs are highly dependent on the number of production hours, since the machines are subject to frequent breakdowns or require an active operator. In other cases, the labor cost is largely independent on the number of production hours, as the labor costs are largely driven by the setup time. The cost structure is mainly estimated through interviews since a quantitative estimation is deemed unfeasible within the scope of this report. With the current production crew, machines capable of running at night have a maximum of 4848 hours of yearly production time available. This figure is used for calculating the possible cost reduction as a result of increases in the number of production hours.

1.5.2.2. The production lead time model

Both for the analysis of representative products and for the investment evaluations, the production lead time is calculated, as defined in chapter 1.6. This lead time is important for customers as explored in chapter 2.4.

The production lead time is obtained by measuring cycle times, setup times, etc., for each production step. This has been done by the author, specifically for this analysis, since no such data is collected by the company. Based on this, a theoretical lead time can be calculated for each production step, which is done for a batch size corresponding to the median order quantity. This way, theoretical lead times are obtained, for each of the production steps.

Then, the theoretical production lead time is compared to the actual production lead time, resulting in an estimation of the non-value adding time, hereby referred to as the *Wait time*. Note however that, the *Wait time* corresponds to the entirety of the production lead time which is unaccounted for in the theoretical calculations, and may therefore include other types of non-value adding time, such as downtime. Meanwhile, the theoretical lead time for a given production step is generally value adding. An important exception to this is the lead time associated with the outsourced heat treatment, which is largely composed of non-value adding activates, such as storage, packing and transport times. These non-value adding activities were included in the heat treatment production step since they are a direct consequence of the outsourced heat treatment process. As such, this allows for better comparison between the lead times of different heat treatment solutions.

1.5.2.3. The Corona crisis

The corona crisis has had a significant impact on the sales of punches, especially in the leather-segment. Sales volumes are however expected to return to pre-crisis levels. Therefore, basing managerial and investment decisions on sales volumes during this crisis would be misleading and could lead to poor investment choices.

Instead, the data which has been temporarily affected by the crisis shall be based on the sales for a "normal" year. The data for a normal year is assumed to be equivalent to the average for the years 2017 through 2019. In such case that data is unavailable for these years, more resent data is used, but it will first be adjusted for the difference in volume. This approach is used both for product cost calculations in this chapter and for the investment analysis in the following chapters.

1.5.2.4. Finding possible improvements

Finding prudent managerial changes and investments which would improve the profitability of the company can be done with different goals in mind. The possible improvements can largely be divided into four categories:

- Increase number of units produced and sold, increasing profits in absolute terms.
- Do a larger fraction of the production in-house, resulting in better margins.
- Increase product value, allowing for higher sales prices or larger sales volumes.
- Decrease resources utilized, resulting in a reduced production cost.

In this report, all four approaches are considered for each of the representative products and for the company as a whole. That is, rather than just focusing on, for example, cost reduction, this study attempts to elaborate on various different ways to improve profitability. As such, a variety of managerial options are considered, but they may not all be recommended.

1.5.3. Investment evaluations

An investment analysis is made for each of the investment options identified in the previous chapter. A multitude of factors are evaluated as a part of this analysis, in order to illustrate both opportunities and threats relating to the proposed investments. These factors include effects on production cost, lead time, product quality and risks involved.

When analyzing economical aspects of the investments, the payback-time (PB)[4] and the Internal Rate of Return (IRR)[4] are used. These two measures are deemed sufficient and they are understood by key representatives at Gerdins. By not using the Net Present Value (NPV)[4], no risk-adjusted version of the desired rate of return has to be calculated or assumed. As the company has no model for the calculation of this figure, avoiding its use likely both reduces errors and makes the company's investments strategy more consistent.

The depth of the analysis carried out varies between different investment alternatives depending on the size of the investment and the degree to which to company is ready to make the investment in question. Several possible investments identified have been excluded from the study and the report, as a result of low interest from the company.

The raw data used in these analyses are based on measurements performed by the author, interviews, information from the company ERP-system, literary studies, communications with potential suppliers and information collected in previous chapters. The calculations, in their entirety, are the product of the author.

1.5.4. Discussion

In this chapter, results and calculations from previous chapters are compared and discussed. Furthermore, managerial and operational dilemma are addressed in this chapter, as well as their relation to the proposed investments. This results in operational and managerial recommendations for company, along with motivations for these. Topics for further studies are also addressed here. The discussions build on calculations previously presented in the report and data collected for those calculations.

1.6. Definitions

ERP-system Enterprise Resource Planning-system. Generally refers to a software used in production planning, corporate management and economic planning.

Customer lead time This refers to the time from when an order is placed until the same order is shipped to the customer.

Acceptable customer lead time The customer lead time that the average customer is willing to accept, LT_{cAcc}.

Delivery reliability The percentage of orders which are shipped within the acceptable customer lead time, LT_{cAcc}.

Production lead time Refers to the time from when an order is initiated by the production, typically beginning with machine setup, until the first batch leaves the production area. The batch size used in these calculations depend on the sales volume of the product in question.

Graphic segment This refers to punches intended to be used for paper products, including both traditional paper and cardboard.

Leather segment This refers to punches intended to be used for leather products, manly in the production of shoes.

Product group A group of products which are similar in terms of size, design and sales volume, in such a way that they are manufactured in the same machines and follow the same production steps.

Screw machine A lathe which does not have CNC capabilities, but is controlled mechanically using cams.

Transfer machine A machine which, rather than producing one product at a time, produces several products simultaneously. This is performed in different production steps, which are all integrated in the same machine. Transfer machines are generally custom-made for the production of a specific product and therefore require a large investment but provides a low cycle time.

Side eject A product property which describes products that have an angled expulsion hole on the side, see cover. This hole is for material removed during the stamping process. The waste expulsion holes must be drilled, either during the initial machining process or in a separate production step.

Height adjustment This refers to the process of grinding the punches to ensure that their height is within tolerances.

Oil bath selector system This refers to the a system that collects the parts fabricated in a machine and stores them in an oil bath. This solution has a cooling capacity, prevents part clashing and increases the storage capacity after the production machine. For example, see [5].

Utilization rate The fraction of time that a specific resource, such as a machine, is used productively.

PB Payback time, the time it takes to pay back the initial investment. Calculated as the initial investment divided by the yearly return, which is assumed to be constant. For more info see [6].

IRR Internal Rate of Return, the return rate to which an investment corresponds. It is expressed in % and the calculation does not assume constant yearly payoffs. For more info see [6].

WIP Work In Progress. Articles for which the production has started but not yet finished.

2. Pre-study

2.1. Investment strategy

The company has no established investment strategy. Few investments are made on a yearly basis and there are no rules or guidelines regarding how an investment analysis should be performed, or under which criteria an investment shall be undertaken. This is problematic as it makes investments incoherent. It implies a risk of missing prudent investment opportunities whilst other investments are made without sufficient information and may turn out to be unwise. Furthermore, the lack of a investment guidelines and procedures mean that different people will perform calculations in different manners, resulting in investment options not being comparable. Furthermore, it also increases the risk of differences between the pre- and post-investment analyses.

The effects of this are many-faceted can be observed at all levels of the company. For example, there is a general sentiment in the perforating punches department, that this department is overlooked when it comes to investments. Employees are often referring to the aged machine shop when making such claims. Furthermore, investment analysis' made by representatives of this department have in the past been overlooked, since they had not been conducted in accordance with the wishes of the central management.

It is therefore proposed that an investment analysis guideline is employed, which specifies the models and figures to be used for different kinds of investments. This guideline may help to overcome some of the aforementioned challenges. A proposed version of such a guideline has been developed by the author and it can be found in appendix A. The investment analyses performed in this study follows the steps explained in chapter 1.5, which have been developed specifically for this study. The economical aspects of investments are however largely evaluated using the PB method, since this is the measure that the company uses. That is, using other basis of evaluation would further increase the inconsistencies in the investment analyses. Based on discussions with the company it was concluded that a Payback time (PB) of up to 7 years could be accepted by the company.

2.2. Discount rate

The Weighted Average Cost of Capital (WACC) is calculated for the company. This is done using the interest rate and amount of bank loans (i_{loan} and a_{loan}), as well as the expected rate of return and on equity (i_{equity}), the equity amount (a_{equity}) and the amount of untaxed equity founds (i_{equity}). The untaxed equity is adjusted for the 2021 corporate tax rate of 20,6%[7], resulting in the WACC[8] as calculated through equation 2.1.

$$WACC = \frac{a_{loan} \times i_{loan} + (a_{equity} + a_{found} \times 0.794) \times i_{equity}}{a_{loan} + a_{equity} + a_{found} \times 0.794} = 6.82\% \quad (2.1)$$

This WACC is the necessary return on any capital invested in the company, if the expectations of both lenders and owners are to be met. Therefore, the WACC marks the lower limit of acceptable returns. If an investment is associated with risk, however, the discount rate used shall be adjusted for this. In this report, the WACC is used as the discount rate for capital bound in material stock, product stock and Work In Progress (WIP). The risk in these cases is regarded to be negligible, in large part due to the fact that products rarely get outdated in this industry.

The discount rate employed when calculating the machine depreciation cost, as calculated using the annuity method, is 1.5 times that of the WACC, namely 10.02%. This reflects the increased risk taken when investing in machinery and corresponds to a payback time of approximately 11 years.

2.3. Customers

Based on an internal study carried out by *Jonas Gerdin*, costumers are found to be satisfied with the Gerdins offer, especially with the product range and the product quality. The problem, as identified by this study, is the long lead times. Several customers request that something be done to decrease lead times, especially for the graphic segment. 68% of customers answer that a lead time of 1-2 weeks would be acceptable, notably however, this was the shortest lead time option that was available to them. This means that customers with more demanding lead time requirements are not reflected by this study. The remaining 32% answered that a lead time of 2-3 weeks would be acceptable. If disregarding the limitations of the question options, an average accepted lead time can be calculated to be

$$LT_{Acc} = 1.5 \times 0.68 + 2.5 \times 0.32 \tag{2.2}$$

weeks. It shall however be noted that the acceptable lead times as provided by customers naturally include transport time, which has to be excluded when calculating a desired lead time from order to shipment, here called the *customer lead time*, as defined in chapter 1.6. As a result, the average acceptable customer lead time can be calculated to be

$$LT_{cAcc} = [1.5 \times 0.68 + 2.5 \times 0.32] \times 5 - t_{transp} \tag{2.3}$$

work days, where t_{transp} is the transport time in days. Transport times vary greatly from a few days to a couple of weeks. Most customers are however located in Europe. Furthermore, lead times are most important to customers in the graphic segment, and this segment is sold only in Europe. Therefore, when calculating an approximate transport time for Europe is used. Transport times in Europe vary between 2-3 days and 5 days, resulting in an estimated average accepted customer lead time of

$$LT_{cAcc} = [1.5 \times 0.68 + 2.5 \times 0.32] \times 5 - \frac{2,5+5}{2} = 5,35 \approx 5 \tag{2.4}$$

days. In the rest of the report the calculated LT_{cAcc} will be used for comparison with actual customer lead times. This approach has some dangers, for example:

- The *average* lead time requirement is a questionable measure for desired lead time since there is a risk that all customers with stricter requirements than average may be unsatisfied and leave. An alternative measure would be the minimum lead time requirement but such data is, as commented, unfortunately not available.

- Customers with more strict lead time requirements may have already left the supplier, so this study may not reflect the market as a whole. Actual lead time requirement may be higher than the study indicates.
- The absence of short lead time options for customers responding to the study implies that actual acceptable lead times are likely lower than calculated.
- There is always a trade-off between cost and lead times. The fact that customers are wishing for shorter lead times does not necessarily imply that they are prepared to pay for the extra cost that the change might entail.

The conclusion is that customer lead times are desired to be lower than LT_{cAcc}, but cost aspects of this shall also be considered. Note that Gerdins is a quality focused, high-end brand. As such, all aspects of the customer service, including customer lead times, are of crucial importance since they form an important part of the extended product. Arguably, lead times are therefore more important than the product cost, in the market segment where Gerdins operates.

2.4. The importance of the production lead time

As explored in chapter 2.3, the customer lead time needs to be be shorter than 5 work days to satisfy customer requirements. This may be compared to the current customer lead time, which can be calculated based on the order date and the shipment date for each order. Note that each order typically contains multiple different products and that there are no data available for the customer lead times of single products, making it impossible to calculate customer lead times for a specific product. It is however the case that customers generally order products from either the graphic or the leather segment, see chapter 1.6. This allows the calculation of the customer lead time for each of the product segments separately.

Since there are changes to the the customer lead time over time, mainly due to changes in management and the number of orders received, the analysis of customer lead times is analyzed for the last three months, in order to capture the current situation. Another complexity in relation to this analysis is that some orders are modified before shipment, making this data incomparable since there is a question as to which order date should be used. Note that the reasons for modifications to orders may vary, some being driven by long lead times whilst others are due to other causes. Therefore, this analysis utilizes two measures for the current customer lead time, one excluding the modified orders, and one using the original date of modified orders. The results are shown in table 2.1.

	Leather products		Graphic products	
	Excluding modified orders	Including modified orders	Excluding modified orders	Including modified orders
Delivery reliability	40%	35%	70%	40%
Average customer lead time	13.5 days	20.2 days	6.8 days	24.9 days
Median customer lead time	7 days	10 days	3 days	10 days

Table 2.1: Delivery performance for leather and graphic products at Gerdins. The delivery reliability is defined as the percentage (%) of orders which are shipped within the acceptable customer lead time, LT_{cAcc}. The average and median delivery times are expressed in work days.

When analyzing the data, it is important to pay attention to the different lead time drivers as illustrated in figure 2.1. It is observed that a fair fraction of the orders are shipped the same day as they are received, which occurs when the required products are in stock. This is largely reflected by the delivery reliability, which is defined as the percentage of orders which are shipped within the acceptable customer lead time, LT_{cAcc}.

Further, it can be observed that the delivery reliability is better for graphic products than it is for leather products. The number of different articles is usually smaller for orders regarding graphic products, which may be one of the reasons for this. Due to the long customer lead times in the graphic segment, more orders are modified for products in this segment, than for products in the leather segment. This has a significant effect on the lead time performance when excluding modified orders.

It shall be noted that the delivery reliability has potential for improvement. When analyzing the delivery performance of companies, these figures are normally desired to be exceeding 90%. The reason behind the low delivery performance at Gerdins is that products, which are not in stock when an order is received, have to be manufactured before they are shipped. This generally takes considerable time, as is reflected by the long average and median customer lead times, see table 2.1. This may be the result of long production lead times, or the lack of available machines, see figure 2.1.

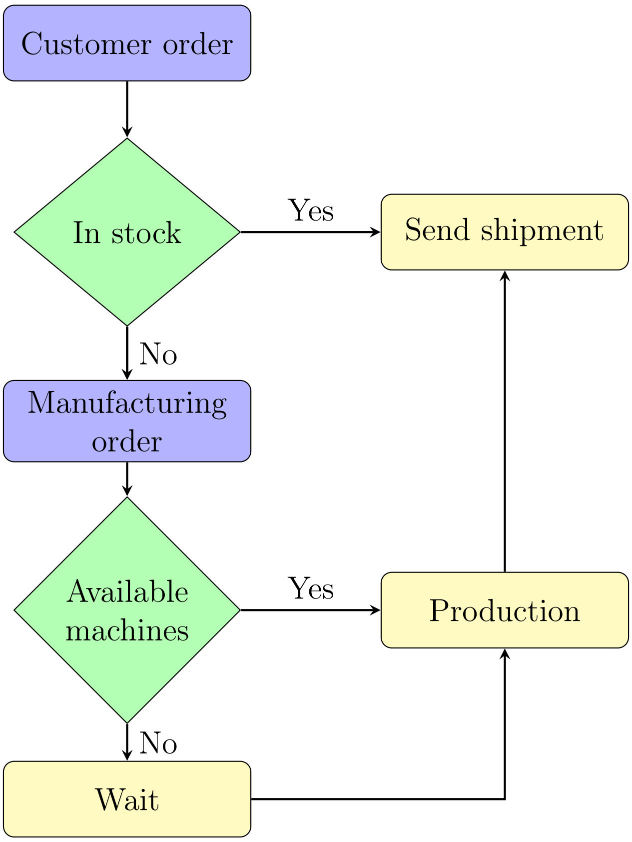

Figure 2.1: The process from the reception of a customer order to its shipment.

To improve the delivery reliability, stock values need to be increased to allow more shipments to be sent directly from stock. Allowing more orders to be shipped directly from stock will also free up time for machines to manufacture against stock, generally resulting in lower production costs as a result of larger batch sizes.

Given the large variety of different products, it will however not be possible to keep a sufficient stock of all articles at all times. This means that, at times, products will need to be manufactured against order. It will however be less commonly occurring, due to the higher stock values. As such, when it is necessary to produce against order, the risk that the needed machinery is already being utilized for production against another order, is reduced. Thereby, the risk of having to wait before initiating the production order in question, is reduced. Having several machines which can take on similar jobs is also preferable in this regard.

The final component to accomplishing a higher lead time performance is to make sure that the production lead time is lower then the acceptable customer lead time. If it is not, any order which is not in stock will be delayed longer than acceptable. Therefore, when addressing the production lead time in future chapters, it is compared to the acceptable customer lead time.

Note that, when producing against a customer order, partial batches are delivered in the production. For example, if 1 000 units are to be manufactured for a customer, a production order may be issued for 20 000 units in order to keep production costs down. But after having produced the first 1 000 products, a partial delivery is made, to make sure that the customer receives the ordered articles as fast as possible. Therefore, when comparing production lead times to the acceptable customer lead time, the production lead time is calculated based on a batch size corresponding to the average customer order for the given product.

3. The production of representative products

A great number of different products are being produced at Gerdins, in a whole range of different shapes and sizes. The punches typically range from 2 mm to 36 mm in diameter and from 9.7 to 32.0 mm i height. In total there are about 3 000 different products offered, see figure 3.1. These largely fit into two segments, leather and graphics, for which the usage and therefore tolerances and demands, are different. In the leather segment, both punches and pattern prickers (prickers) are offered. These are sold under two different brands, Gerdins and VICOP, for which the quality and specifications also differ. For both brands in the leather segment, the punches and prickers are offered as both one-sided and two-sided models. Other aspects which also differ between products are the shape of the edge (round, square, heart, etc.), the type of waste expulsion system (side eject, through hole or spring solution) and the clearance angle of the punch, to mention a few.

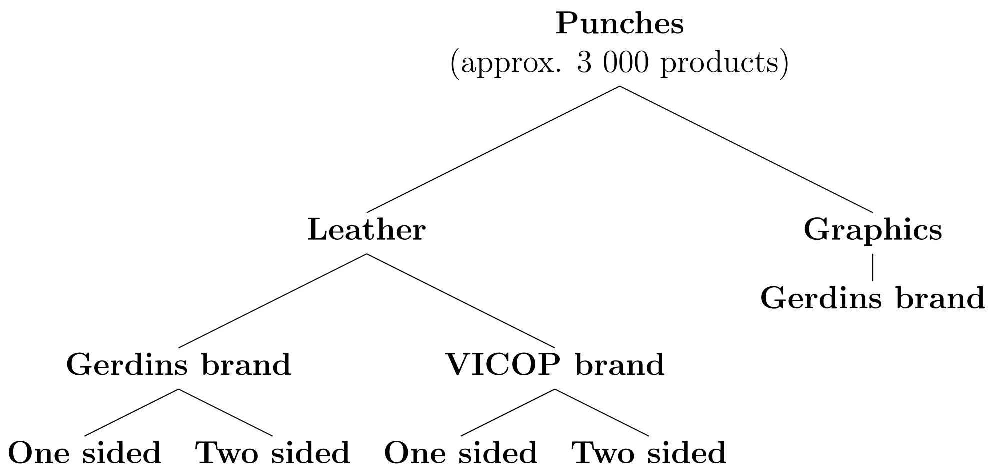

Figure 3.1: The punches offered at Gerdins and their division.

Apart from the complexity in the product offering, there is significant complexity when it comes to the production. Of the almost 50 machines used in the production of punches, most are unique machines, with unique specifications. This means that input material dimensions, possible production operations and production rate vary significantly between machines, resulting in a complex production flow which can vary significantly between similar products. Furthermore, there is a lack of data for production times, costs and volumes.

As a result, the modeling of the the entire process becomes too complex to address within the scope of this report. Instead, a few representative products are selected, for which data is collected and analyzed. When selecting the representative products, the production volume, sales revenue and complexity of the production are the main considerations. This chapter details the production cost and lead times of some of these identified representative products. In some instances, several representative products were analyzed per product group, in such case, only one is presented here.

3.1. Leather segment

There are a many different products within this segment, but volumes are relatively high, especially for products with smaller diameters. The production flow of these products largely depend on the brand and the diameter of the product, as is shown in figure 3.2. This flow chart is however simplified. For example, the production of pattern prickers of the Gerdins brand are not included, since they have not been analyzed as a part of this study. Furthermore, if products are not produced to order, semi-finished products are put into storage before the side drilling production step. This not reflected by the flow chart either.

When analyzing the production of this specific product segment, possible cost reductions per unit are especially interesting since there is a large pressure for cost reductions on the market.

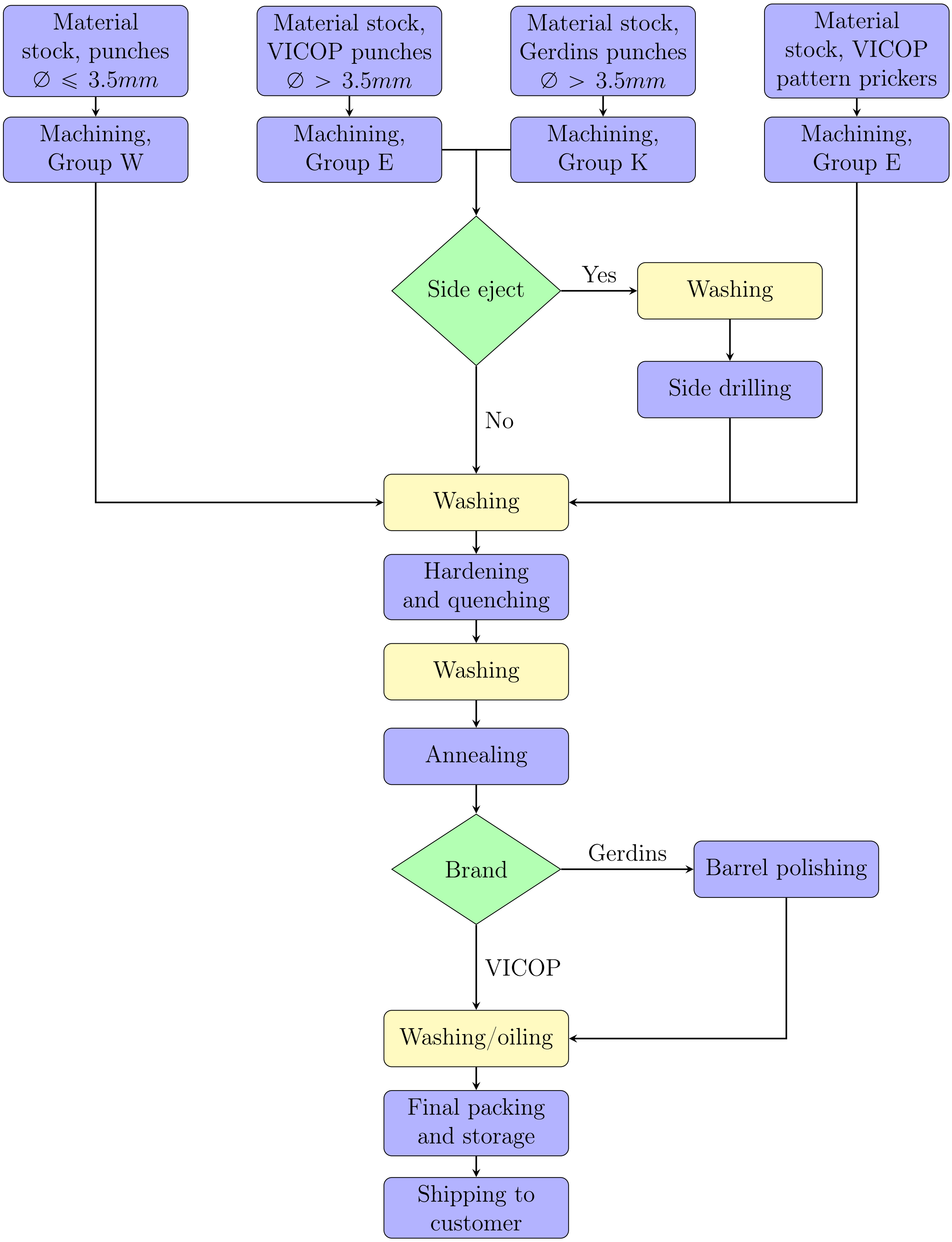

Figure 3.2: The production flow of leather products. The flow chart has been simplified and could be broken down into more production steps.

3.1.1. Punches, both brands, $\varnothing \leqslant 3.5mm$

The products in this product group are produced in production group W. This production group is specialized on the production of small diameter punches and provides high production volumes. The fixed costs are however significant. The machine is currently used for the production of Leather punches of both brands and the full production process of those products is outlined in figure 3.2.

There is a wide range of products belonging to this product group which all have different designs, diameters and lengths. What they have in common is that they are products produced and sold in large volumes at low unit prices. The production costs of these products are heavily dependent on production volume and cycle time, which is product dependent. A more detailed analysis of production cost and lead time has been performed for a representative product within the group, a double-edged VICOP product, see figure C.1c. The results can be found in figures 3.3 and 3.4 respectively.

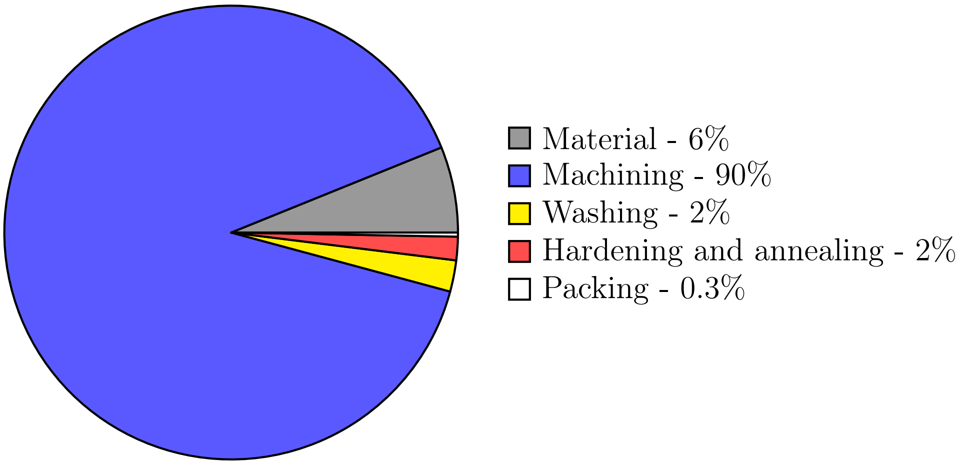

Figure 3.3: Breakdown of production cost(in %) for the representative product analyzed in chapter 3.1.1, for a batch size of 25 000 units. Management and sales costs not included.

Note that instead of finishing the full batch in the machining stage before continuing to the washing operation, partial deliveries are made, typically corresponding to a customer order. The calculated lead time, see figure 3.4, is the average production lead time for an average customer order. One of the reasons why this lead time is low, is that the cycle time for the machine in production group W is kept below 5 seconds, significantly lower than for other production groups.

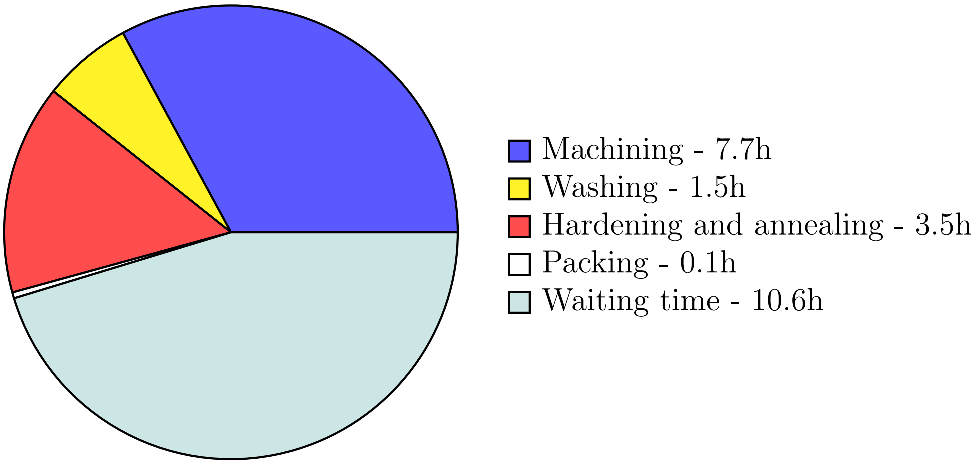

Figure 3.4: Breakdown of production lead time for the product, for a batch size corresponding to the median order quantity. Figures are in work hours (h), that is, if machines run outside work hours, this time is not included. The total production lead time is estimated at 3.0 work days.

Furthermore, the wait time is an estimation based on the average wait time. Therefore, when producing against customer order, wait times are typically reduced since the production order is prioritized. As a result, the wait time shall not be considered concerning, which is elaborated further in chapter 5.5.3. On the other hand, due to large sales volumes in this product category, the major part of production is not against order but rather against storage, making the production lead time less important. In conclusion, the lead times are satisfactory and shall not be regarded an issue for this product group.

The production cost however, leaves room for improvement. Currently, quite small batches are produced and the machine has considerable planned downtime due to small sales volumes and high stock values. The unit production cost consists largely of fixed machining costs and fixed per-batch costs. By drastically increasing the yearly production volume and batch sizes, the fixed machining costs and machine setting costs can be significantly reduced on a per-product basis. In this example, the yearly production hours are increased from 650 to 4848 hours and batch sizes are increased from 25 000 to 100 000 units, which results in a per-unit price reduction of 78%. For a cost breakdown of the production costs, after applying the proposed changes, see figure 3.5.

Naturally, this would require larger sales volumes, but the company has been receiving large volume offers within a reasonable price range. As such, the implementation of the proposed changes appear possible. Due to labor overcapacity and low material costs, the capital cost for extra bound capital is negligible, compared to the expected returns.

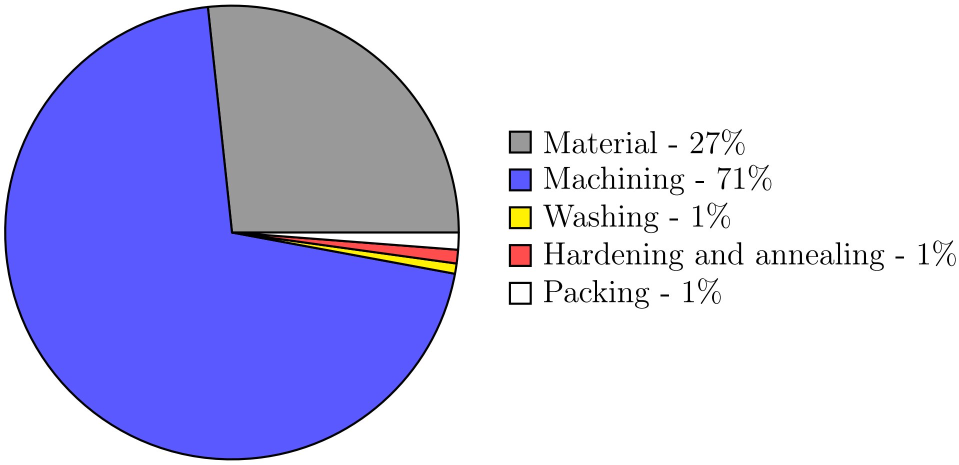

Figure 3.5: Breakdown of production cost(in %) for the representative product analyzed in chapter 3.1.1, after proposed changes. Management and sales costs not included.

Note also that the production of punches with diameters up to 4.0 mm will be made possible in this machine, due to recent purchases of tooling equipment. As such, a greater range of volume products will be produced in this machine, further allowing for its increased utilization rate.

3.1.2. Pattern prickers, VICOP, $\varnothing = 2.5, 3.0mm$

This product group consists of pattern prickers produced in production group E. These are sold under the VICOP brand and come in two diameters, 2.5 mm and 3.0 mm, respectively. A standard 2.5 mm pricker has been chosen as the representative product for this group. The production cost and lead times calculated for this product are shown in figures 3.6 and 3.7.

In these figures we see that production cost is dominated by machining costs, which can be reduced by increasing the machine utilization and batch size. If the batch size is increased from 75 000 units to 200 000 units and the yearly production hours are increased from 286 to 4848 hours, this corresponds to a cost decrease of 77%. While 286 hours were the estimated number of production hours in 2020, this was a year with exceptionally low production in this segment, due to the Corona crisis. A breakdown of the production cost after proposed changes can be found in figure 3.8.

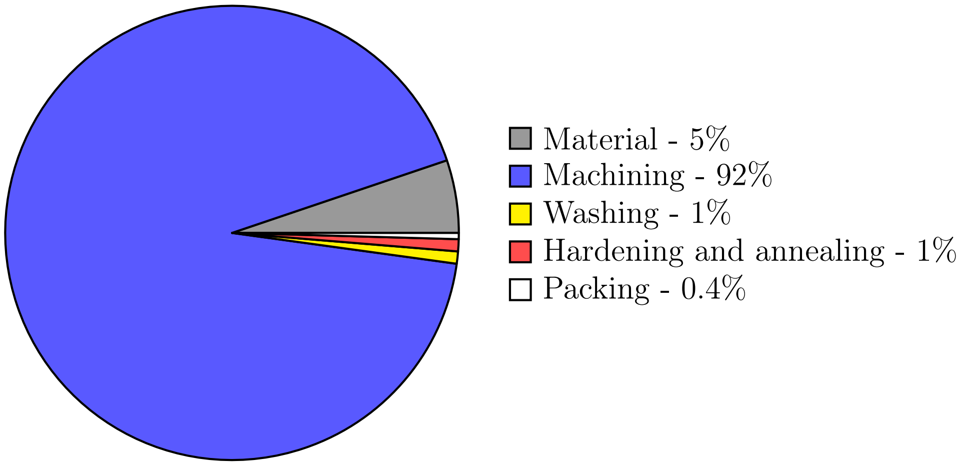

Figure 3.6: Breakdown of current production cost(in %) for the representative product analyzed in chapter 3.1.2. Management and sales costs not included.

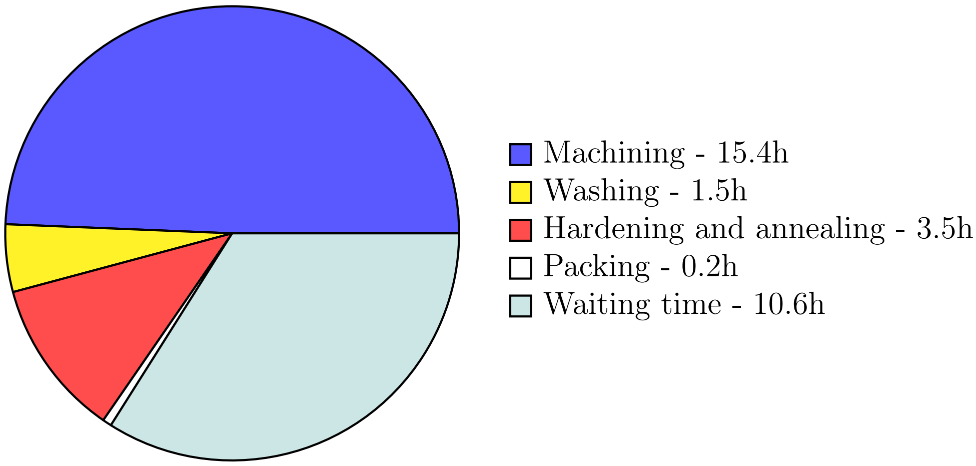

Figure 3.7: Breakdown of production lead time for the product, for a batch size corresponding to the median order quantity. Figures are in work hours (h), that is, if machines run outside work hours, this time is not included. The total production lead time is estimated at 4.1 work days.

It can also be concluded from this study that these machines are particularly suited for production of prickers. For prickers, quality reduction rates are low compared to producing punches in the same machines. Meanwhile, production of prickers in these machines leaves less metal shavings with the product, meaning that manual washing can be avoided later in the production. Neither are there any quality issues with this solution. Therefore, it is proposed that all prickers be produced in this production group. This would also increase its utilization rate and thereby result in lower production costs, as demonstrated.

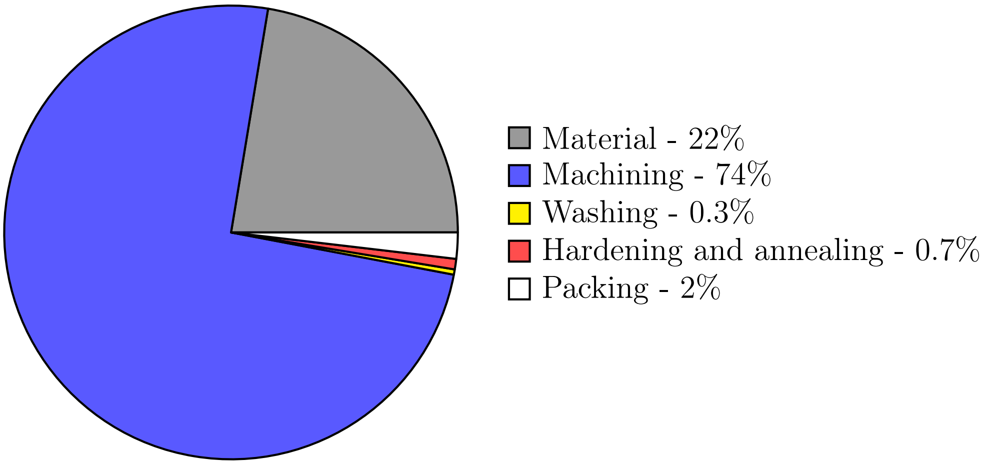

Figure 3.8: Breakdown of production cost(in %) for the representative product analyzed in chapter 3.1.2, after proposed changes. Management and sales costs not included.

3.1.3. Punches, VICOP, $\varnothing > 3.5mm$

This product group consists of punches machined in production group E. These punches have diameters which are too large to allow for production in production group W, see chapter 3.1.1. Notably, production group E consists of older so-called screw machines, which are mechanically controlled. These do not have the ability to side-drill expulsion holes, which therefore has to be done is a separate production step, see the full production process in figure 3.2. The machines also have longer cycle times than production group W, and can produce approximately one punch every 15 seconds. The sales volumes and orders are however smaller than for punches with smaller diameters, decreasing the impact of this on the production lead time.

The punches in this product group are represented by a double-edged punch with an outside diameter of 3,6 mm. For this product, the production cost and lead time have been calculated and the results are shown in figures 3.9 and 3.10.

Production costs are significantly higher for punches manufactured in this machine group compared to those addressed in chapter 3.1.1. There are several reasons for this, including the difference in size of the punches. It is however the case that, even if the yearly production hours are increased from 286 to 4848, the production cost would still be significantly higher than the corresponding production cost in production group W.

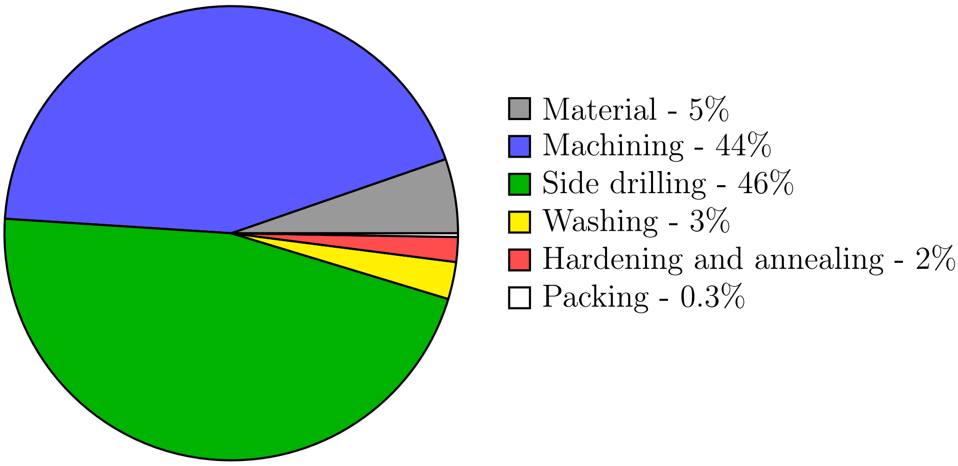

Figure 3.9: Breakdown of current production cost(in %) for the representative product analyzed in chapter 3.1.3. Management and sales costs not included.

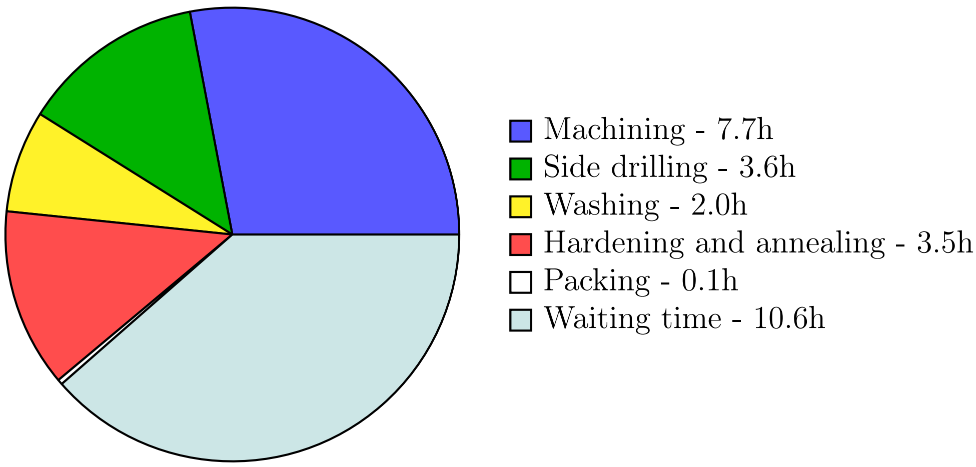

Figure 3.10: Breakdown of production lead time for the product, for a batch size corresponding to the median order quantity. Figures are in work hours (h), that is, if machines run outside work hours, this time is not included. The total production lead time is estimated at 3.6 work days.

This is largely the result of the added side drilling production step, which accounts for 46% of the production cost. It is likely that the employment of another production machine, capable of performing side drilling would be more cost efficient. At present, the company does not have the necessary production capacity in machines which can perform side drilling. Therefore, the investment in such a machine is considered in chapter 4.2.

Furthermore, the machines in production group E are screw machines of an older model. This poses a problem since the operator responsible for this production group will retire within 2.5 years and the company believes that it will not be possible to replace this operator. This is a result of the control mechanism employed by these machines being outdated, so finding an employee with the right interest and competences is not considered possible. This further expresses the need for investment in a new production machine.

Note that if a new production machine is purchased for the manufacturing of VICOP punches of this size, this would mean that only the pattern prickers would be assigned to production group E, see chapter 3.1.2. There are 12 different models of pattern prickers and 7 machines. Ergo, the machines could be permanently set to producing the 7 most sold pattern prickers, of both brands. Then, the production of pattern prickers may continue in these machines, after the operator has retired, as there would be no need for machine setups.

3.1.4. Punches, Gerdins, $\varnothing > 3.5mm$

Leather products of the Gerdins brand with $\varnothing > 3.5mm$ are produced in production group K. This production group consists of 9 production machines of an older model. A wide range of products are produced in the production group and these are represented by a punch with a through hole for waste expulsion (back clearing) and a diameter of 3.6 mm, see figure C.1d. This means that no side drilling is necessary for this particular product. Note however that, for products where side drilling is necessary, this has to be done in a separate production step, as these machines are incapable of performing side drilling. The production cost and lead time are calculated for the product and the results are shown in figures 3.11 and 3.12.

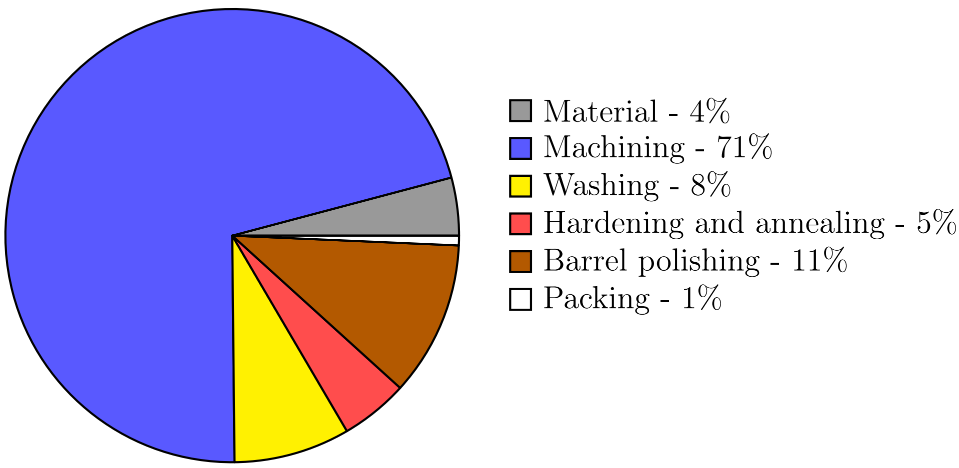

Figure 3.11: Breakdown of current production cost(in %) for the representative product analyzed in chapter 3.1.4. Management and sales costs not included.

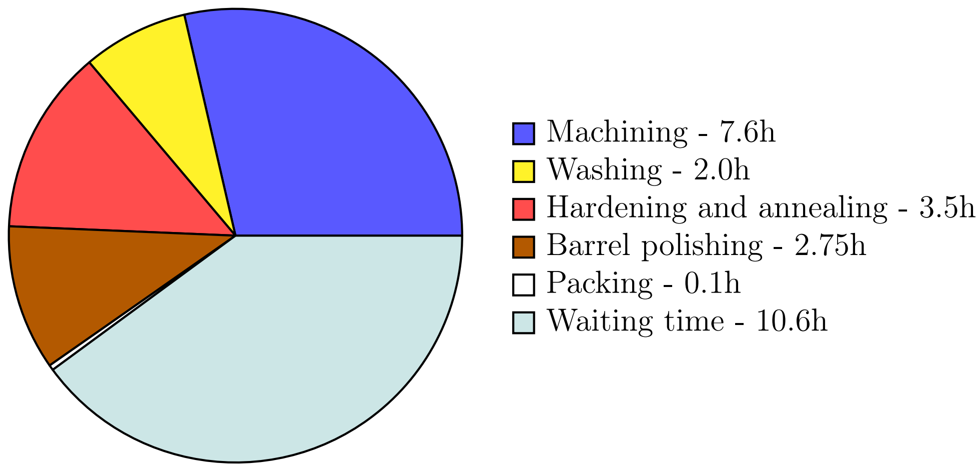

Figure 3.12: Breakdown of production lead time for the product, for a batch size corresponding to the median order quantity. Figures are in work hours (h), that is, if machines run outside work hours, this time is not included. The total production lead time is estimated at 3.4 work days.

Much like in chapter 3.1.3, production costs are higher than for comparable products produced in production group W, analyzed in chapter 3.1.1. However, decreasing production costs by increasing volumes is an unlikely scenario for production group K, due to a low production flexibility. Specifically, despite there being 9 production machines in the production group, a given product may only be produced in one machine. This makes high utilization rates problematic from a production perspective as sales volumes vary significantly between products. Furthermore, a smaller portion of the production costs are fixed costs, compared to other production groups described in chapter 3.1. As a result, production cost for this product group can not be significantly decreased.

The only feasible way of significantly reducing production costs, is through investment in new a production machine, which has already been suggested in chapter 3.1.3. If this machine meets required quality standards, products produced in production group K could also be produced in this new machine, as the designs and dimensions are otherwise the same. Therefore, the investment alternative investigated in chapter 4.2 is required to fulfill these quality standards, allowing it to also replace production group K. Finally, it is noted that the production lead time is acceptable for this production group.

3.2. Graphic segment

The graphic segment stands for about 40% of the sales revenue as of 2020, after having increased its portion during the corona crisis, as a result of a drop in sales for the leather segment. The sales volumes for the graphic segment is however significantly lower as prices are higher for this segment. This has implications for the production. For example, a large batch in the leather segment may be around 100 000 units whilst a large batch in the graphic segment may be around 5 000 units. Notably, these products do have much stricter quality requirements than the leather segment and are, partially for this reason, produced in other, generally more expensive, machines. This is what motivates the difference in production cost and price.

Much like in the leather segment, there are larger volumes for products with smaller diameters. The diameters in this segment are however somewhat larger overall. The products are produced in different machine groups depending on the product diameter, though some diameters can be produced in several machines/machine groups. Some of these machines are capable of side drilling expulsion holes whilst some are not. The fraction of side drilled products is however small in comparison that of the leather segment. As such, it is possible for the punches with side drilled expulsion holes to be machined in machines capable of side drilling. For planning-related reasons, it is however not always the case that they are produced this way, making side drilling necessary in some cases. Note that side drilled expulsion holes are only offered for small diameters. The production flow is shown in figure 3.13.

Note also that, both the Gerdins and the VICOP brands are used in the Graphic segment. For VICOP products, the height adjustment is not performed. The volume for these VICOP products is however so low that the author has chosen to exclude them from this study.

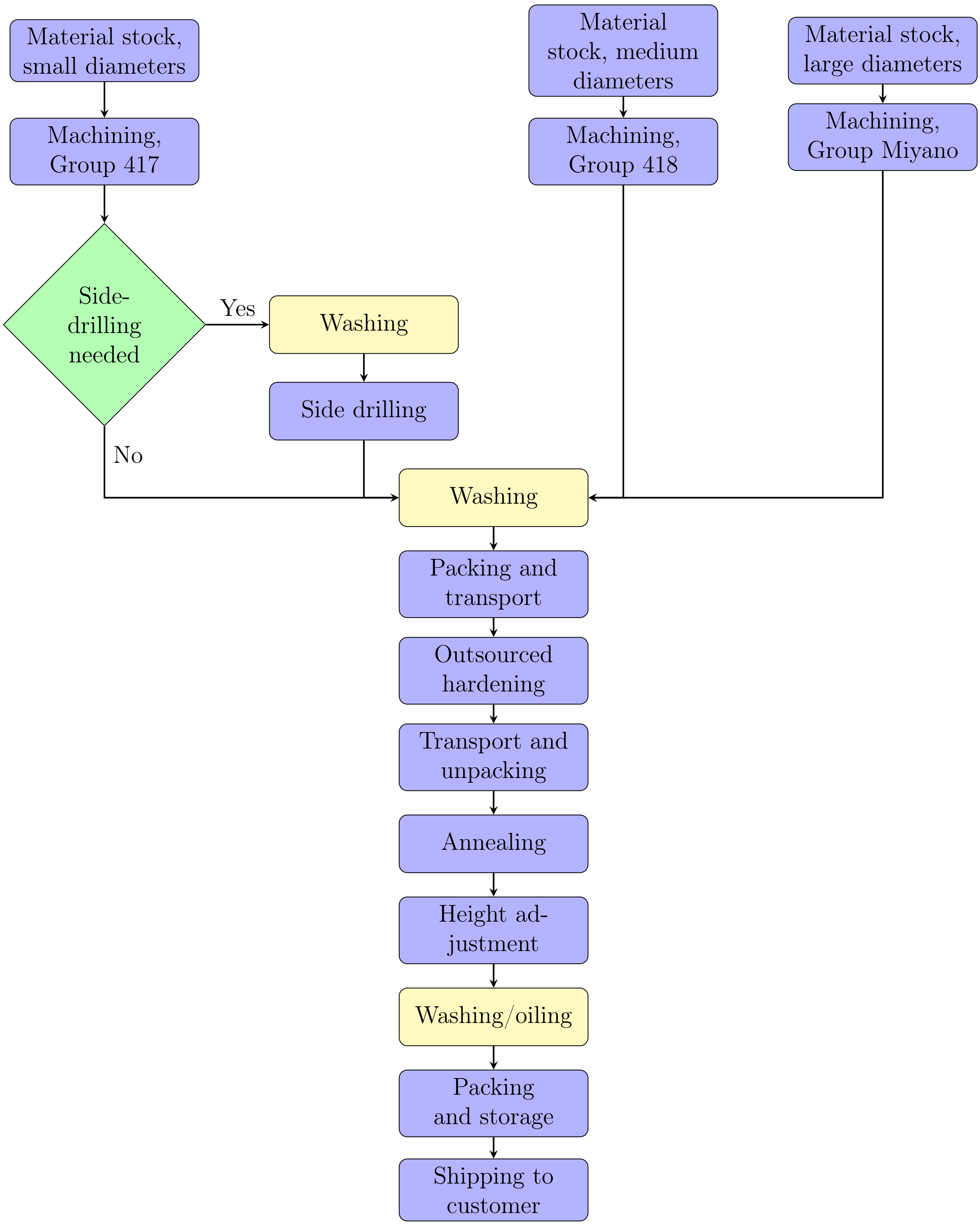

Figure 3.13: The production flow of graphic perforating punches. Different machines are used for machining, mainly depending on the product diameter. The flow chart has been simplified and could be broken down into more production steps.

3.2.1. Small diameters

In this study, this product group is represented by a punch with side ejection and an edge diameter of 5 mm, see figure C.1a. In these calculations it has been assumed that the product in question is side drilled in a separate production step. Both production cost and lead time has been calculated for the representative product and the results are presented in figures 3.14 and 3.15.

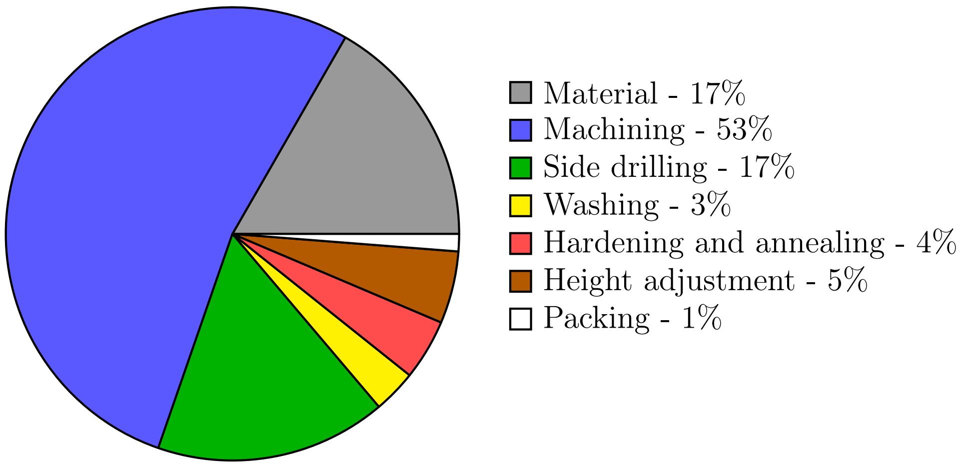

Figure 3.14: Breakdown of current production cost(in %) for the representative product analyzed in chapter 3.2.1, for a batch size corresponding to half the annual order quantity. Management and sales costs not included.

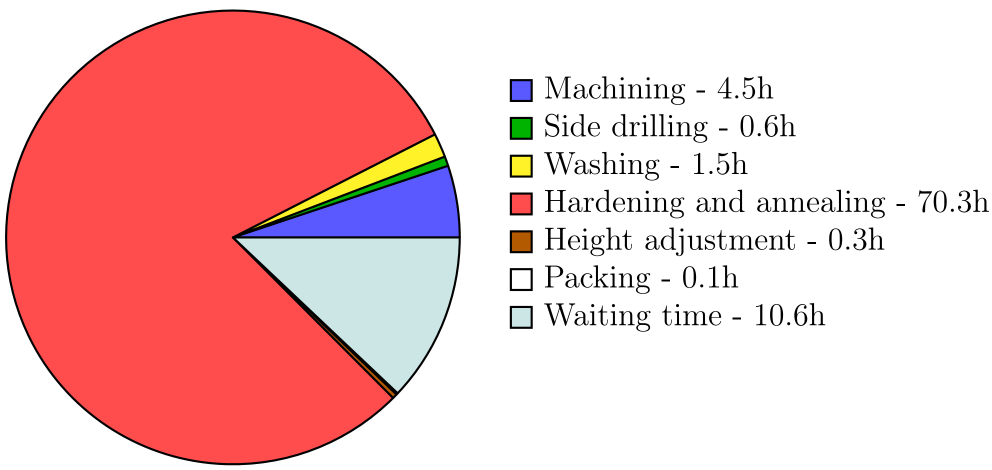

Figure 3.15: Breakdown of production lead time for the product, for a batch size corresponding to the median order quantity. Figures are in work hours, that is, if machines run outside work hours (h), this time is not included. The total production lead time is estimated at 11.4 work days.

First of all, it shall be observed that the lead time is significantly longer than acceptable. In chapter 2.3 it was concluded that an accepted customer lead time is, at the most, 5 work days. In this case, the the production lead time is more than double that. Most of this time is spent in the production stage "hardening and annealing". This is due to this stage being outsourced for the graphic products. In order to solve the lead time problem, the hardening process needs to be performed in-house. This would require investment in a furnace, which is investigated further in chapter 4.1.

When it comes to the production cost, it can be concluded that the side drilling stands for a sizable fraction of the production cost. Handling this operation in the machining stage would naturally increase the machining cost somewhat but would decrease the overall production cost. As such, it is advised that, to the greatest extent possible, side drilling is not performed in a separate production step. This would require more efficient production planning and potentially also lager stock values, as a result of the reduced production flexibility.

The production cost may also be reduced by increasing batch sizes and increasing machine utilization as elaborated previously. This effect is however not as large for the graphic segment as it is for the leather segment. Another possible way to decrease production costs is through investments in a new production machine capable of higher production rates, and of side-drilling. This is addressed in chapter 4.2.

3.2.2. Medium diameters

This product group is represented by a punch with 10.0 mm edge diameter, of the "outside bevel" design, which has a through hole for waste expulsion (back clearing). The production cost and lead time has been calculated for this product and the results are shown in figures 3.16 and 3.17.

Much like in the case of graphical products with smaller diameters, the lead time poses a major issue. This problem can potentially be solved through the investment in a furnace as investigated in chapter 4.1.

Again, production costs can be improved by increasing batch sizes and machine utilization. In order to increase the machine utilization it is necessary to run the machines at night, as is done for many of the production machines. For the machine in which the representative product is normally produced, this is however not possible. In order to run this machine at night, it is necessary to invest in an oil bath selector system, which is investigated in chapter 4.4.

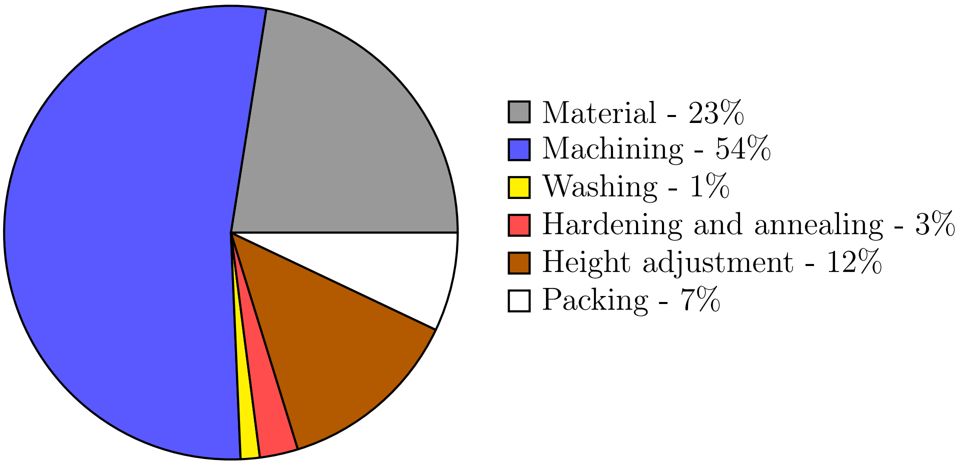

Figure 3.16: Breakdown of current production cost(in %) for the representative product analyzed in chapter 3.2.2, for a batch size corresponding to half the annual order quantity. Management and sales costs not included.

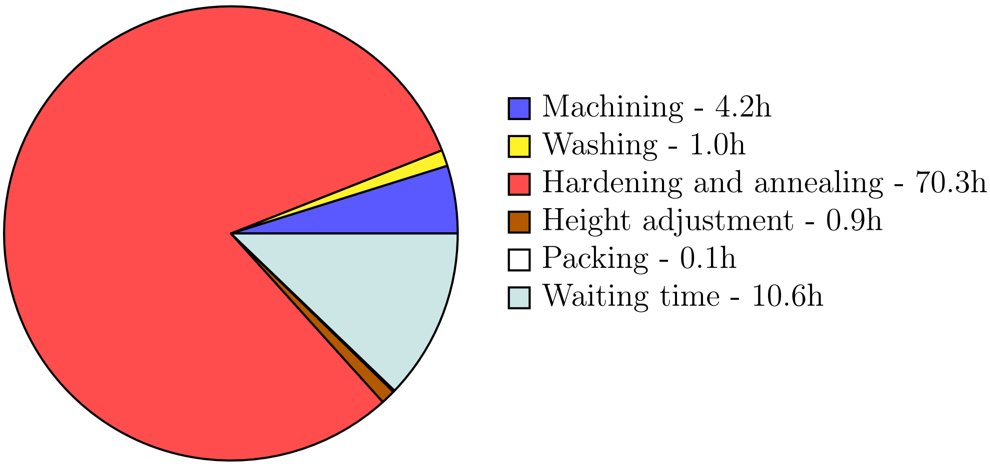

Figure 3.17: Breakdown of production lead time for the product, for a batch size corresponding to the median order quantity. Figures are in work hours, that is, if machines run outside work hours (h), this time is not included. The total production lead time is estimated at 11.3 work days.

3.2.3. Large diameters

This product group is represented by a punch with 20.0 mm edge diameter, which has a through hole for waste expulsion (back clearing). The production cost and lead time have been calculated for the product and the results are presented in figures 3.18 and 3.19.

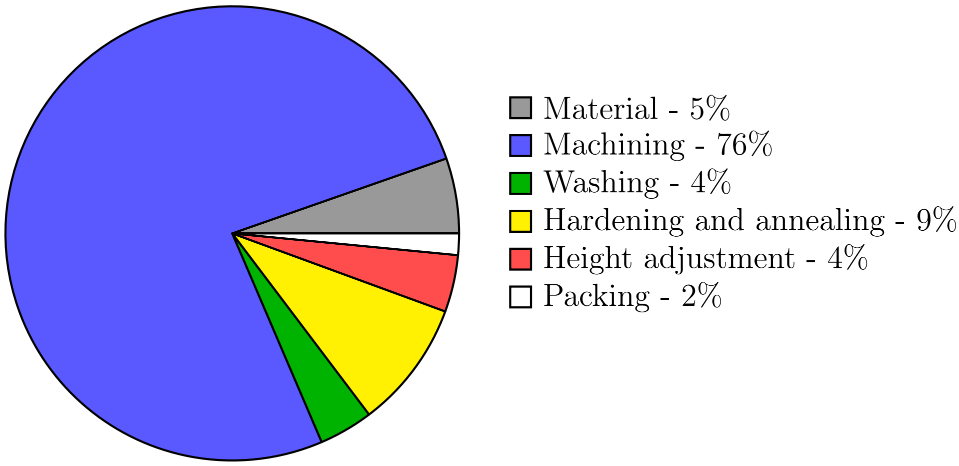

Figure 3.18: Breakdown of current production cost(in %) for the representative product analyzed in chapter 3.2.3, for a batch size corresponding to half the annual order quantity. Management and sales costs not included.

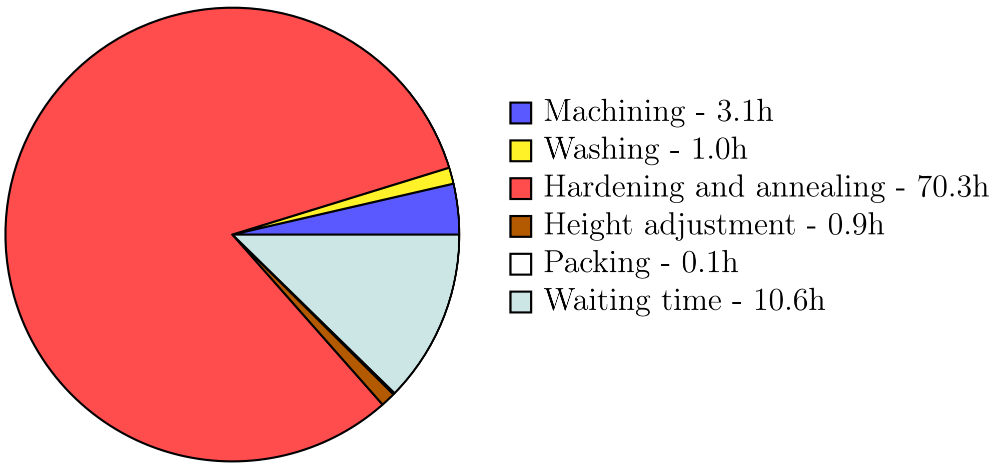

Figure 3.19: Breakdown of production lead time for the product, for a batch size corresponding to the median order quantity. Figures are in work hours, that is, if machines run outside work hours (h), this time is not included. The total production lead time is estimated at 11.2 work days.

The production cost has increased dramatically compared to the smaller graphic products. This is due to current manufacturing problems, which drastically increase the machining cost. Thereby it also indirectly increases the cost in other production steps, as a result of the quality rejections in those production steps.

Historically, the same material has been used for the manufacturing of this product, as is used in the previously investigated products. However, this material is no longer available in the right dimensions. Therefore, a different material with unfavorable machinability is used, which incurs in a tripled cycle time and the need for an operator to manually aid in the production process. As a result, the production of this product becomes comparatively expensive and the production capacity is greatly reduced, making the company unable to deliver on customer orders. This has resulted in very long delivery times and the need for reselling products from competitors to fulfill customer orders. The total cost of this issue is therefore considerable.

One of the main reasons why the company hasn't identified another suitable material is that the company has no way of assessing the toughness of materials. As such, they are unable to verify whether products produced with other materials indeed do satisfy the quality requirements. It is therefore suggested that the company invest in equipment for toughness testing of materials, so that these situations may be resolved swiftly in the future, and to help in the continuous quality improvement work. An analysis of the proposed investment is found in chapter 4.3. The use of material with similar machinability properties as the material previously used, would result in a cost reduction of 60%. The cost distribution is shown in figure 3.20. It is further recommended that the batch size be larger than the batch size used in these calculations, as this has a significant impact on the production cost.

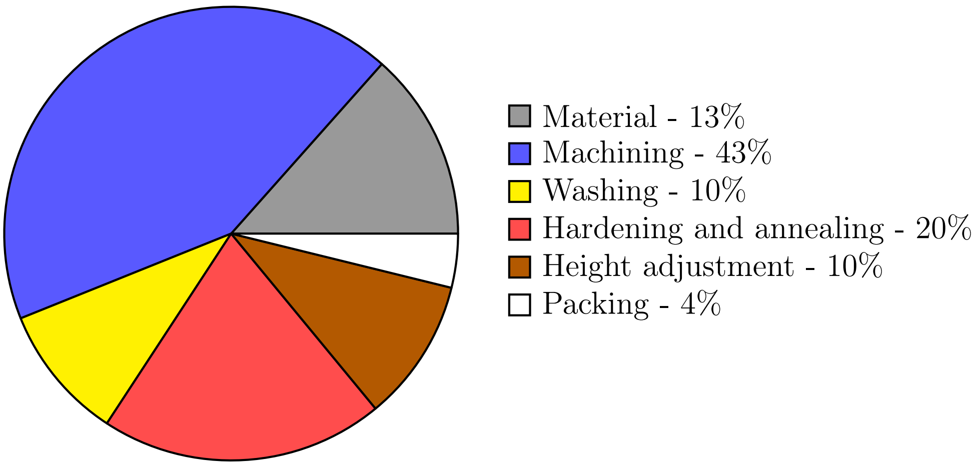

Figure 3.20: Breakdown of current production cost(in %) for the representative product analyzed in chapter 3.2.3, for a batch size corresponding to half the annual order quantity. Management and sales costs not included.

Finally, it shall be noted that the lead time is longer than acceptable, as is the case for the previously investigated graphical products. To resolve this issue, the investment in a furnace is proposed and investigated in chapter 4.1.

3.3. Other products

The company also offers a wide range of products in uncommon shapes and dimensions, but these are sold in low volumes. Many of these products belong to the product segment called "Fancy" which is separate from the leather and graphics product segments. The company regards these products as unprofitable and, as a result, efforts are made to move the production of these products to partners in countries with lower production cost. As such, investments in this product segment and improvements in the manufacturing of these products are of little interest to the company. Therefore, no representative product is analyzed for this particular product group.

There are also some development projects undertaken at Gerdins. These are generally complex punches, machined in CNC machines, but there are also some fairly simple geometries considered. For example, the company is considering the production of *Easy Setter Pins*. New packing solutions would however be necessary in order to allow for sales of this product. As such, this was considered as an investment alternative in this study. After investigations it was however found that the company was not at a stage where an investment analysis would have had an impact on the decision making process. Therefore, further investigation of this investment option was suspended. The company is recommended to contact relevant patent holders before a further study on this matter is pursued.

4. Investment evaluations

The investigations into the production of seven representative products, as detailed in chapter 3, identified four possible investment alternatives. These alternatives are analyzed in this chapter in order to determine if they are advisable for the company. The depth of the analysis depends on the size of the investment and the time plan for the investment in question.

4.1. Hardening furnace

4.1.1. Issue

As identified in chapter 3.2, the production lead time is significant for all graphic products. The production lead time was found to be longer than 11 work days for each of the products investigated, over 80% of which can be attributed to the outsourced hardening process. Notably, the production lead time is more than double the accepted customer lead time, $LT_{cAcc} \approx 5$ work days. Note that lead times have been identified as being especially important for this product segment. As such, it can be concluded that improving said lead times is of importance.

Furthermore, the current solution implies that the company has little control over the hardening process. Given that the main quality aspects of the product are its hardness, toughness and dimensions, the hardening process is of significant importance to the quality of the product. Not retaining the control over this critical aspect of the manufacturing process is a treat to the company as it leaves little control over its main selling point, the product quality. Not only does it make the company dependent on its supplier to deliver in accordance with specifications, it also makes material-related product development practically impossible. As such, the outsourced heat treatment process could threaten the long-term existence of the company.

4.1.2. Proposed solution

In the authors view, customer lead times can principally be improved though two different strategies. The first strategy is to improve customer lead times by significantly increasing stocks, reducing transport wait times between the company and the site for the outsourced hardening process, and to work in closer relation with the company performing the hardening process in order to reduce their lead times. This strategy is problematic for many reasons. It implies significantly increased administration, increased dependency on the supplier and likely increased costs for the outsourced hardening process. Finally, the increased stock levels necessary are considerable. This implies increased costs of bound capital, increased risks of products going obsolete, etc.

The other strategy for improving the customer lead time is to perform the hardening process in-house, resulting in a significantly reduced production lead time. The total possible lead time reduction of this strategy, see chapter 4.1.5, is greater than that of the aforementioned strategy. Furthermore, it enables the company to regain control over this critical part of the manufacturing process, allowing it to control the product quality and engage in product development. In conclusion, this strategy for reducing the customer lead time is to be preferred.

Several different furnace types have been evaluated as a part of this project, which all have their merit. For example, the option of carburizing or carbonitriding has been evaluated since these are methods used by competitors in the industry. Both of these methods increase the surface hardness of the product while retaining a softer core, so called case-hardening[9].

The difference in material properties between the surface and the core is however considered negative by the company, as the absence of these differences, in the current product offering, is a selling point for the company. Furthermore, this hardening method poses limitations on the materials that can be used and the method is deemed unsuitable for some of the geometries produced[10]. This, coupled with the generally high purchase price of such furnaces, resulted in these production options being ruled out.

After ruling out some of the more elaborate furnace options, a Request for Quotation (RfQ) was formulated by the author, see appendix B, regarding traditional furnaces. These specifications are formulated in such a way that they satisfy the demands of the production, for example with regards to the production capacity. A similar RfQ was made for vacuum furnaces and both of these RfQs were sent to potential suppliers. For each furnace type, a price was requested both for a smaller and for a larger model. The smaller model would be capable of replacing the outsourced heat treatment whilst the larger model would also allow for replacing the hardening furnace used for the leather segment. Such a replacement would both simplify the production and improve the quality of the products in the leather segment.

Based on the discussions following these RfQs, the option of selecting a vacuum furnace was ruled out. This was mainly done due to their generally higher price, compared to traditional furnaces, and due to problems with the use of gas quenching. Specifically, a high gas flow is necessary when gas quenching, resulting in a significant circulation of the smaller products. This causes scratching and deformations on these smaller products, making gas quenching incompatible with the quality requirements. Given that gas quenching can not be used, the extra cost of a vacuum furnace can not be motivated.

The company has received quotations for three different traditional hardening furnaces. Two of these are fully automated with regards to the quenching process whilst the third is manual. It is the authors assessment that the manual alternative does not live up the the necessary specifications, see appendix B, and that there may be quality issues with this option. Furthermore, if installed in the current facilities, it would constitute a safety hazard.

The automated furnaces, however, are deemed to fulfill the specifications and could be integrated with the current process in a satisfactory manner. The quotations received for the two automated furnaces correspond to a cost of 1 800 000 SEK and 2 800 000 SEK, respectively. These furnaces are however in the high-end spectrum of furnaces, used mainly in the watch industry in Switzerland, and there is reason to believe that alternatives to these furnaces can be found at lower cost.

This sentiment is enforced by the fact that the price received for the manual furnace is 265 000 SEK, despite that this supplier also may be considered as a high-end supplier. Therefore, the following analysis will not regard any specific furnace, but rater elaborate on the possible size of investment for an automated furnace fulfilling the specifications. Changes to running costs and lead time are estimated based on the given quotations as well as the current production.

4.1.3. Risks

The current solution is associated with numerous risks, some of which have already been mentioned. Starting with risks directly relating to the current sole supplier, there is always the risk of supplier bankruptcy. This risk is however deemed to be low since the company has consistently made profit for the last 10 years and has a solidity of 54%, which is higher than the industry average[11].

The risk that the supplier might choose to stop offering this service is however significantly larger, since the supplier is focusing on providing hardening processes for larger units in larger orders. Despite the supplier being a small company, the total value of the outsourced heat treatment from Gerdins amounts to about 0.5% of the total turnover. This means that the exchange is rather insignificant to the supplier and, given that this service is not normally offered by the supplier, it is not self evident that the supplier will keep offering the service. And, even if this should be the case, there is no guarantee of the product quality, or lead times, remaining at the current levels.

Furthermore, apart from the risks directly relating to the supplier, there are also risks relating to the company. These include the risk of loosing market share as a result of not being able to conduct product development in-house, and the significant risk of loosing customers due to the long customer lead times. The dissatisfaction with the current solution among employees is likely to be a contributing factor to personnel problems or even to employment terminations.

On the other hand, there are also risks associated with the proposed investment. These are mainly related to the risk of the furnace not living up to specifications, despite investigations prior to the investment. The risk of furnace breakdown and uncertainties in figures regarding the investment constitute other risks. On the whole, these are however considered smaller than the risks of having an outsourced heat treatment.

4.1.4. Expected return on investment

The hardening furnace specifications, coupled with the investigation of received investment alternatives, are sufficient for estimating the annual usage cost. Together with the calculated cost of the current solution, this gives the annual amount saved by investing in the furnace. The profitability of the investment is then only dependent on the size of the investment, including shipment costs, installation costs and other expenses, see table 4.1.

Investment	800 000 SEK	1 000 000 SEK	1 200 000 SEK	1 800 000 SEK
PB	5.5 years	6.8 years	8.2 years	12.3 years
IRR	22.7%	18.9%	16.3%	11.8%

Table 4.1: Payback time (PB), in years, and Internal Rate of Return (IRR), in %, for a fully automated furnace satisfying the specifications, at different price points, in SEK.

The IRR takes into account the projected increase in sales volumes, as per company estimation, as well as the inflation. This investment, which is to be used for products which are currently offered and sold, implies a relatively low investment risk. As such, a payback time of about 7 years is accepted by the company, see table A.1. This corresponds to an investment of 1 025 000 SEK, including shipment costs, installation costs and other expenses.

This is however under the assumption that different baskets are used in the hardening and annealing furnaces. If the same baskets may be used, it is estimated that this would reduce the handling time by 15 minutes per batch, thus reducing the running cost. This would allow the furnace purchase price to be 250 000 SEK higher, whilst retaining the same payback time of 7 years.

Furthermore, these calculations disregard the shortened lead time obtained as a result of the investment. This also has a substantial value, tough it is difficult to estimate. It is however possible to make an estimation of the value of the decreased lead time by calculating the capital cost for an increase in stock which would have a similar effect. Note however that, the mechanics of having short production lead times and having large stock values are different and, as such, they are not directly comparable.

Assume there is stock, for each product, corresponding to the largest order volume received during a period corresponding to the lead time reduction. Then, the response towards the customer can be assumed to be similar to that obtained when reducing the lead time. As such, the capital cost of this needed extra stock can be used to calculate the value of the reduced lead time.

In order to accurately estimate the amount of stock needed, for each product, well structured sales data for all products is necessary. Due to lack of such data, an accurate estimation of this figure can not be calculated. Nevertheless, one may note that a significant fraction of the turnover is relating to products which are sold in low volumes, to less than 5 customers yearly. This fraction is estimated at about 40%. Furthermore, there are a significant amount of products which are not sold each year, and keeping those in stock would likely correspond to a bound capital larger than the yearly turnover. As a rough estimation it is therefore assumed that the stock level would need to be increased by about 50% of the yearly production volume, to give a similar response to the customer.

Therefore, the production lead time reduction obtained through this investment can be evaluated using the cost of bound capital induced by a stock corresponding to 50% of the yearly production volume, for this product segment. The value of this is calculated to 475 000 SEK. In other words, the investment size may increase by 475 000 SEK compared to the previously calculated figures, to account for the value of the reduced lead time, assuming a payback time of 7 years.

4.1.5. Product cost and lead time

By investing in on-site hardening, the production lead time is be reduced by 7.8 work days. Meanwhile, assuming an investment of 1 000 000 SEK, and that the baskets used are incompatible with those of the annealing furnaces, the production cost per batch is reduced by 24%. Note that this cost calculation does not include the value of the reduced lead time, which means that there is also a value increase which is not accounted for.

This investment will affect all graphic products but the impact on the production lead time and cost will be different for each product, mostly depending on batch size. The differences are however not substantial and, as such, they are here exemplified by the graphical product of medium diameter, see figures 4.1 and 4.2.

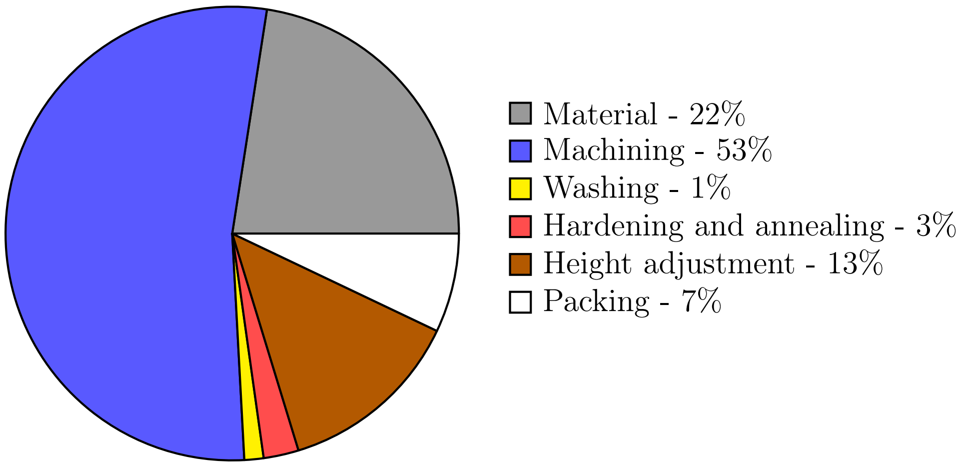

Figure 4.1: Breakdown of production cost (in %), after the furnace investment, for the representative product analyzed in chapter 3.2.2, for a batch size corresponding to half the annual order quantity. Management and sales costs not included.

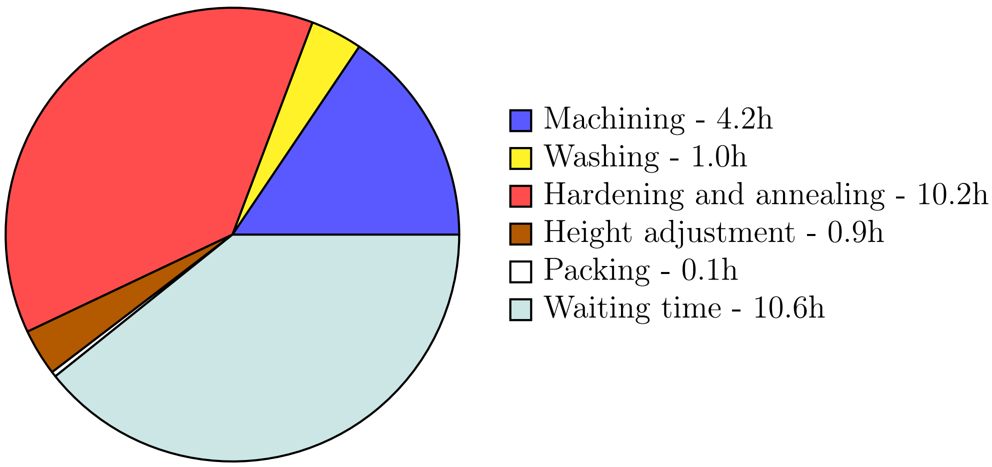

Figure 4.2: Breakdown of production lead time for the medium diameter graphic product, for a batch size corresponding to half the annual order quantity, after the furnace investment. Figures are in work hours (h), that is, if machines run outside work hours, this time is not included. The total production lead time is estimated at 3.5 work days.

The investment has little impact on the product cost, about 0.5%. This is expected as the cost includes depreciation and capital costs for the investment. Note also this cost reduction will apply to all graphic products. The lead time reduction is however significant, namely 70%. After the purchase of a furnace, the production lead time is lower than the accepted customer lead time, making the production lead time satisfactory.

4.1.6. Pros with new solution

- Significantly reduces production lead-time, to a level below the accepted customer lead time.
- Keeps core competences and core operations within company.
- Quality issues can be solved internally, in a faster and less resource-intensive fashion.
- Allows for process and quality optimization related to heat treatment.
- Reduces dependency on suppliers, both for the heat treatment and the transport, and its associated risks.
- Reduces variance in production lead time, allowing for better customer supply time predictions, to be communicated to customers.
- It is very popular with the staff which strongly encourages the investment. As such, it will have a positive effect on employee relations.
- Reduces need for planning and administration, resulting in better personnel utilization.
- Simplifies the production by removing several production steps.
- Reduces bottle necks, mainly in the height adjustment-stage, induced by the uneven flow of products of the current solution.
- It is likely that the quality obtained with a new furnace is higher than that provided by the outsourced hardening process.
- The automated traditional furnaces considered have the option of performing case-hardening operations, allowing for this to be employed in the future.

4.1.7. Cons with new solution

- Currently missing required in-house expertise.
- Larger dependency on key employees.
- Large uncertainties in the estimation of the value of the reduced production lead time. The estimation of 475 000 SEK is however believed to be in the right order of magnitude.

4.1.8. Recommendation

The analysis shows that a fully automated traditional furnace fulfilling the specifications detailed in appendix B may cost up to 1 025 000 SEK in order to fulfill the economic requirements of investments as posed by the company. But, other than the directly quantifiable economic value of the investment, there are a number of significant benefits to the investment, which are hard to quantify. The most important of those are the reduced lead time and the increased control over this core production step.

As stated in chapter 2.3, the lead time is important to customers, especially for the graphic segment. A failure to improve the lead time is likely to have a significant negative effect on sales, possibly putting the future of this product segment in jeopardy. On the other hand, a good customer lead time aligns well with the company' strategic goals of being a high-end supplier with focus on product quality.

In conclusion, the improved lead time, along with increased control over this core production step and other aspects of this investment, constitute motivation for accepting a higher purchase price. Based on the calculations in chapter 4.1.4, the author finds an increase in investment size by 475 000 SEK to be motivated. As such, it is the authors recommendation that a furnace be purchased, so long as the price of the purchase and installation does not exceed 1 500 000 SEK. Should it be possible to use the same baskets in both the hardening furnace and the annealing furnaces, the purchase and installation price may be allowed to increase by another 250 000 SEK, to 1 750 000 SEK. This means that one of the already received offers could be acceptable, provided a marginal price reduction. Considering the offers received, it is deemed that this should be possible to achieve.

4.2. Production machine

4.2.1. Issue

There are several problems linked to the production capability of the current machine park. First of all, production group E is composed of screw machines which are controlled mechanically. The operator of these machines will retire within 2.5 years and it is not deemed possible to find a replacement with the necessary qualifications to operate these machines. Therefore, the punches produced in these machines would have to be produced elsewhere, unless the sales of these products are to be discontinued. Also, this would open op for the possibility of producing pattern prickers in these machines as described in chapter 3.1.2.

Secondly, the production cost of the punches produced in production group G have been identified as possible to improve through the investment in new production capabilities. Other than affecting the production cost, it would also allow for production using harder materials, which is of importance during the selection of materials. This, in turn, affects the product quality.

Finally, it is also observed that graphical products could be produced in such a production machine, should the quality and production volume be satisfactory. As a result, all side drilling could be performed in the primary production machines, for those products which require side drilling. Therefore, production groups G and I would be rendered unnecessary, saving both space and money for the company. Furthermore, this would help to make the production process less complex.

4.2.2. Proposed solution

In order to solve the issues identified, it is necessary to buy one or more production machines which would

- be cost efficient
- be reliable and not require excessive time from operators
- provide the necessary production capacity
- be able to manufacture all necessary product types
- be able to manufacture all necessary product sizes
- not have too long changeover times
- use metal bars, rather than coil, as input material.

The manufacturing using metal bars, rather than coil, is necessary to achieve the required quality of the products produced in this machine. Based on these criteria there are two possible purchasing strategies.

The first option is that several CNC machines are purchased. This would imply a lower per-machine investment and larger flexibility. On other hand it would require investment in several machines due to the lower production rate, likely resulting in a considerable total investment. The alternative is to purchase a transfer machine, which would have higher production rate but be more expensive per unit. This would be suitable for higher production volumes and could then imply a lower production cost, compared to the purchase of several CNC machines.

It is not evident which of these strategies would be best for the company. The production machine would however mainly be used for the production of leather products, which are relatively high in volume. A transfer machine is already in use for this segment, as discussed in chapter 3.1.1. The production department is satisfied with the performance of this machine as it is a high-quality machine, requiring little time from operators in relation to its output. The only objection to this particular machine is economical, but these objections can largely be explained by low utilization rates resulting from low sales volumes. As this report advocates that sales volumes should be increased, even at the expense of the average sales margin, it would be inconsistent to invest in machinery adapted to low sales volumes.

As such, this report investigates the proposed solution of investing in a transfer machine for the machining of the articles in question. A request for proposal has been made by the author, see appendix C, and sent to the manufacturer of the transfer machine already owned by the company. The purpose of this is not to identify and recommend a specific investment but rather to investigate the feasibility of this kind of investment. Due to internal delays in the company, no proposal from the manufacturer has been received by the completion of this report. Therefore, the figures used in subsequent chapters, for the calculation of return on investment and lead time, are estimations based on machines previously purchased. These calculations may be updated at a later time, when more information is received from the manufacturer.

4.2.3. Risks

There are risks associated both with the current production machines, and with the proposed investment. The main risks with the current production is related to the machinery being relatively old. Firstly, the machines have been in operation for the better part of a century. During this time, changes have been made to the machines and modules have been added. This, coupled with the lack of maintenance performed for these machines in recent years, makes some of the machines, or their modules, prone to break down. As such, there is a risk of maintenance costs and unplanned downtime increasing in upcoming years.

Secondly, the outdated technology used in many of these machines makes the production more dependent on the current personnel. This is the result of people outside the company being unlikely to be familiar with similar machines and their operation. Therefore, there is a risk of production disturbances related to employment terminations. Finally, the machines are unable to work with harder materials, making the company unable to select materials freely. As such, there is a risk of losing the competitive advantage of providing products of better quality than competitors.

On the other hand, there are a number of risks with the proposed investment. These are largely relating to uncertainties in the information obtained regarding the investment. That is, while these risks are considerable at the time of this feasibility study, they may be mitigated through further investigations. The main risks are in the estimated machine specifications, the estimated machine cost, the assumed future production volume used in the investment calculations and the risk of miscommunications between the company and the supplier. E.g., when the previous transfer machine was purchased from the supplier, there were a number of misunderstandings regarding its production capabilities and the purchased machine was incapable of producing all product types it was desired to produce.

4.2.4. Expected return on investment

The return on investment is calculated under the assumption that the proposed investment is able to replace the production of punches in production groups E, G, K and I and that the investment cost is similar to that of production machine W. Costs associated with production group E are divided into two categories for this calculation, those which will, and those which will not remain after the investment. The costs which will remain for production group E after the investment are those associated with the production of pattern prickers. For the remaining production groups, no costs are assumed to remain after the proposed investment.

It is the authors belief that these are reasonable assumptions at this stage of the analysis. There is however a risk that the supplier may not be able to provide a transfer machine to the specifications, in which case it may not be able to replace all the aforementioned production groups entirely. Note also that one machine in production group G is devoted to a specialty product, which the transfer machine will not be able to manufacture. Volumes for this product are however low and this has therefore not been considered in the calculations.

Given the aforementioned assumptions, the expected payback time is 3.6 years and the expected IRR is 28.7%. Note however that the expected return on investment may change as more accurate data is obtained.

4.2.5. Product cost and lead time

Following the proposed investment, the production cost is expected to decrease. For the representative products addressed in chapters 3.1.3 and 3.1.4, the production cost is expected to be reduced by 68% and 17% respectively. See figures 4.3 and 4.4 for a cost breakdown. Note however that, this investment will make the production more volume dependent, by increasing the per-batch costs. This means that certain low-volume products may not be cheaper to produce in the transfer machine. This also implies that this investment should come with a change in operations management towards larger batch sizes. If this is employed, costs can be further reduced.

Furthermore, the production lead time is also affected by the proposed investment. For the representative products addressed in chapters 3.1.3 and 3.1.4, the production lead time is expected to be reduced by 15% and increased by 0.2% respectively. This demonstrates the lead times dependency on volume. Namely, small orders may get a longer production lead time as a result of the proposed investment, whilst larger orders or articles which require side drilling will get shorter lead times as a result of the proposed investment.

The proposed investment' affect on production lead time is however not as significant as the affect on the production cost.

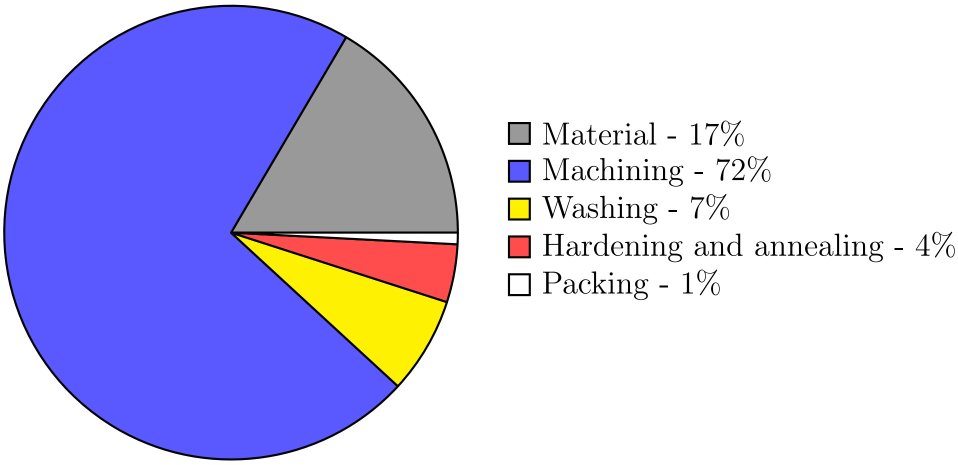

Figure 4.3: Breakdown of production cost (in %), after the production machine investment, for the representative product analyzed in chapter 3.1.3, for a batch size corresponding to half the annual order quantity. Management and sales costs not included.

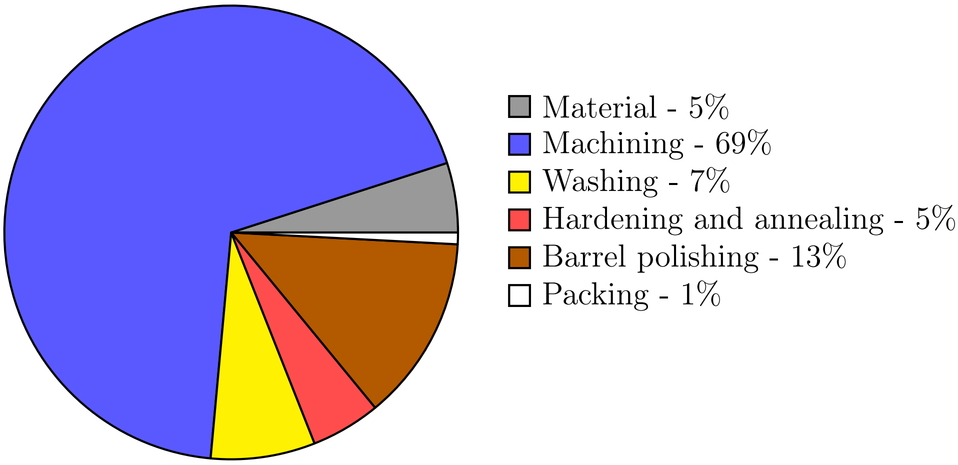

Figure 4.4: Breakdown of production cost (in %), after the production machine investment, for the representative product analyzed in chapter 3.1.4, for a batch size corresponding to half the annual order quantity. Management and sales costs not included.

Perhaps more importantly, however, is the effect the proposed investment will have on machine utilization. That is, production which is currently distributed between numerous production machines with low utilization rates, is moved to a single production machine, which consequently will have a higher utilization rate. As a result, the risk that a machine is not available at the time when a manufacturing order is placed, increases. This may have a negative effect on the customer lead time. By extension, it is necessary to maintain an increased stock level to mitigate this problem. For more information see chapter 2.4 and figure 2.1 in particular.

Finally, it shall be noted that the proposed production machine is to be used for the leather segment. That is, volumes are higher than for the graphic segment and products are more standardized, making it more appropriate to have larger stock volumes. Note also that, for this product segment, the production cost is deemed more important than the customer lead time.

4.2.6. Pros with new solution

- Solves the problem of not being able to produce VICOP punches of larger dimensions after personnel retirement. Whilst the turnover is small for these products, compared to other leather products, they are an important part of the product offering, and thereby affect customers in the whole leather segment, which constitutes 60% of the total turnover.

- Makes production group E available for the production of pattern prickers.

- Is estimated to significantly reduce production costs. The reduction varies from product to product, but for the two representative products analyzed, the reduction is estimated at 68% and 17% respectively. The favorable economic aspects of the investment are also reflected by the payback time, as estimated to 3.6 years.

- Makes side drilling in production groups G and I unnecessary, resulting in lower costs and production complexity after its removal.

- Largely replaces production group G, resulting in lower costs and production complexity after its partial removal.

- Reduced personnel dependency, as a result of the usage of more modern equipment.

- Greatly simplifies the production, since fewer machines types, from fewer manufactures, will remain.

- Allows for production with harder materials, allowing for a freer choice of materials. This decreases the risk of being unable to offer better quality than competitors.

4.2.7. Cons with new solution

- There is an uncertainty in the assumptions made for the calculations.
- The new machine would be more suitable for high-volume production, thus requiring larger stocks and increasing the risk of the machine not being available at the reception of a order, see figure 2.1.
- This constitutes a relatively large investment for the company, witch leverages the risks of the investment, as compared to alternative investments.

4.2.8. Recommendation

The proposed investment shows economical potential (PB = 3.6 years and IRR = 28.7%), along with several other positive effects. Note that while the calculated savings are significant even at current volumes, they are even more significant at larger production volumes. This is the result of the proposed production machine being well adapted for high production volumes.

The main limitation is the risk of increased customer lead times, which implies a need for increased stock levels as a result of the investment. The associated cost is however small in comparison the the cost savings implied.

In conclusion, the proposed investment is promising, though the investment has to be further investigated. Therefore, it is strongly advised that a further analysis be made with regards to the proposed investment, when more accurate data has been received from the supplier.

4.3. Charpy test rig

4.3.1. Issue

Quality is a core value at the company and the customers regard it as one of the mayor selling points. The company prides itself on providing high-quality products and is ISO 9001-certified. ISO 9001 is a quality management standard by the International Organization for Standardization (ISO)[12].

As such, it is important for the company to deliver high-quality products, and hardness testing has become standard procedure when evaluating the quality of batches produced. The company does however not have any way of measuring the toughness of the products produced even though it is a central component of the product quality. Not only the product hardness, but also its toughness, is of importance when the products are used. Other material properties may also be of some interest but these are generally more difficult to measure and interpret. Therefore, the measurement of other material properties is not deemed feasible for the company.

By not having the means to measure the product toughness[13], improvements to the hardening process cannot be performed at the company. This problem also extends to a lack of competence in the area. As such, the company runs the risk of loosing market share to competitors who continuously improve their products, something which has already been observed by the sales department.

Furthermore, a resent supply shortage of the steel used in production has forced the company to use another steel, which they know satisfies the quality standards. This does, as elaborated in chapter 3.2.3, cause serious problems in the production, resulting in significantly increased production cost and lead time. The ability to measure material toughness would allow for the selection of a different material which also satisfies the quality standards but has a favorable machineability.

4.3.2. Proposed solution

There are several ways in which the material toughness may be assessed. In this case, the investment in a Charpy test rig is advised, mainly due to the feasibility aspects relating to the investment size and the equipment usage. Furthermore, it is advised that the company appoints one person to be in charge of quality assurance. This person would then have responsibility over the optimization of the hardening process to achieve a desired hardness and toughness. Furthermore, this person would, using both new and existing equipment, be able to assess the quality that can be achieved with new materials. This is crucial in making sure that the company has the opportunity to change materials as new and better materials become available.

Based on the material specifications provided by the current material supplier, these materials imply the need of an impact strength capacity of about 20J, post hardening processes. This is relatively low for a steel, meaning that a bit of a margin would be desirable, to allow for testing of other relevant materials.

Note that the toughness of a specimen post-hardening depends on parameters such as geometry. Therefore, toughness testing of non-standard specimen may be of interest as it could allow for testing of the actual product. It would also reduce the need for specimen machining. Should the company choose to use non-standard specimen, a larger capacity may however be necessary.

Reviewing the market for Charpy test rigs, this leaves two options. Either, a test rig with a capacity of 50J could be purchased, or one with a capacity på 150J. Test rigs with a capacity of 50J are made primarily for Charpy tests in plastic whilst those with a capacity of 150J are primarily for metal/steel. It is deemed that a simple, analogue, version of a Charpy test rig would be sufficient to meet the company needs. As such, test rigs of the lower capacity can be found to a price of approximately 15 000 SEK[14], whilst the larger capacity rigs can be found for a price of approximately 20 000 SEK[15][16]. Note that these prices are for simple rigs in the lower price segment. More sophisticated versions of these test rigs may be significantly more expensive.

Finally, it has been concluded that standardized specimen can be manufactured with existing equipment though it would likely require some programming. The costs for this is arguably negligible as this can be done during periods of overcapacity.

4.3.3. Risks

The largest risk with the investment is that the rig isn't put to proper use after it is purchased, either due to a lack of competence or a failure to see the necessity. Both these risks can be reduced greatly by making sure that the management takes initiative in the question and appoints a person responsible for the quality assurance as suggested above.

The risks of not making the investment are however arguably larger than the risk of investment. As explained above, not investing the in quality assurance and improvements is likely to lead to a reduced market share as a result of quality improvements from competitors. It also makes the company unable to assess new materials or improve the hardening process.

While choosing a Charpy test with lower capacity would be a cheaper option, it also impels the risk of the capacity being to small for some of the specimens tested. Since these are generally adapted for fracture toughness testing of plastics, there is also a risk of the equipment not following all desired standards for metal testing.

4.3.4. Expected return on investment

It is not possible to accurately estimate the return on investment for this investment since it regards quality testing equipment to be used mainly in development. Neither is the investment large enough to motivate such an analysis. Therefore, no such analysis has been conducted.

4.3.5. Pros with new solution

- Adds new aspect taken into consideration for the quality assurance.
- Significantly facilitates the selection of new materials.
- Allows for continuous improvements to, and optimization of, the hardening process.

4.3.6. Cons with new solution

- There are few quality complaints, which indicates that this may be an unnecessary investment.
- There is a risk that this equipment might not be put to its full use, this risk can however be mitigated by the management.
- If a Charpy test rig with a capacity of 50J is chosen, this could potentially result in capacity problems for some materials tested. There is also a risk of the equipment not being suitable for metal testing.

4.3.7. Recommendation

The equipment is crucial to the continued quality development of the product range and is also important for questions of material selection. The upside of this investment outweighs its potential downsides. Therefore, the author recommends that this investment be made, under the condition that management undertakes necessary steps to implement its usage. The purchase of a Charpy test rig with a capacity of 150J is advised.

4.4. Oil bath selector system

4.4.1. Issue

The production machines are not able to run at night unless there is a storage system for finished goods following the machine. For one of the production machines, investigated in chapter 3.2.2, such a storage system is missing. This results in the machine not being run at night, and thereby longer production lead times as well as lower production capacity. It shall also be noted that more manual work is needed for the machine, since the storage needs to be emptied more frequently. This is however a marginal effect.

4.4.2. Proposed solution

It is proposed that an oil bath selector system is purchased, which is a system of trays submerged in oil that collects and stores parts manufactured in the preceding production machine. This solution has a cooling capacity, prevents part clashing and, importantly, increases the storage capacity following the production machine. As such, it allows for night runs of the production machine in question. The company has been quoted an oil bath selector system, which meets the requirements of the process, for a price of 61 743 SEK.

4.4.3. Risks

By making this investment, production capacity will be increased. It will however not result in any increased profit unless this production capacity is actually used. Since the company currently has unused capacity, this risk is deemed significant. The cost of depreciation, calculated as an annuity, is 6447 SEK/year.

It shall however be noted that there are significant fluctuations in order quantities, on a yearly basis. In the past, the machine in question has been running at full capacity. As a result, there is also a risk of having insufficient production capacity should demand increase. Since the delivery time for this product is approximately 15 weeks, this risk is not deemed to be moderate.

4.4.4. Expected return of investment

The yearly cash inflow from the investment can be seen as the added value of the investment to the production, minus the added cost. To make this calculation, the added hourly value is assumed to be equal to the current hourly production cost. As such, the yearly cash inflow is calculated to be

$$I = \frac{c_{old}}{t_{old}} \times (t_{new} - t_{old}) - (c_{new} - c_{old}) \tag{4.1}$$

where c_{old} and t_{old} are the yearly production cost and yearly production hours prior to the investment. c_{new} and t_{new} are the yearly production cost and yearly production hours after to the investment. Based on this, the payback time is calculated to 0.35 years assuming all the extra capacity is utilized and 0.7 years if only half the extra capacity is utilized. Note that the relation is not linear between utilization rate and the payback time.

Alternatively, the internal rate of return can be calculated for the investment. The IRR corresponds to 287% and 144% for full and half utilization of the extra capacity, respectively.

4.4.5. Product cost and lead time

Assuming full utilization of the increased production capacity, the production cost would decrease by 12% as a result of the investment. The effect on production lead time for the average customer batch size is dependent on the time at which the order is received, but is expected to be about 0.2%. More importantly, by providing a higher production capacity, the risk of production machines not being available for production when orders are received, is reduced, see figure 2.1. As such, the effect on the customer lead time is likely more significant.

4.4.6. Pros with new solution

- Allows production at night, resulting in a cost reduction of up to 12%.
- Allows production at night, resulting in a larger production capacity.
- Allows production at night, resulting in a reduced customer lead time.
- Removes the need for stacking products upon exit from the production machine.
- Reduced need for direct manual labor at the machine, due to a less frequent need for emptying the storage following the production machine.

4.4.7. Cons with new solution

- There is a risk of the equipment not being fully utilized, as there is currently an overcapacity in the production.

4.4.8. Recommendation

The benefits of this investment clearly outweighs the risks and the return on investment is substantial. The investment is economical even for very low utilization rates of the equipment. Therefore, this investment is strongly recommended.

5. Discussion

5.1. Overcapacity

It is important to understand that many investments free up labor (or machine) resources from production. In order for these investments to perform the calculated return on investment, it is necessary that the freed-up resources do not remain unused. If freed-up labor is unused, no decrease in labor cost can be ascribed to an investment.

All free production capacity corresponds to a cost, weather it be unused machine capacity or unused labor. That is, the actual production cost of the products produced is increased, to account for this unused capacity. The unit production cost does therefore decrease when increasing the utilization rate, as observed in chapter 3.1.

In conclusion, any overcapacity has to be utilized, to decrease resource waste, referred to as *Muda* in lean production[17]. Overcapacity can be utilized in different ways. For example, the company may use the overcapacity to increase production by producing against stock rather than against customer orders. Furthermore, the freed-up resources can be used to do a larger fraction of the production in-house. Alternatively, personnel may engage in maintenance work, or research and development (R&D) activities. Note that, at Gerdins, there is no dedicated R&D department and, as a result, the product development is largely carried out by the production department.

5.2. Production and stock volume

Keeping down the amount of tied-up capital at a company has been an important topic of discussion in industry over the past years[18], since this management philosophy was popularized by Toyota. Decreasing the amount of tied-up capital in material and product stock can be incredibly important as it can allow for investments in machinery and reduces the risk of material and products becoming obsolete while in stock.

This is especially important in the car industry, where this movement started[19]. There are many reasons as to why this philosophy works well in the car manufacturing industry. The main reason is that, in the car industry, an overwhelming majority of costs come from suppliers. About 80% of the costs are supply costs and margins are typically low[20].

Therefore, a pull-production is typically implemented[21]. That is, the company only produces cars if there is a demand for them and they are not producing to stock. This is beneficial as it reduces the amount of parts that the company needs to buy, parts which cost much more than the profit margin of a sold car[21]. This also prevents that cars get obsolete while in stock.

The situation is however much different at the perforating punches department of Gerdins. Material costs constitutes only a small fraction of the total production cost and products in stock are typically not rendered obsolete.

A pure pull-production approach is not to be advised as it implies that machines are not run to capacity. Reducing the production volume does not come with significant cost savings. Most costs in production are fixed and not utilizing the production capacity that they render is a waste of resources.

The marginal cost for producing more punches is largely made up of material costs, which are quite low. Therefore, the marginal production cost can be as low as 10% of the total production cost, in the current production. Note that it is important to base the calculations of stock value on the production cost, and not the sales price, when doing internal calculations for decisions related to production. If not, the results may appear misleading.

In conclusion, due to the low marginal production cost and low risk of product stock getting obsolete, a push-production approach is preferable, in the case of high volume products. These high-volume products should be produced at full capacity against product stock. When stock values get too high, they can be sold off by offering the products at lower price to new markets. It then becomes a way to obtain new costumers on new markets without risking a reduction in future sales volumes on current markets. Offers received by potential future customers, on new markets, indicate that large volumes can be sold at a profitable price point. This high-volume production strategy would lead to significantly lower unit production costs, as exemplified in chapter 3.1, and thereby increased profits overall. Note that the costs for stocking, i.e. rent, product handling, etc., are independent of the amount of items in stock, as a result of the products being small and the storage area being large.

Meanwhile, products with exceptionally low sales volumes may be produced against order, rather than stock, but there should be a minimum order quantity established. The usage of a minimum order quantity is of importance since changeover costs in the production of small batches is substantial. As a result, small orders for low volume products are never profitable.

5.3. Operations management

Currently, the company manually compares the stock volume to the average yearly sales volume on a bi-annual basis to determine if production orders are to be placed. Apart from this, production orders are also placed against customer order. While this approach allows the company to manufacture against stock, it leaves room for improvement as this approach as a few issues.

Firstly, the activity is labor intensive, which incurs significant yearly costs. Secondly, it is dependent on key people within management, resulting in issues and frustration when these people are unavailable. Finally, since the assessment is only done bi-annually, there are significant variations in production order volume over time, making the assessment sub-optimal.

An alternative solution would be to automate the production planning using software. Then, production orders can be suggested based on current stock levels and historical customer orders, using a probabilistic approach. For example, production orders may be issued unless all customer orders regarding a given product, received during the upcoming 3 months, can be supplied from stock, with a probability of 95%. This approach would help to reduce customer lead times, compared to the current model.

Meanwhile, an optimal production order quantity can also be calculated, for example using the Economic Order Quantity (EOQ)[22]. This model would however have to be adjusted with regards to a desired production flexibility and for products with few, but large, orders.

Finally, such software could also recognize when the desired stock levels have been reached and then place orders on products to be used for high volume products to be used for sales pushes. As such, this integrated system could free up labor whilst providing well optimized and updated suggestions. This kind of solution may be implemented either through the currently used ERP-system directly, or by creating a separate program communicating through its Application Programming Interface (API).

5.4. Sales and management costs

Currently, the management and sales costs in the department of perforating punches at Gerdins, correspond to a mark-up of 19.4% on the production cost. On top of this comes the corporate management costs. Increasing the sales volumes, as proposed throughout this report, would likely reduce the mark-up for these costs. It will however increase the absolute costs as more sales activities are necessary.

The changes to operations management, as proposed in chapter 5.3, coupled with changes to the layout of the shipping area, will free up time for sales activities and make those more efficient. Furthermore, it is recommended that more of the decisions regarding production shall be left to the production department. This would allow for these decisions to be reached more effectively whilst also freeing up more time for management and sales activities.

Management shall however be aware that this may not be enough to allow for the desired sales increase. More labor resources may need to be allocated, for example by hiring more personnel.

5.5. Evaluation of research method used

There are many different ways that the questions posted in the problem statement of this report, see chapter 1.3, can be investigated. The choice of method depends on factors such as the resources allocated to the investigation, the accuracy needed and the expected application of the findings. In this report, the method described in chapter 1.5 was used. In this chapter, error sources and other relevant considerations for interpreting the results, are discussed. It also points out possible changes to the method to be used in future investigations.

5.5.1. Identifying investments

Arguably, the identification of relevant investment alternatives is one of the most crucial components of any investment analysis. Oftentimes, this identification process is reactive, that is, investments are considered only when the current solution is no longer functional. Sometimes, investments are not even considered in these cases. The use of a proactive investment strategy is preferable[23], but puts higher demands on the analysis.

This report attempts to employ a proactive investment strategy by not only identifying current problems in the production but also future opportunities and threats. This has been achieved through extensive dialogues with employees, coupled with the lead time and cost analysis for representative products. Initially, the running of a complete simulation of the production was considered as an alternative to the analysis in chapter 3. Such an analysis would have provided more information regarding bottle necks and given an understanding not only of the manufacturing of representative products, but of all products. This analysis was however not deemed possible to execute with the resources available due to the complexity of the production.

The method used has identified both proactive and reactive investments, which have not been previously analyzed by the company. For this particular case, it is believed that the method used provides the required accuracy and ability to identify investment. It shall however be noted that this part of the investigation was particularly resource intensive and, as such, the author recognizes that the company will not be able to conduct investment analysis on a regular basis using this approach.

5.5.2. Economic models

The economic model used for estimating the product production cost is, as commented, a complex version of the ABC model. This makes the model more accurate than commonly used alternatives. The model is, as commented, largely time-based and uses the hourly machine and labor cost for the calculations. The focus of this model is to enable the highlighting of mayor cost drivers for each production step, to allow for cost reductions, either though investments or through changes in the production management.

An important reason for choosing this particular model is that it gives a similar cost breakdown to the models already used by the company. Whilst having this similarity to the cost models used, it is however significantly more complex and requires input data which is not systematically collected by the company. As such, it is not feasible for the company to use this particular model as a basis for the calculation of production costs. Nevertheless, it is recommended that the company improve the accounting of costs to allow for a more accurate determination of the cost source. The traditional costing model currently used by the company is, in some instances, subject to large errors. This is partially due to the model used, and partially due to its implementation.

Finally, it shall be noted that the cost model is dependent on the discount rate used for investments in equipment. Therefore, changes to the discount rate may have an impact on the recommendations in this report.

5.5.3. Lead time variations

There are large variations in both lead time for the outsourced hardening production step and for the wait time. This variation naturally depends on a variety of factors, such as utilization rate, order priority and the performance of third parties. Given that there is a limited access to data regarding lead times, this results in an error source to the analysis.

An example of the variations in lead time can be observed in the outsourced hardening process. The outsourced hardening process will take a minimum of 5 work days, including the following annealing process. Meanwhile, assuming the production capacity in not underutilized, this production step is estimated to increase the total lead time by an average of 9.4 days. This includes added waiting times and transport times that are directly caused by the outsourced hardening process. This constitutes significant variations to the lead time.

It shall further be observed that, whilst the lead time for the outsourced hardening production step is hard to affect, as much of it depends on third parties, the wait time is easier to influence. This may be a reasons for the large variations in wait time. Namely, when producing against customer orders, the corresponding production orders are prioritized and the wait time is therefore reduced.

The data concerning wait time, as collected specifically for this report, indicates that the wait time may be lower for products that are sent for external hardening. This may be a result of better planning and a greater awareness of the lead time issue, but there is not enough data to support this theory.

In conclusion, the fact that there is a substantial variation in both wait times and lead times for the outsourced production step is a source of error for the calculations made in this report. These two figures have both been measured during the execution of the study, as the company does not keep record of these figures. As such, the resulting data is likely affected by the low utilization rate which marked the period during which this report was conducted.

The great variations in wait time combined with a lack of data has resulted in the assumption that lead times are constant. While the number of articles per batch may have an impact on the wait time, the largest factor is likely the number of production steps, as products are likely to wait between operations. Since the number of operations are largely constant, the simplification seems justified.

5.6. Recommendations

There are a number of changes to the production and production management which the author would like to advise the company to undertake. These proposed changes are listed below, some up them have previously been addressed.

- Better utilize overcapacity for value-adding activities, such as R&D. See chapter 5.1.
- Focus on the increase of production and sales volumes rather than prioritizing the minimization of capital costs. Any overproduction can likely be sold at profitable prices on new markets, see chapter 5.2. Note that the cost of capital, tied up in stock, shall be based on the production cost, rather than the sales price.
- Extend the usage of the production planning software, which would require resources to set aside. This would reduce the planning time necessary, as estimated to 6 weeks of full time work annually whilst also providing better production planning, see chapter 5.3.
- Calculate optimal batch sizes to be used as a guideline when placing production orders.
- Remove machines which are no longer in use and remove oil barrels stored on the production floor. This would make movement and transportation easier on the factory floor, make cleaning operations easier and allow employees to more easily (visually) check that machines are running according to plan.
- Implement the 5S methodology, from the lean manufacturing philosophy. 5S is built on the 5 pillars, *Sort, Set in order, Shine, Standardize* and *Sustain*[24]. It is the belief of the author that the company would greatly benefit from the implementation of 5S, as the company lacks order and structure in the factory.
- Add post-production quality check which does not necessarily have to be for each batch. This would help with the company's overall focus on quality and to make sure that quality does not decline over time, which otherwise constitutes a significant risk.
- The setup time, and thereby cost, is dependent on which product the machine was previously set to manufacture. In some instances, this can make the difference between a 1 minute setup time or a 7 hour setup time. The key aspect is that the setup is shorter between similar products. Therefore, it is advised that all products be divided into product groups, within which the setup times are short. Then, if placing a production order on one of the products in the group, orders may be placed on the other products too. This would reduce the resources spent on machine setup.

- Delegate more production-related operational decisions and responsibility to the production department. This would free up time for sales activities for the sales and management personnel, see chapter 5.3. Meanwhile, it would allow the production team to work with more autonomy. This is a necessity since many projects and issues are delayed significantly due to sales trips and other absences on the part of the management.

- Improve communications between the production department and corporate management. This is necessary for the long term prosperity of the company. In particular, it is of importance that the R&D projects undertaken, which imply significant cost, are also properly capitalized. To accomplish this, it is necessary that production, sales and management discuss the development projects undertaken, their benefits and the customer offer, including the sales price.

- Work actively to provide better data for decision making, especially in relation to lead times and production costs. Currently, relevant data is missing or only logged for the department as a whole. For example, the production lead time is not measured at all by the company, making any related improvement work difficult. Similarly, machine reparation costs are only reported for the department as a whole, making analysis of product production costs very difficult. Furthermore, the access to better data would much facilitate future investment evaluations and help identify products which are under priced or generate significant losses.

- Work more actively to identify and evaluate investment opportunities. Currently, this has a low priority within the company.

- Make the distinction between internal and external accounting at the company, especially when it comes to investments. It's unreasonable to assume that the value of machines depreciate to nothing within 5 years, when machines are typically used for up to 40 years. This way of accounting will make most investments appear poor, even if this is not the case. Also make the distinction between the decision rule, ex. PB $<$ 7 years, and the machine depreciation. In this report, annuity is used to calculate the depreciation.

- When performing a post-calculation on investments, care shall be taken to include all costs of the pre-investment solution. If this is not done, the assessment will be inaccurate.

5.7. Further research

There are a number of changes to the production and production management which lie outside the scope of this report, which the author would advise the company to investigate further. Further research within these areas are likely to result in profitable investments or managerial changes.

- Reducing lead times internally can be quite expensive and an alternative to this is the reduction of lead times in the transport of products to the customers. These lead times have been commented to be high by some customers. It is proposed that a small study be conducted with regards to the actual transport time and how it can be reduced.
- Investigate the possibility of in-house production of screws, and other parts, used for the punches. It is likely to be cheaper than buying them, and would allow for usage of the overcapacity. Furthermore, it would make the company less dependent on suppliers.
- The production of *Easy Setter Pins* is an opportunity worth considering, see chapter 3.3. It does however require that a dialogue be started with the patent holders of this product. It is advised that such a dialogue be started to investigate this opportunity.
- As the company strives to focus evermore on quality and on the top-price segment, providing customers with individualized products may be a logical and profitable diversification of the current product offering. Specifically, the company could implement a solution where customers choose some variables or measures freely trough the web page, resulting in the automatic rendering of 3d-models which can then be supplied to the CNC machines for production. A market analysis should be carried out before any investments are made into the development project. If successful, this project could make the company less vulnerable to low cost alternatives and competition.
- The products in the graphic segment of the current production are stacked and re-stacked manually at many points in the production process, which implies significant manual handling costs. Solutions to this problem should be evaluated. A possible such solution would be the use of trays, on which the punches may be stacked in the same man-

ner throughout the whole production. This would reduce the need for stacking to one point in the production.

- The choice of production material should be re-evaluated. The use of harder steels may allow for targeting new markets, such as the electronics market. That harder material would not necessarily have to be used in all production. Meanwhile, provided the significant development of new materials, it is probable that materials could be found which have better hardness and toughness properties whilst retaining the same level of machinablility.

- More careful consideration shall be taken to the price level of the products and an investigation on this subject is advised. It appears advisable that prices be increased in accordance with inflation. Furthermore, there are a number of special products which are rumored to be much more expensive to buy from our competitors, this should be investigated and prices adjusted in accordance with the findings. Note that customers do not find the company product offering to be expensive, which indicates that the price point is not too high. Furthermore, care should be taken regarding services and products sold internally, or services sold externally, which should not be priced lower than the variable costs associated. This appears to be the case in some instances.

6. Conclusion

This report identifies and investigates investments opportunities and elaborate on operational and managerial strategies which are prudent in the production of perforating punches, using Gerdins Cutting Technology AB as a case study. Three key issues were identified, for which suitable investments and managerial changes were identified.

Firstly, the importance of lead times was established and elaborated. It was concluded that this aspect of the production requires more attention than it is currently given, based on customer input. It is believed that the customer lead time is crucial in retaining customers and gaining market share. In order to improve customer lead times, stock levels need to be increased and the production lead time needs to be decreased. In order for the production lead times to be sufficiently decreased it is necessary to invest in an in-house hardening process for which a new hardening furnace is necessary. Provided specifications as outlined in this report, a purchasing price of up to 1 750 000 SEK is deemed acceptable.

Secondly, the problem of increasing production costs was identified. It was concluded that this issue is induced by a decrease in production and sales volumes. As a result of large fixed costs, the production is considerably volume dependent. Therefore it is advised that sales volumes be increased, even at the expense of the average unit sales price, as it will improve the profitability of the operation. It was also shown that that the company needs to produce larger batches and the benefits of having larger stock values was shown to be large in comparison to the added capital cost.

However, the production cost may also be decreased through investments. Namely, the investment in an oil bath selector system is advisable as it will increase production capacity and flexibility at a low cost. Furthermore, the investment in a production machine, to replace several production groups, has been investigated. It was found that this proposed investment has potential for being highly profitable, but will require further investigations.

Thirdly, the quality development of the products was addressed. Whilst the customers deem the product quality to be good, it has been observed that the product quality of the competition is significant. As such, it is necessary to work more actively to ensure and improve product quality. This report advises that a Charpy test rig be purchased, to allow for fracture toughness testing of the products. Furthermore, it is advised that this be accompanied by the appointment of a employee reasonable for quality assurance, who would work with the optimization of the hardening process and the material selection.

Finally, further improvements are advised, such as improvements to the production planning procedure and an increased focus on 5S. Further investigations regarding price levels, material selection and delivery options, as well as new projects, are proposed.

The report gives the reader insight into the challenges of manufacturers on the global and local perforating punches markets. It highlights important considerations for the manufacturing of these products and related operational considerations. As such, it may serve as a reference for future investigations on the subject. The method used provides a many-faceted view of the company analyzed, and may therefore be of interest to any study of smaller production companies.

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Appendices

A.
Investment analysis at Gerdins Cutting technology

A.1. Introduction

This document is meant to serve as a guide for calculating the profitability of investments at Gerdins, for example into new machinery. It is meant to outline the procedure as well as to contain crucial data needed to make the calculations.

A.2. Return expectations

A.2.1. WACC

The Weighted Average Cost of Capital (WACC) is calculated for the company. This is done using the interest rate and amount of bank loans (i_{loan} and a_{loan}), as well as the expected rate of return and on equity (i_{equity}), the equity amount (a_{equity}) and the amount of untaxed equity founds (i_{equity}). The untaxed equity is adjusted for the corporate tax rate of 20,6%[7], resulting in the WACC as calculated through equation A.1.

$$WACC = \frac{a_{loan} \times i_{loan} + (a_{equity} + a_{found} \times 0.794) \times i_{equity}}{a_{loan} + a_{equity} + a_{found} \times 0.794} = 6.82\% \tag{A.1}$$

This WACC is the necessary return on any capital invested in the company, if the expectations of both lenders and owners are to be met. Therefore, the WACC marks the lower limit of acceptable returns. For more risk filled investments, higher returns are however desired, as elaborated below.

A.2.2. Risk

For capital bound in storage of material, finsihed products or Work In Progress (WIP), risks are low. As such, the WACC can be used directly for calculating the cost of bound capital.

If an investment implies higher risk, for example as a result of unsure data, then a higher expected return is necessary. This is the case since investments with higher risk reduce the stability of the company since they sometimes fail. GTC has traditionally used the payback method (PB) to calculate the profitability of investments. In such case, a pay-back time of 7 years has been seen as the maximum acceptable. Based on this, table A.1 outlines the acceptable PB times based on the risk level.

Risk level	Details	PB	Discount rate
0	Used as internal rate of return for storage of material, WIP and finished products.	-	6.82%
1	Used for investments in machines which are central in the current production or are replacement investments for already existing machines.	7 y	-
2	Used for investments in machines to be used for producing new product groups for which sales risks have been largely mitigated or where the data is believed to be accurate.	6 y	-
3	Used for investments in machines to be used for producing new product groups for which sales are uncertain or for which data is particularly scarce.	5 y	-

Table A.1: Outline of the payback time (PB), in years, and discount rate, in %, for different risk levels.

A.3. Investments

Since it takes time to conduct any sort of investment analysis, not all investments require the same rigid investment analysis. If the investment is too small, conducting the analysis will be to expensive in comparison to the cost of the actual investment. Therefore, the necessary investment analysis depends on the investment size, in accordance with figure A.2.

Investment	Required analysis
< 50 000 SEK	No investment analysis needed.
< 1 500 000 SEK	A simplified investment analysis is to be made.
> 1 500 000 SEK	A full investment analysis is to be made, taking all relevant factors into consideration, for example the indirect impact of the investment on other parts of the production.

Table A.2: The necessary investment analysis depending on the size of the investment

Below follows an overview on how the different kinds of investment analysis' is to be carried out. It is important to remember that not all aspects of an investment analysis are easily quantified. For example, it can be hard to estimate the value of short lead times or a reduced supply risk.

A.3.1. Conducting a simplified investment analysis

When conducting a simplified investment analysis the purely economic aspects of the investment shall be evaluated an be presented in the form of a pay-back time (PB). Other benefits and shortcomings of the proposed investment shall also be listed, such as the reduction of lead-time, bound capital and production flexibility.

The PB can be calculated as a function of the required investment (I), the yearly cost of the current solution (C_{curr}), the yearly cost of the new investment (C_{new}) and any added value of the new investment (V_{add}). This is calculated in accordance with equation A.2.

$$PB = \frac{I}{C_{curr} - C_{new} + V_{add}} \tag{A.2}$$

The investment is calculated as the sum of the investment in equipment ($I_{equipment}$), installation costs ($I_{installation}$) and the expenses for needed for education of the personnel and any associated costs ($I_{personnel}$), see equation A.3. Note that, in such case that the new investment allows for the sale of old equipment, this sales price (I_{sales}) shall also be included in the calculation.

$$I = I_{equipment} + I_{installation} + I_{personnel} - I_{sales} \tag{A.3}$$

Then, the yearly cost of the current machinery is calculated as the sum of the yearly machine costs (C_{currM}) and the yearly labor costs (C_{currL}), see equation A.4. If the investment affects the material costs, these should also be included in the calculations.

$$C_{curr} = C_{currM} + C_{currL} \tag{A.4}$$

Meanwhile, the yearly cost of the new investment is calculated as the sum of the yearly machine costs (C_{newM}) and the yearly labor costs (C_{newL}), see equation A.5.

$$C_{new} = C_{newM} + C_{newL} \tag{A.5}$$

Finally, in such case that the investment would create any extra value, this is reflected by V_{add}. This variable should reflect any improvement in quality, increase in volume, or other factors deemed important. In the case of a volume increase, the actual sales price of the extra products produced shall be used for calculating V_{add}. Note that, in such case, C_{new} shall also have to be adjusted to include any extra costs associated with the increase in volume, such as increased material costs.

A.3.2. Conducting a full investment analysis

When conducting a full investment analysis, the same basic models are to be used as for the simplified investment analysis. However, the following aspects should also be taken into consideration:

- Capital cost for bound capital
- When calculating the C_{curr} and C_{new}, as outlined above, these calculations shall also include other associated costs, such as management costs and inferred costs in other parts of the production.

- To the extent possible, the value of reduced supply risks and other non-quantified data shall be quantified in economic terms.

In the case of making a simplified investment analysis, the calculation of a pay-back time is sufficient. The pay-back model does however have some shortcomings as it, for example, doesn't take the time-value of money nor uneven revenue streams into consideration. Therefore, the Internal Rate of Return (IRR) shall also be calculated when making a full investment analysis, along with the corresponding return on equity. No other methods, such as Net Present Value-method (NPV), are to be used for the investment analysis as these have not previously been used by the company and much necessary data is missing for the proper investment evaluation using such models.

B.
Furnace, request for quotation

B.1. Our process

Some quick information about our process can be found below. More information can be found on our website gerdins.com. You are also welcome to contact us with any questions, see contact details below.

Product	Perforating punches with diameters ranging from 2 mm to 36 mm. The length varies from 9.5 mm to 32 mm. Our lightest components have a weight of 0.4g. They are to be hardened in batches.
Material	Currently using Zapp 20AP (1.1268EA) and Zapp 14AP (1.0759EA), but in we are the process of changing materials
Material thickness	1 μm to approx 20mm
Volume	Production volumes are relatively small. Do however please indicate the cycle time of proposed furnaces.
Hardness after hardening	HRC 68
Hardness after annealing	HRC 56
Material condition when entering furnace	Clean and degreased

Table B.1: Our production process.

B.2. Furnace demand specifications

We would like a quotation for the two furnace alternatives below, which would be integrated in our process in a different ways. We will evaluate the alternatives based on their price and capabilities, to select the option which would work best for us. The criteria for the furnace alternatives can be found in table B.2 below.

Note that the specifications in table B.2 are minimum specifications, for the two furnaces. For example, this means that if you have a furnace with larger dimensions than what we have specified, it satisfies this demand. The furnace may be round or rectangular.

Specification	Furnace 1	Furnace 2
Furnace type	Traditional furnace (seghärding)	Traditional furnace (seghärding)
Max hardening temperature	1000 °C	1000 °C
Basket dimensions, WxDxH (mm)	210 x 210 x 130, corresponding to ∅300	480 x 280 x 130 mm
Weight capacity	20 kg	50 kg
Quenching medium	Oil (max. 80°C), or possibly gas	Oil (max. 80°C), or possibly gas
Annealing	No	Quotation both with and without
Max annealing temperature	-	350 °C
Washing	No	No
Working hours per week (h)	60	60
Other requirements	No bumping or shaking of the parts may take place in the process. This could harm the edges of our punches, for which we have very strict tolerances.	

Table B.2: Specifications of the furnace investment alternatives.

Other than the oven itself we may also be interested in accessories such as:

- Baskets for the batches. We may want these to be fabricated to our specifications
- Installation services
- Warranty
- Necessary associated employee training

B.2.1. Gas quenching

In the case of gas quenching we are concerned about the risk that some of our very small components, which can weigh as little as 0.4g, may come to move around during the gas quenching stage. This could harm the edges on our punches, for which we have very strict tolerances. As such, we would like some input from you regarding how this risk may be mitigated and if you believe that gas quenching is possible at all.

B.3. Questions

- Which delivery time can we expect, from order to installed furnace?
- Are any of the demand specifications above, particularly difficult for you, so that it may be of interest for us to review that particular specification?
- Would a reduction in any of the demand specifications above, such as the volume, result in a significantly reduced furnace price?
- Is it possible to send test hardening specimen to you so that we may confirm that we get desired results in the furnaces you propose?

C. Production machine, request for proposal

C.1. Purpose

The purpose of this request for proposal is to serve as material for a feasibility study for the possible replacement of existing production machines. Any proposal given is not binding and may be subject to change. In such case that the feasibility study shows that this investment is feasible, it is the intention that more detailed specifications shall be formalized and a more detailed study shall be performed.

C.2. The transfer machine

We are fabricating perforating punches of different dimensions and are considering the purchase of a machine for the replacement of machines producing some of these dimensions, see table C.1. Currently, we are using the materials Zapp 20AP (1.1268EA) and Zapp 14AP (1.0759EA), but we are in the process of changing materials. We are interested in the purchase of a transfer machine similar to the one purchased from you by Gerdins Cutting Technology in 2014. This machine should be able to manufacture perforating punches with the four different designs shown in figure C.1.

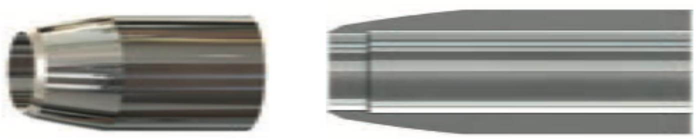
Having discussed the machine specifications internally, we have realized that the "single edge side eject rear"-design, see figure C.1b, may be especially difficult and costly to implement. If this is the case, please exclude this specific design from the specifications.

In table C.1 below, further specifications are given for the transfer machine. Note that all diameters shall be available for each of the lengths.

(a) The "Single Edge Side Eject Edge" design

(b) The "Single Edge Side Eject Rear" design

(c) The "double edge" design



(d) The "Single Edge Back-clearing" design

Figure C.1: The four designs in this figure should be possible to manufacture in the transfer machine.

More information about us can be found on our website gerdins.com. You are also welcome to contact us with any questions, see contact details below.

C.3. Requested information

We request that you provide us with estimates for the following data based on the specifications we have provided.

- Estimated purchase price, including all necessary tools and equipment.
- Estimated changeover time
- Estimated installation costs (if not included in the purchase price)
- Estimated production rate
- List of your mayor cost drivers. For example, is the diameter range that the machine can work with an important cost driver? Is there any specific aspects of the designs which constitute important cost drivers?

Length	9.7mm, 19mm and 32mm
Material	metal bars (not coil)
Outer diameters	4.0mm, 4.25mm, 4.5mm, 4.75mm, 5.0mm, 5.5mm, 6.0mm
Inner diameters	2.4mm, 2.6mm, 2.8mm, 3.0mm, 3.2mm, 3.5mm, 3.8mm
Designs	See figure C.1

Table C.1: Specifications for the transfer machine.

- Please let us know whether you have excluded the "single edge side eject rear"-design, see figure C.1b, from the specifications. Please do so if, and only if, this design implies a significantly added cost.

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