

Improvement of the Procurement Function in a Medium-Sized Metalworking Company

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To my family

Abstract

The present dissertation was conducted in FELINO, a company in the metalworking industry that produces bakery and pastry machines, as well as subcontracted technical parts, which result from its production in iron casting in the Sobrado unit and mechanical constructions and machining in Ermesinde.

The object of this dissertation is the process of procurement and purchasing, centralized in the Purchasing Sector in Ermesinde, responsible for managing all the internal requisitions of the organization to ensure the normal functioning of operations.

This project arose from the need to develop and improve the purchasing function of the company, particularly with regard to the analysis and selection of suppliers, to increase the efficiency and effectiveness of the procurement process and reduce the administrative load and costs.

In effect, after analyzing the current situation and identifying the biggest constraints and current supply problems, in a first phase, market research was done for the items considered most critical internally, following a proposed model that adds a strategic component to the process. In a second phase, using inventory management tools, pilot cases were explored to evaluate the possibility of supplier concentration, reduction of the number of internal orders and costs, through the possibility of order aggregation and also a structured approach to the calculation of stock management parameters.

While the absolute savings from these cases were marginal in the company's total costs, they highlighted the potential for significant reductions in administrative load, order volume, and the number of suppliers. These cases served as pilots, showcasing the impact of small incremental improvements that accumulate into significant overall results.

Melhoria da Função de Aprovisionamento numa Empresa Metalomecânica de Média Dimensão

Resumo

A presente dissertação foi realizada na FELINO, uma empresa da indústria metalomecânica que produz máquinas de panificação e pastelaria, bem como peças técnicas subcontratadas, que são resultantes da sua produção em fundição de ferro na unidade de Sobrado e de construções mecânicas e maquinação em Ermesinde.

O objeto desta dissertação é o processo de aprovisionamento e compras, centralizado no Setor das Compras em Ermesinde, responsável por gerir todas as requisições internas da organização para garantir o normal funcionamento das operações.

Este projeto surgiu da necessidade de desenvolver e melhorar a função de Compras da empresa, nomeadamente no que toca à vertente de análise e seleção de fornecedores, aumento da eficiência e eficácia do processo de aprovisionamento e a redução da carga administrativa e custos.

Com efeito, após análise da situação atual e identificação dos maiores constrangimentos e problemas de aprovisionamento atuais, foi efetuada numa primeira fase uma prospeção de mercado para os artigos considerados mais críticos internamente, seguindo um modelo proposto, que acrescenta uma componente estratégica ao processo. Numa segunda fase, utilizando-se ferramentas da gestão de inventário foram explorados casos piloto para avaliar a possibilidade de concentração de fornecedores, redução do número de requisições internas e custos, através da possibilidade de agregação de encomendas e também uma abordagem estruturada para o cálculo de parâmetros de gestão de stock.

Embora as poupanças absolutas destes casos tenham sido marginais tendo em conta os custos totais da empresa, estes casos evidenciaram o potencial para reduções significativas na carga administrativa, no volume de encomendas e no número de fornecedores, demonstrando o impacto de pequenas melhorias incrementais que se acumulam em resultados globais significativos.

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List of Abbreviations

EOQ – Economic order quantity

GFRP – Glass fiber reinforced polymer

IF – Iron foundries (Sobrado)

MC – Mechanical constructions (Ermesinde)

RFI – Request for information

RFQ – Request for quotation

ROP – Reorder point

SS – Safety stock

TCO – Total cost of ownership

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1 Introduction

This project was undertaken within the scope of the Dissertation curricular unit of the last semester of the Master's in Mechanical Engineering of the Faculty of Engineering of the University of Porto, in the Engineering and Production Management option. The dissertation project was conducted in the Purchasing Sector of the company FELINO, focusing on the procurement function of the company, considering the need for improvement and development of the latter, in terms of processes, methods and strategies to increase the efficiency and effectiveness of the procurement function.

1.1 Company Presentation

FELINO, founded in 1936, is a metallurgical and metalworking company, in the area of iron foundry as well as in the mechanical constructions sector. Their activities are centered on the production of bakery and pastry machines for the food industry, such as dough mixing machines of various sizes, and on the production of technical parts for other companies. More recently, in 2020, FELINO launched a new sustainable heating product brand, so they also produce pellet stoves and outdoor fireplaces. Figure 1 shows the company logo.



Figure 1 - FELINO company logo

The Company has two main production sites. One is in Sobrado, where the iron foundry is located, focused on casting grey iron, nodular iron, and Ni-resistant iron, up to 500kg per part. The other site is located in Ermesinde, where it is also headquartered. In the Ermesinde unit, the focus is on the production of technical parts and assembly of the machines. There, the parts produced in the foundries are finished in the Job Shop, which includes machining equipment such as milling machines and lathes, as well as welding equipment and various conventional machines. In Appendix A, FELINO's bakery and pastry machines are presented.

The Company has several sectors (or departments). The main focus of this dissertation was on the Purchasing Sector in Ermesinde, responsible for the ordering process for all the needs identified by the organization, mostly technical items, thus interacting with and supporting the whole organization. The management of orders is centralized for the two production units in the Ermesinde site. Some of the other sectors are Design, which is responsible for the development of technical and functional specifications and drawings, Production, responsible for production management and scheduling, Quality, responsible for quality assessment and control, and Technical Assistance, which provides maintenance, repair, and spare parts services for customers. The Purchasing sector also frequently interacts with the Administration, that validates orders and with the Warehouse, which plays a big role in inventory management.

1.2 Project Goals

This project has the ultimate goal of optimizing and improving the procurement function of the organization. Therefore, this project aims to improve the supplier selection process by following a model that combines quantitative and qualitative analysis with strategic thinking.

Furthermore, this project addresses the goals of reducing the administrative load, increasing efficiency, and reducing total costs, by exploring pilot cases that would lead to the concentration of the supplier base and reduction of orders and costs, to mention a few benefits.

1.3 Method applied to the project

The initial period was dedicated to understanding the context and processes involved in the procurement process of the company. Several informal interviews with employees were conducted, especially from the Purchasing Sector responsible to map the process and gather information about the current problems and constraints. Simultaneously, data and information from the IT system was gathered and analyzed.

After the initial situation analysis, firstly, market research for critical items previously identified was conducted and ended when all the approached supplier proposals were received and analyzed. Secondly, a few pilot cases for order aggregation and stock management were developed that show the potential of cost reduction and supplier concentration, among other benefits.

Lastly, additional improvements to the process and future work are also suggested, based on the information gathered during the course of the project.

Figure 2 shows the project's Gantt chart.

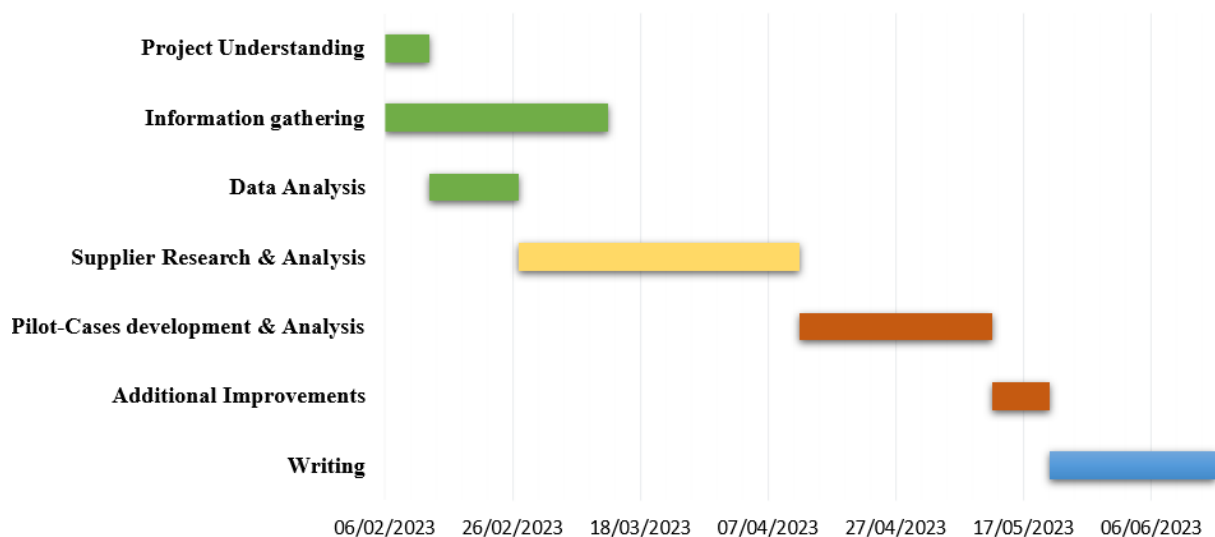


Figure 2 - Project Gantt chart

1.4 Dissertation structure

The dissertation is composed of five chapters.

In the first chapter, the company and project were presented, including goals and methodology followed.

In the second chapter, a literature review on the most relevant topics for the dissertation is presented, namely procurement and inventory management.

In the third chapter, the initial situation of the company is analyzed, first with a process analysis, then a quantitative analysis on spending and lastly with an identification of supply problems.

In the fourth chapter, supplier research and analysis is conducted, as well as proposals for order aggregation and inventory management.

In the last chapter the conclusions and future work developments are presented.

2 Literature Review

In this chapter, a literature review on the subjects relevant to the project development will be presented, namely Procurement and Inventory Management.

2.1 Procurement

Procurement (or purchasing) is an integral part of the Value Chain (Figure 3), situated in the Support Activities, which are required to support the company's Primary activities (Porter, 1985).

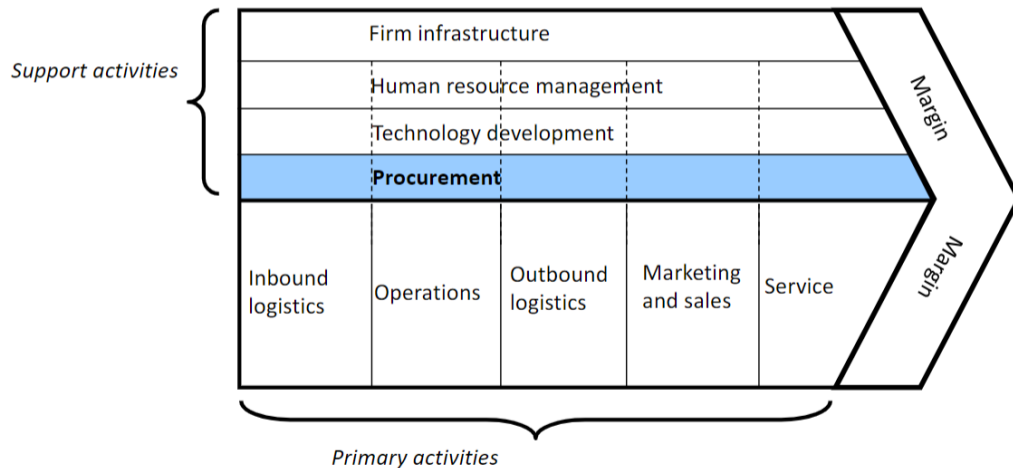


Figure 3 - The Value Chain

According to van Weele (2018), Procurement entails effectively managing a company's external resources to ensure the acquisition of all essential goods, services and knowledge required to operate both primary and support activities. The objective is to secure these resources under the most favorable conditions, encompassing the flow of materials, information, and financial transactions up to the point of consumption.

2.1.1 Purchasing Process

The process presented in this Section is the Linear Purchasing Process Model developed by van Weele (2018), which shows how different purchasing activities are interrelated (Figure 4).

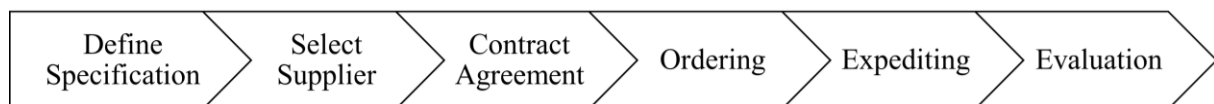


Figure 4 - The linear purchasing process model

The stages of the model and a brief description are the following:

1. **Specification phase:** In this phase, the technical and functional specifications of the product are defined. A functional specification defines the functionality the product must have, while a technical specification describes the technical characteristics of the product, usually in detailed technical drawings.

2. **Supplier Selection:** The goal of this stage is to select one supplier (single sourcing) or more (in case of multiple sourcing) to do business with. Due to its relevance for this project, this phase will be detailed in Section 2.1.2.
3. **Contract Agreement:** Depending on the circumstances, the terms of the contract can be negotiated, such as price, terms of delivery and terms of payment.
4. **Ordering and Expediting:** A purchase order is sent to the supplier based on the agreed terms. Expediting refers to the process of ensuring timely delivery and fulfillment of purchased goods or services and often involves active communication with the suppliers.
5. **Evaluation:** After the new product is taken into production or a new installation is put into operation, the buyer's responsibilities persist. This includes handling warranty claims and penalty clauses, managing excess and minor work, updating and archiving purchasing and supplier files, and concluding and filing supplier and project evaluations.

Not all purchasing situations involve all the steps mentioned above. In general, three types of purchasing situations are distinguished (van Weele, 2018):

- **Straight rebuy:** Related to the acquisition of a known product from the same supplier.
- **Modified Rebuy:** Situation when the organization wants to purchase either an existing product from a new supplier or a new product from a known supplier.
- **New-task:** Situation when the organization wants to buy a new product supplied by an unknown supplier.

2.1.2 Supplier Selection

According to Monczka et. al (2009), there are seven critical steps involved in the supplier evaluation and selection process (Figure 5) which are:

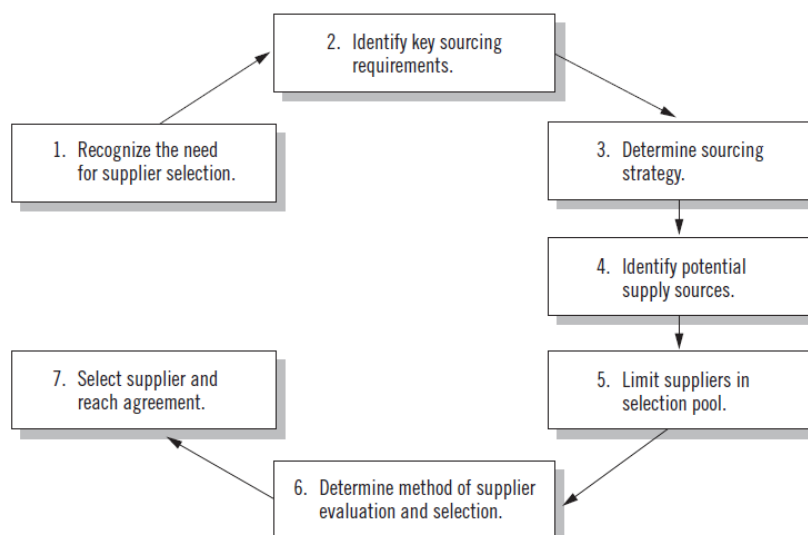


Figure 5 - Supplier selection and evaluation process

1. **Recognize the need for supplier selection:** The need to seek new or potential suppliers due to the development of new products, internal requisitions, or current suppliers' incapability, for example.
2. **Identify key sourcing requirements:** The importance of understanding the requirements of a certain item, such as quality, cost, and delivery performance.

3. **Determine sourcing strategy:** This includes strategic decisions such as domestic versus foreign suppliers, and single versus multiple sourcing. This topic is developed further in Section 2.1.3.
4. **Identify potential supply sources:** Purchasers require several sources of information to identify potential suppliers such as the current suppliers, internal sources, databases, trade journals and directories, business fairs, and the internet. The search intensity depends for instance on the strategic importance and complexity of the product (e.g., new-task situation) and how capable are the current organization's suppliers.
5. **Limit suppliers in selection pool:** Based on available information as well as from Requests for Information (RFI), the supplier pool is shortened.
6. **Determine method of supplier evaluation and selection:** This includes evaluating supplier provided information from Requests for Quotation (RFQ), conducting supplier visits, and using preferred suppliers lists.
7. **Select supplier and reach agreement.**

Regarding point 6, a common multicriteria decision model is the weighted-point evaluation system (Bozarth and Handfield, 2019). In this model, the user assigns weights to the performance measures (W_Y) and rates the performance of each supplier with regard to each dimension (Performance_{XY}). The total score for each supplier is given by Equation 2.1.

$$\text{Score}_X = \sum_{Y=1}^n \text{Performance}_{XY} \times W_Y \quad (2.1)$$

Where:

X= Supplier X

Y= performance dimension Y

Performance_{XY} = rated performance of supplier X with regard to performance dimension Y

W_Y = assigned weight for performance dimension Y

On the other hand, van Weele (2018), proposes four steps to the selection process (Figure 6).

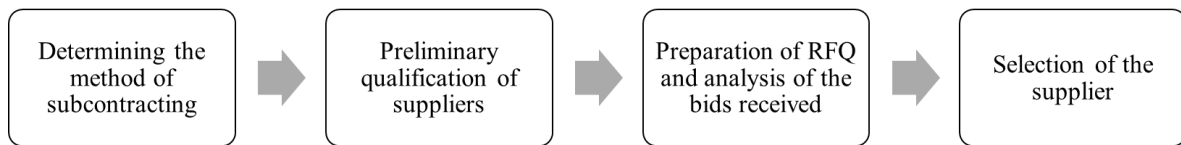


Figure 6 - Supplier selection process, according to van Weele (2018)

2.1.3 Purchasing Strategy

In this Section, a portfolio approach will be described, which was first developed by Kraljic (1983), thus it is also called the Kraljic Matrix. This approach consists of segmenting products in four quadrants based upon two criteria: financial impact and supply risk in each of the axes. Based on the quadrant, a differentiated supplier strategy is developed. The characteristics of each segment, as well as the strategy to pursue are summarized in Figure 7. It is important to note that the same matrix can be applied to products as well as suppliers. For instance, a supplier of a strategic product can be considered a strategic supplier (van Weele, 2018).

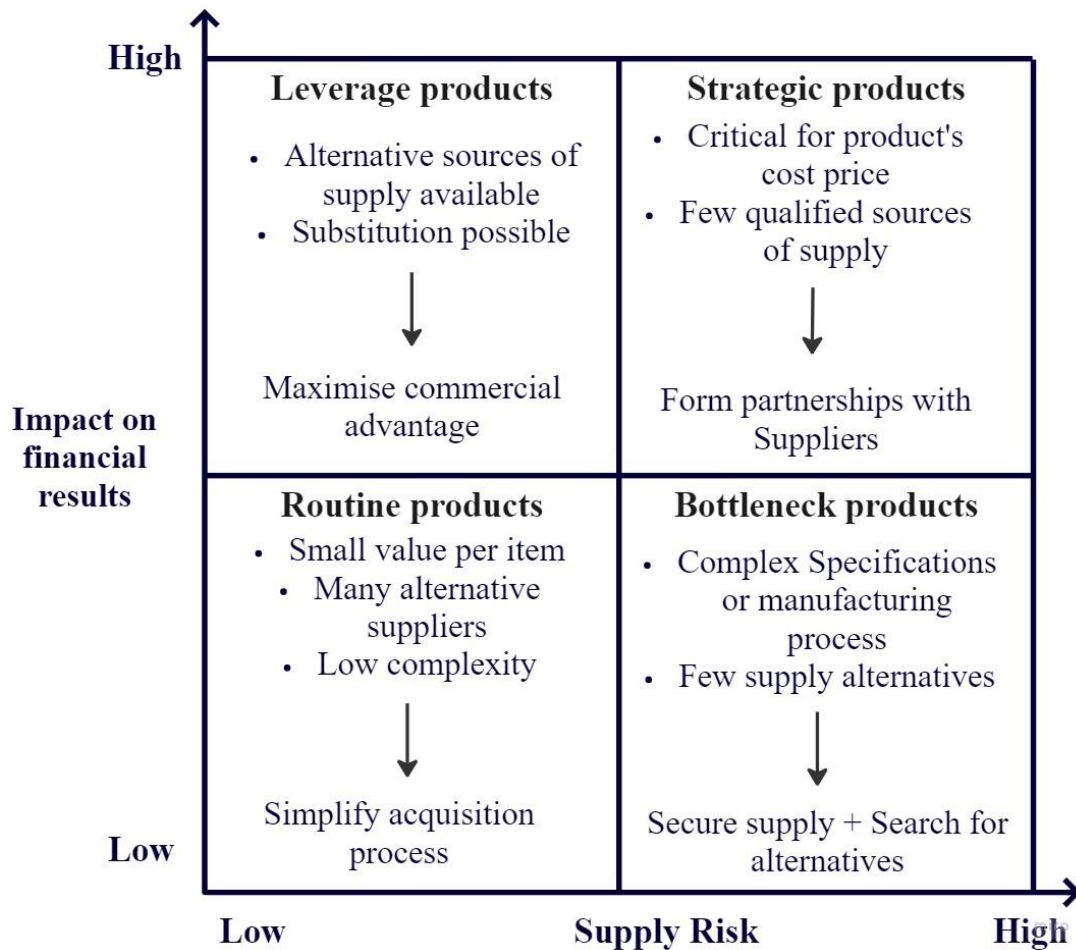


Figure 7 - The purchasing portfolio matrix (Kraljic matrix)

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2.1.4 Spend Analysis

According to Bozarth and Handfield (2019), a spend analysis is the application of quantitative techniques to purchasing data in an effort to better understand spending patterns and identify opportunities for improvement. The 'spend cube' is one of many approaches to spend analysis (Figure 8). This involves analyzing purchasing expenditure from three different dimensions: spend per supplier, spend per category, and spend per department (van Weele, 2018).

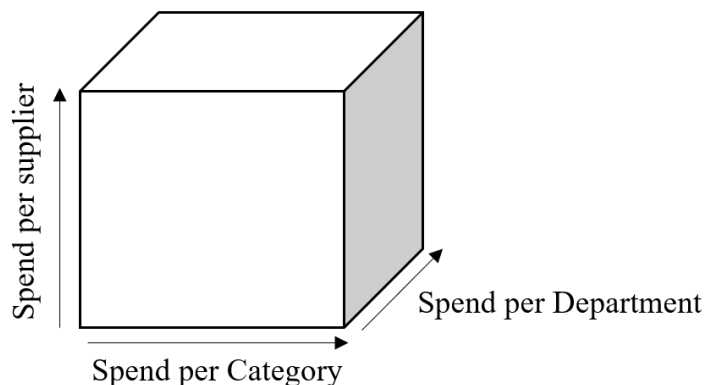


Figure 8 - The spend cube

2.2 Inventory Management

Inventory management is important in the scope of procurement because many purchase order requisitions are a result of the stock management system policies (van Weele, 2018). The main decisions in inventory management are the quantity and timing of the order. To decide these variables there are two systems: periodic review systems or continuous review systems. In periodic review systems, the time between orders is fixed, while the quantity ordered depends on the current stock level (Bozarth and Handfield, 2019). The continuous review system is detailed in Section 2.2.1.

2.2.1 Continuous Review System

In a continuous review system, the inventory level for an item is constantly monitored, and when the Reorder Point (ROP) is reached, an order is released (Bozarth and Handfield, 2019). The Reorder Point is based on both demand and supply considerations as well as on how much safety stock (SS) is desired. If the lead time and demand per period are independent and normally distributed the reorder point is given by the average lead time demand added by the safety stock (Equation 2.2).

$$ROP = D_{avg} \cdot LT_{avg} + SS \quad (2.2)$$

Where:

ROP= Reorder point
 D_{avg} = Average demand per period
 LT_{avg} = Average lead time per period
 SS= Safety stock

Safety stock exists to account for variability in both the demand for an item and in the lead time for the supply of the same item, reducing the probability of stockouts (Bozarth and Handfield, 2019). In Figure 9, the impact of both variables on the stock level after the reorder point is reached can be seen.

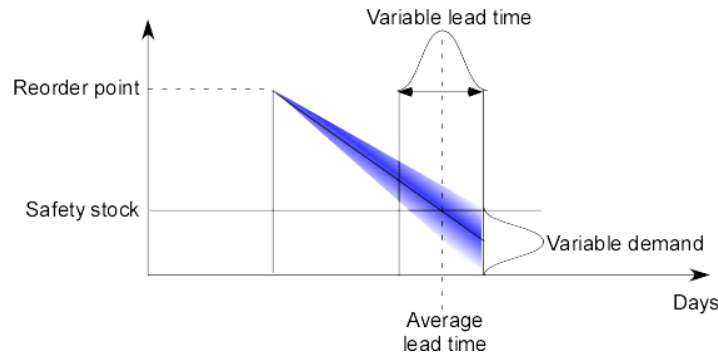


Figure 9 - Lead time and demand variability impact on the stock level

If both lead time and demand per period follow a normal distribution with means LT_{avg} and D_{avg} and standard deviations σ_L and σ_D , respectively, then the lead time demand (i.e., demand during the lead time) is normally distributed with a mean D_{LTD} and standard deviation σ_{LTD} given by Equation 2.3.

$$D_{LTD} = LT_{avg} \cdot D_{avg}; \sigma_{LTD} = \sqrt{LT \cdot \sigma_D^2 + D_{avg}^2 \cdot \sigma_{LT}^2} \quad (2.3)$$

Therefore, to determine the safety stock, the only variable left is the target service level (SL), which is the probability that there is no stockout during a replenishment cycle (e.g., SL=95%). The safety factor Z is the number of standard deviations from the mean, which can be determined by the inverse of the standard normal cumulative distribution function using the desired service level as the probability (Waters, 2003). In Table 1, it may be observed that higher service levels lead to higher safety factors Z (or vice-versa), which reduce the probability of shortages (Waters, 2003).

Table 1 - Safety factor Z , as a function the Service level

Z	Percentage of cycles with shortages	Cycle service level (%)
0.00	50.0	50.0
0.84	20.0	80.0
1.00	15.9	84.1
1.04	15.0	85.0
1.28	10.0	90.0
1.48	7.0	93.0
1.64	5.0	95.0
1.88	3.0	97.0
2.00	2.3	97.7
2.33	1.0	99.0
2.58	0.5	99.5
3.09	0.1	99.9

Thus, the SS formula can be computed by Equation 2.4.

$$SS = Z \cdot \sigma_{LTD} = Z \cdot \sqrt{LT \cdot \sigma_D^2 + D_{avg}^2 \cdot \sigma_{LT}^2} \quad (2.4)$$

And the complete ROP formula, accounting for the uncertainty of demand and lead time is given by Equation 2.5.

$$ROP = D_{LTD} + Z \cdot \sigma_{LTD} = D_{avg} \cdot LT_{avg} + Z \cdot \sqrt{LT \cdot \sigma_D^2 + D_{avg}^2 \cdot \sigma_{LT}^2} \quad (2.5)$$

The continuous review system explains when to order (i.e., when the stock level goes below the ROP), but not how much to order. That is the purpose of the following Section 2.2.2.

2.2.2 Economic order quantity (EOQ)

The economic order quantity (EOQ) is the optimal order quantity (or lot size) for an item of stock that minimizes cost (Lysons and Farrington, 2020). The model to arrive at the EOQ assumes that there are essentially three costs when deciding the lot size (Chopra et. al, 2016):

- Annual material cost
- Annual ordering cost
- Annual holding costs

And the following inputs:

- D = Annual demand of the product
- S = Fixed cost incurred per order
- C = Cost per unit of product
- h = Holding cost per year as a fraction of product cost (mostly an opportunity cost)

Assuming no quantity discounts, the purchase price is independent of lot size, therefore (Equation 2.6):

$$\text{Annual material cost} = CD \quad (2.6)$$

The number of orders per year must suffice to meet the annual demand D . Given a lot size of Q , we have (Equation 2.7):

$$\text{Number of orders per year} = \frac{D}{Q} \quad (2.7)$$

Because an order cost of S is incurred in each order, the annual ordering cost is (Equation 2.8):

$$\text{Annual ordering cost} = \left(\frac{D}{Q}\right) S \quad (2.8)$$

Assuming that demand is constant over time and the lead time is also constant, given a lot size of Q , the average inventory is $Q/2$. Thus, the annual holding cost is the cost of holding $Q/2$ for one year and is given as (Equation 2.9):

$$\text{Annual holding cost} = \left(\frac{Q}{2}\right) hC \quad (2.9)$$

The total annual cost, TC , is the sum of all the costs components and is given as (Equation 2.10):

$$TC = CD + \left(\frac{D}{Q}\right) S + \left(\frac{Q}{2}\right) hC \quad (2.10)$$

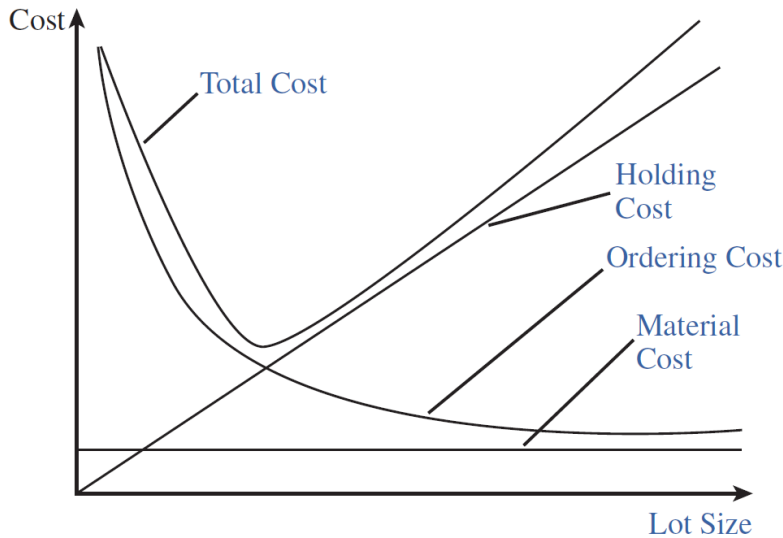


Figure 10 - Costs as a function of lot size

If the cost functions are plotted the result in Figure 10 will be obtained. The total cost function has a minimum, which can be obtained by taking first derivative of the total cost with respect to Q and setting it equal to zero. The optimal lot size is the economic order quantity (EOQ), in Equation 2.11:

$$\text{Economic order quantity, EOQ} = \sqrt{\frac{2DS}{hC}} \quad (2.11)$$

Furthermore, according to Chopra et. al (2016), total ordering and holding costs are relatively stable around the economic order quantity, so a firm is often better served by ordering a convenient lot size close to the EOQ rather than the precise EOQ.

2.2.3 Aggregating multiple products in a single order

Aggregating replenishment across products in a single order allows for a reduction in lot size for individual products because fixed ordering and transportation costs are now spread across multiple products (Chopra et. al, 2016).

Assuming the following inputs:

D_i : Annual demand for product i

S : Order cost incurred each time an order is placed, independent of the variety of products included in the order

If each product is ordered independently, then the optimal quantity ordered is given by the EOQ and the annual frequency of orders is given by Equation 2.7. However, to determine the optimal order frequency when aggregating all products in the same orders the same equations are not valid and will be demonstrated as follows, based on Chopra et. al (2016).

Let n be the number of orders placed per year and supposing we aggregate $i \in \{1,2,3, \dots\}$ products. Then the order quantity of product i is (Equation 2.12):

$$Q_i = \frac{D_i}{n} \quad (2.12)$$

Thus, the annual order cost and annual holding costs are (Equations 2.13 and 2.14):

$$\text{Annual order cost} = S \cdot n \quad (2.13)$$

$$\text{Annual holding cost} = \sum_{i=1}^k \frac{D_i h C_i}{2n} \quad (2.14)$$

Therefore, the total cost (excluding material costs) is (Equation 2.15):

$$\text{Total annual cost} = S \cdot n + \sum_{i=1}^k \frac{D_i h C_i}{2n} \quad (2.15)$$

The optimal order frequency minimizes the total annual cost and is obtained by taking the first derivative of the total cost with respect to n and setting it equal to 0. This results in the optimal order frequency n^* , in Equation 2.16:

$$n^* = \sqrt{\sum_{i=1}^k \frac{D_i h C_i}{2S}} \quad (2.16)$$

3 Initial Situation

In this chapter, the current procurement process of the company will be described in more detail, followed by a section with a spend analysis, and lastly an identification of current critical products.

3.1 The procurement process

The current procurement process can be divided into two subprocesses: the supplier research process and the purchasing process.

3.1.1 Supplier research process

The supplier research process flowchart is presented in Figure 11.

The process is sparked by an internal need. This need is related, for example, with the development of a new product, with problems with current suppliers, either in terms of the need for improved quality or cost, or with the need for alternative suppliers. Therefore, this process is usually followed by the technical departments, such as the Production or the Design department, which develop technical drawings and specifications. After supplier research and consultation, including requests for information (RFI) and requests for quotation (RFQ), the proposals are analyzed. This process is not entirely linear. Hence, some arrows are in the opposite direction of the flow (see Figure 11). For example, after proposal analysis, in case it is not adequate, more supplier research can be conducted. If the proposal is satisfactory, usually a quality assessment is required of one or more samples. If approved, then the purchasing process starts, described in Section 3.1.2.

Since this process is for a new item and possibly a new supplier, a new article code has to be created and inserted in the company's IT system, allowing for instance the creation of orders for the item.

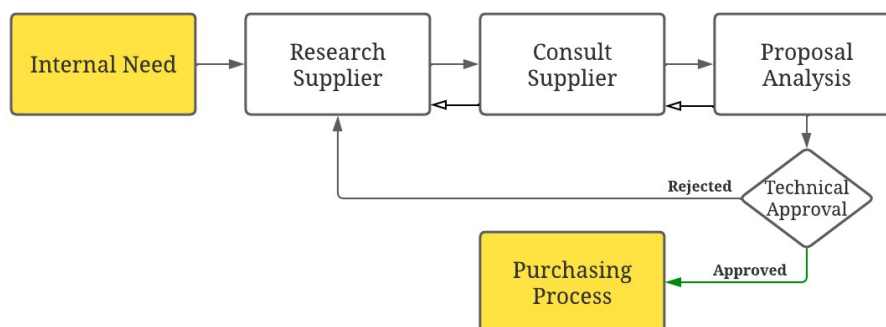


Figure 11 - Supplier research process

3.1.2 The purchasing process

The purchasing process flowchart is presented in Figure 12.

The company's purchasing process is started by an internal buying need from the organization. This need is materialized in the form of an internal requisition (IR) that is inserted in the IT system by a certain user from a certain sector and becomes available to the Purchasing Sector responsible. The IR is a data entry that includes, among other details, the article code, the article description, the quantity, the required due date, and the place of delivery (Ermesinde or Sobrado).

The Purchasing responsible receives all the IRs and has to match them with suppliers. If the article was ordered recently (i.e., within a month) from a certain supplier, then the order is submitted without new consultation. Otherwise, at least three suppliers have to be consulted. The consultation is similar to the one described in Section 3.1.1, with RFQs and comparison of prices and delivery dates. Generally, the choice is based on price, unless the delivery time is too long. The order is submitted to the IT system and includes similar data to the one in the IR but also includes the supplier information. Then, the order awaits approval by the administration. It is rejected if the price is considered too high. Otherwise, upon approval, the order is sent to the supplier, which has to confirm the order.

After the order is confirmed by the supplier, the Purchaser monitors the delivery to make sure it is on time and frequently calls suppliers. After the receipt of the order, the stock level is updated in the IT system by the Warehouse responsible.

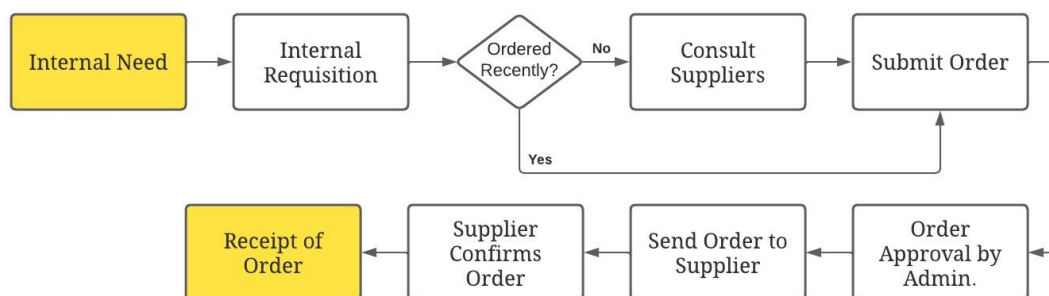


Figure 12 - The purchasing process

Throughout the process, there is frequent communication by other employees with the Purchasing sector about the order and delivery status. For example, Production could ask about components that will be needed soon or ask for updates on supplier consultation. Once in a while, there are also meetings to address problems such as faulty/wrong component deliveries or supplier problems.

Other important aspects are the delays and waiting times that happen throughout the process, which have either internal or external causes. For instance, when the IR is created by a user it stays on hold until being solved by the Purchaser, which can access all pending IRs in the IT system. Then, there is the task of consulting suppliers, which is time-consuming, because one has to wait for a response to all the RFQs sent by email to several suppliers. After that, there is the wait for order approval. Afterwards, the supplier has to confirm the order, which usually takes one day. Finally, there is the delivery lead time from the time the order is confirmed by the supplier up to the moment it is received at FELINO. Naturally, several different IRs, supplier consultations and orders are being dealt with consecutively, which demonstrates the high administrative load and complexity of the process.

In Figure 13, the process flowchart, previously presented in Figure 12, is updated to include the most meaningful delays that happen during the purchasing process.

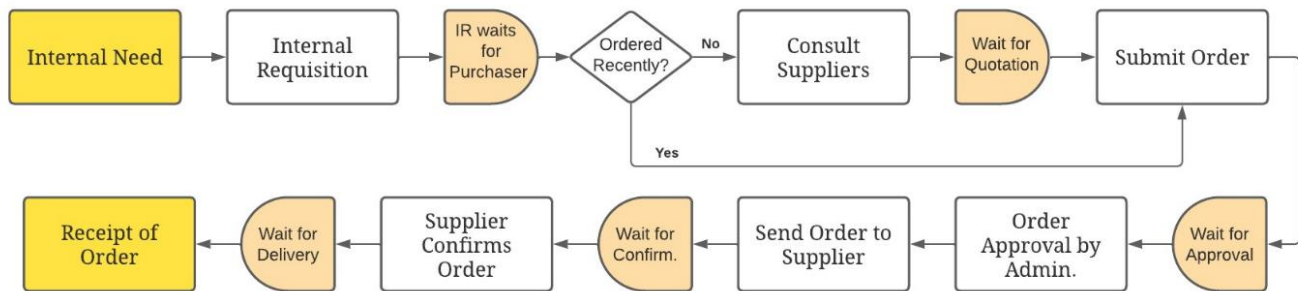


Figure 13 - Purchasing process including delays

3.2 Spend analysis

In this Section, a spend analysis is performed, which analyses the most relevant data regarding the internal requisitions, suppliers, and article categories. All the data was retrieved from the company's internal IT system for the year 2022, the most recent complete year prior to the project. The most relevant charts are presented, while other developed ones, that also contribute to the analysis are shown in Appendix B.

3.2.1 Internal Requisitions

In 2022, a total of 5846 IRs were generated. The majority of IRs were generated from the operations of the company, both from the Warehouse and Production for mechanical constructions (MC) in Ermesinde and the iron foundries (IF) in Sobrado. In Figure 14, is presented a Pareto chart with the number of IRs per sector and the cumulative percentage. There is a visible Pareto effect, with the top four sectors accounting for about 73% of the total number of IRs.

The cause for the amount of IRs in the warehouses is due to the inventory management system being managed by the warehouse responsible both in Ermesinde and Sobrado. The system sends warnings (by email) when the stock levels are below the ROP or SS and the warehouse responsible creates IRs.

As for the value of the IRs (Figure 15) in terms of order cost, it can be seen that the number of IRs is not correlated to the total value of the IRs. For example, the Warehouse - MC accounts for 30% of the internal requisitions but only 10% of total spend, while the Warehouse-IF accounts for 54% of the spend with only 16% of internal requisitions. Most of the iron foundries cost is from the raw materials for casting.

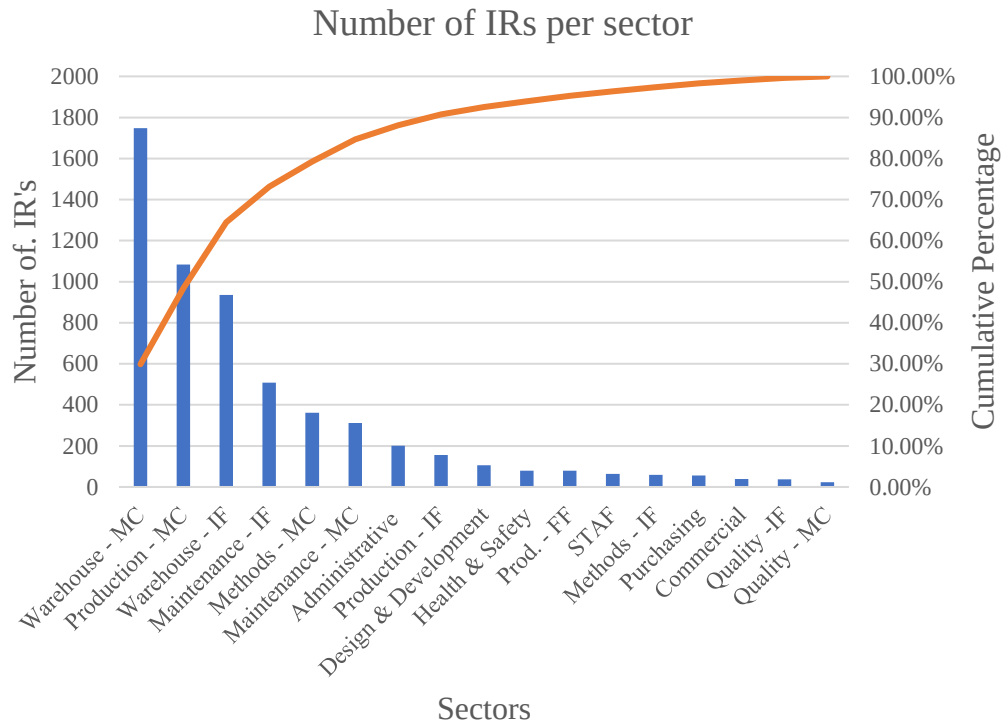


Figure 14 – Pareto chart for the number of IRs per sector

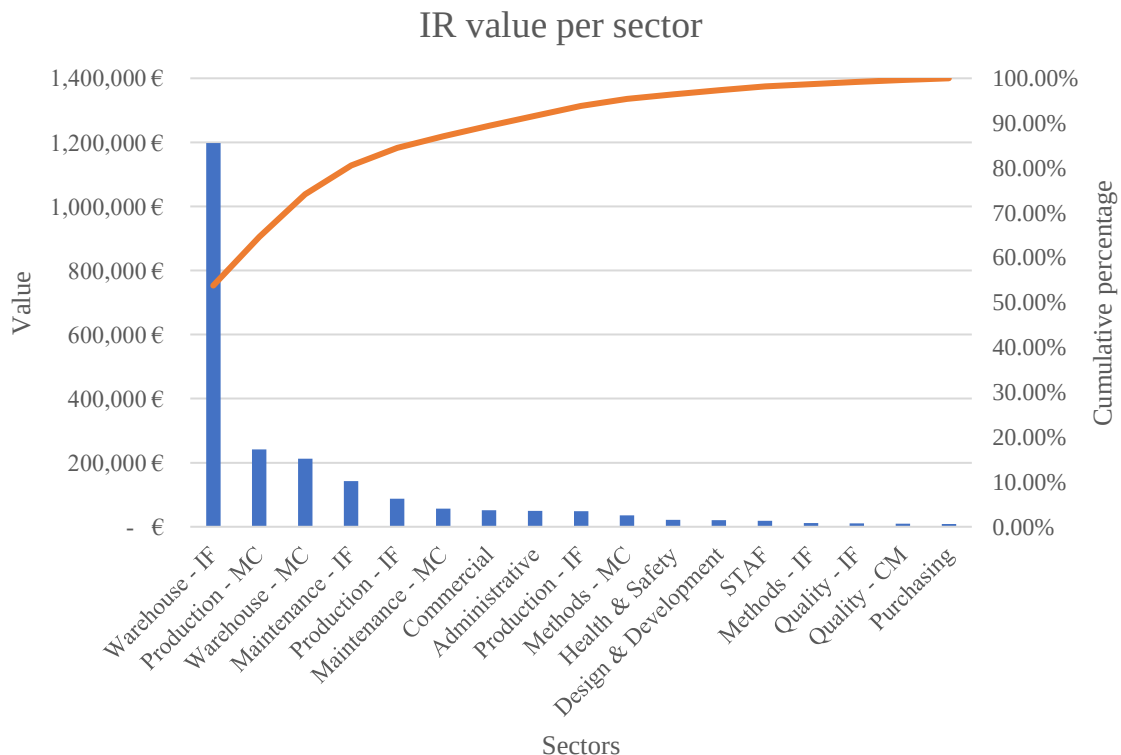


Figure 15 – Pareto chart for the IR value per sector

In the chart in Figure 16, the IRs were grouped in bins of growing values, starting from [0, 5€ [until [500, +∞ [. Then, the cumulative percentage of their values as a percentage of the total IR values was also plotted in the secondary axis. Most of the IRs are of small value and represent a fraction of total spending. For example, IRs with values between 0€ to 250€ are about 80% of the total IRs generated, but only account for 8.4% of total IR cost. This demonstrates that most of the time is spent on low value items, which are nonetheless important for the operations.

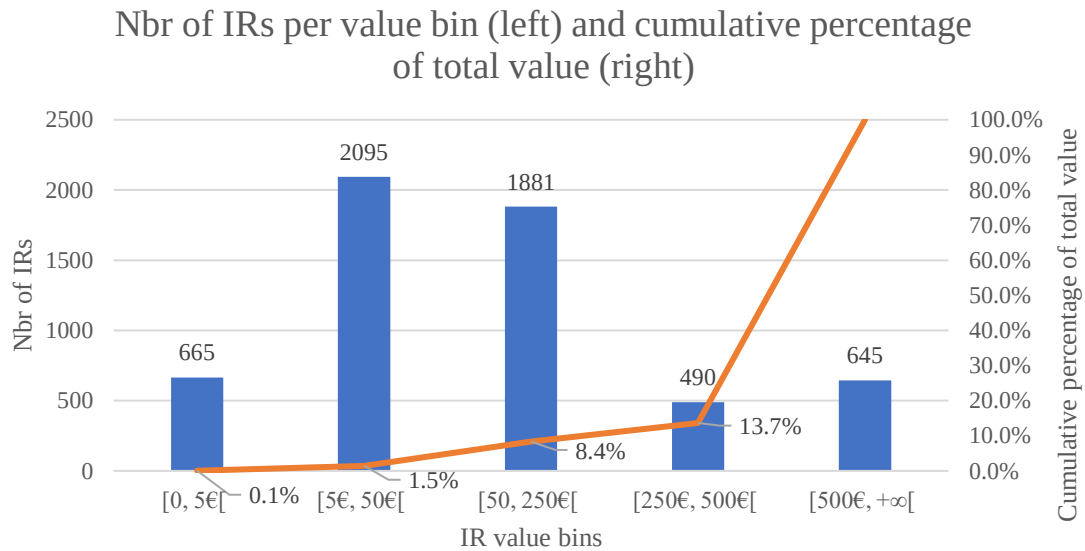


Figure 16 - Absolute frequency of IRs per value bin and cumulative percentage of total value

3.2.2 Suppliers

In 2022, FELINO used a total of 499 suppliers. In Figure 17 a Pareto chart is shown with the spend per supplier, showing a clear Pareto effect. The supplier names are omitted to present the whole supplier base and for confidentiality. There is one supplier that stands out, which is the iron supplier for the foundries in Sobrado, accounting for one fifth of the spending.



Figure 17 - Pareto chart of spend per supplier

In Figure 17, it is visible that there is a very significant number of small suppliers (in terms of spending). To quantify that, in Table 2, the number of suppliers accounting for a certain percentage of the lowest spend was counted. For instance, it was observed that 1% of the smallest suppliers represented 41% of the total number of suppliers used in 2022.

Table 2 - Number of suppliers for a certain percentage of the lowest spend in 2022

% of Lowest Spend	Nbr suppliers	% of Total suppliers
1%	204	41%
5%	317	64%
10%	378	76%
20%	429	86%

Furthermore, from the point of view of how many times the suppliers were used (i.e., an order was placed), Table 3 presents the number of suppliers as a function of the number of times used during the year, showing that 110 suppliers were only used once, corresponding to 22% of the suppliers for 2022.

Table 3 - Number of suppliers as a function of the number of times used in 2022

Nbr times used	Nbr suppliers	% total
1	110	22%
2	83	17%
3	52	10%
4	31	6%
5+	223	45%
Total	499	100%

Finally, to measure supplier fragmentation visually, a supplier density chart was used (Pandit and Marmanis, 2008). This is a stacked bar chart that shows the percentage of spending on the top three suppliers, followed by the next five suppliers and remaining suppliers (Figure 18). The top seven categories, in terms of spending, were selected. The complete chart is in Appendix B, for all categories.

It is possible to conclude that the Tools and Electrical Equipment product categories are the most fragmented ones in the chart, with only about a quarter of the spending in the top three suppliers for the Tools. The most fragmented categories show that there is potential for supplier concentration, i.e., to concentrate purchases in less suppliers in order to obtain better deals in terms of price discounts or better terms (van Weele, 2018). On the other hand, the steel bowls are very concentrated. This is both due to the nature of the product, but also to the way the company operates, with a lot more tool and machine variety.

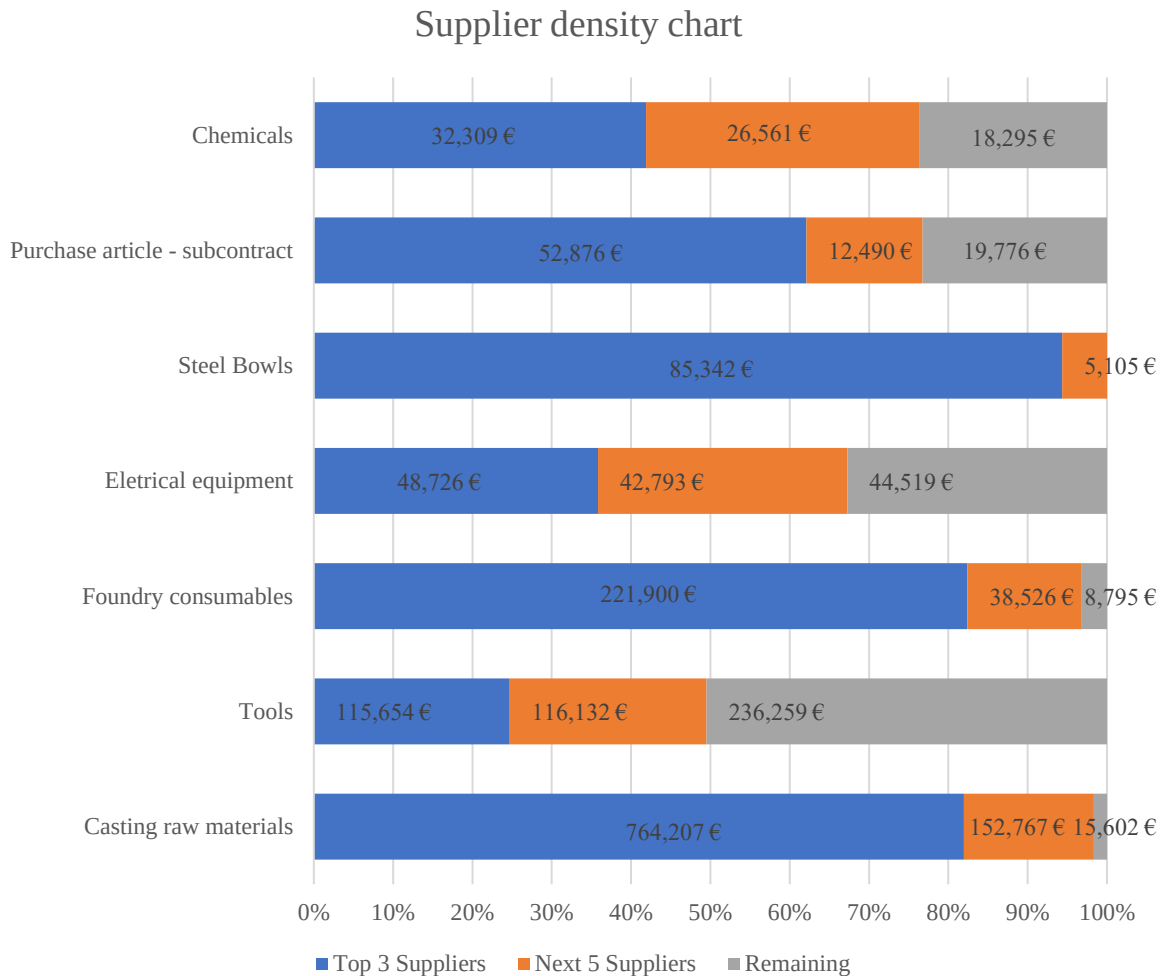


Figure 18 - Supplier density chart for selected for top categories

3.3 Critical products identification

With regard to the sourcing and supply problems faced by FELINO, this Section describes the products or services in need of new supplier research.

The products or services identified were the following:

- Sheet metal services subcontracts
- Composite material shields
- Stainless steel bowls

The sheet metal services include services such as cutting, bending, and welding. As a result of the subcontracting provided by FELINO, the company frequently also subcontracts sheet metal services from third parties. Problems with some current suppliers, namely unacceptable delays, and poor communication, have led to the need to look for alternatives.

The composite material shields are glass fiber reinforced polymers (GFRP) used to shield or cover the machines' head. Due to quality problems with the current supplier, the latter is unable to supply the parts with the final surface finish, lacking the polishing and painting, which is

performed by FELINO in Ermesinde. In addition to this, the company is relying on only one supplier of these products, therefore, an alternative is needed.

Lastly, the stainless steel bowls are the large containers where the dough is mixed in the mixing machines. Due to product design changes, specifically the addition of a central tube in the center instead of a flat bowl, the production process requires changes. The current supplier's production process was considered too expensive and slow, with delivery times around three months.

The research and analysis of new suppliers is further developed in Section 4.1.

4 Proposed solutions

This chapter presents the proposed solutions to address the problems identified in Chapter 3, along with their corresponding results. Specifically, it focuses on two key aspects: the methodologies employed for supplier research and analysis (Section 4.1), and the development of three pilot cases centered around inventory management (Section 4.2).

4.1 Supplier research and analysis

In this section, the supplier research and analysis on the constraints identified in Section 3.3 are described. The method followed is similar to the one mentioned in the literature review in Section 2.1.2 from Monczka et. al (2009). The method followed for each product is described in subsections 4.1.1 to 4.1.3, as well as the explanation for the positionings of Figure 19.

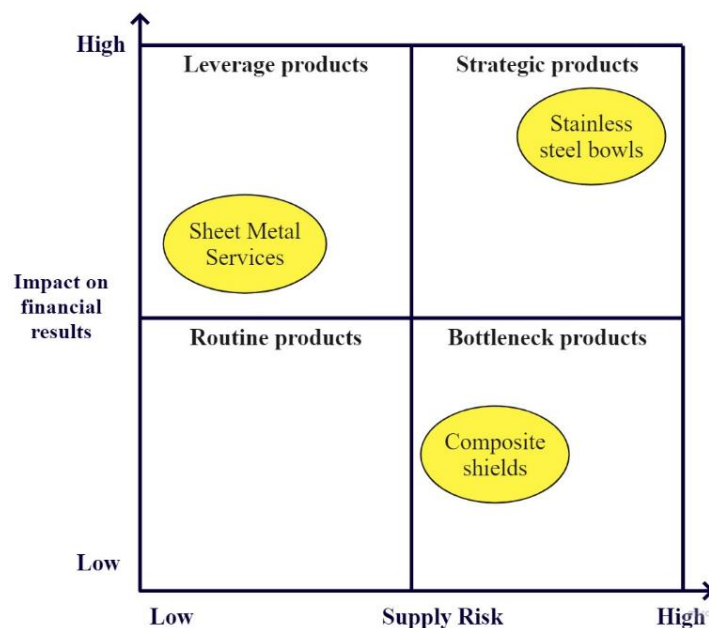


Figure 19 - Critical products positioning in the Kraljic matrix

4.1.1 Sheet metal services

The technical specifications of sheet metal services, especially with regard to the technical sheet drawings, are very diverse and depend on what is to be built according to the requirements of FELINO's customers and FELINO itself.

To define the strategy, it is important to understand the market conditions and the degree of complexity of the product, to be able to assess the supply risk and the balance of forces in the market. In this case, for sheet metal services, it is something relatively standardized, with many available substitutes and competition. Therefore, the supply risk is low. As for the financial impact, it is included in the fifth largest category (out of 18) in terms of spending, so it is considered to be medium-high impact. Therefore, sheet metal services are situated in the leverage products of the Kraljic matrix (Figure 19), and the strategy is to maximize the commercial advantage.

Firstly, a supplier pool was developed from the various sources available on the internet and internally. Then, to be able to compare the new suppliers with current suppliers in a fair way, a recent order comprised of 15 different part numbers, each with a certain order quantity, that had

been sent to a current supplier, representing a large range of specifications, was used as a reference. The RFQs were sent to multiple suppliers for this hypothetical order, and the proposals were analyzed. The bids received are summarized in Table 4. The suppliers' names are substituted by SM (standing for sheet metal) and a letter. Supplier SM-A represents the current supplier, used as reference.

Table 4 - Bids summary for sheet metal services

<i>Suppliers</i>	<i>Bid (excl. VAT)</i>	<i>Observation</i>
SM-A	1438.40 €	Great price, but very poor service and delivery
SM-B	1576.35 €	Good price, excellent service, and good delivery
SM-C	2282.55 €	Very expensive, and does not show unit costs
SM-D	1868.04 €	Expensive, and does not show unit costs

The reference supplier is the cheapest, but it is to be replaced because of the very poor service, delivery, and communication. Poor service and late delivery also has hidden costs from production delays, so price cannot be the only factor. Two suppliers, namely SM-C and SM-D, did not show the costs for each part number in their proposals, but rather the total cost for the order or subsections of the order. From the point of view of the buyer, that is not useful, because it does not allow for comparison at an individual item level.

Supplier SM-B quoted the unit costs (and total costs) for each part number and had good qualitative aspects in terms of the response speed (answering RFQ's within 24 hours) and deliveries (within 3 days and without additional costs).

If it was intended to measure both quantitative and qualitative aspects objectively using the weighted-point evaluation system, using three performance dimensions (price, delivery, and service) and assuming weights 65%, 25% and 10%, respectively, the results are in Table 5 for suppliers SM-A and SM-B. The performance dimensions and the respective weights were defined after meeting with the Purchasing and Production departments. The scale used assumes 1 as very poor up to 5, meaning very good.

Table 5 - Weighted-point evaluation system for suppliers SM-A and SM-B

Performance dimension	<i>Weight</i>	<i>SM-A</i>	<i>SM-B</i>
Price	65%	5	4
Delivery	25%	1	3
Service	10%	1	5
Score	100%	3.6	3.85

Therefore, if service quality and delivery are also considered, the supplier with the highest score is supplier SM-B, which should be selected.

4.1.2 Composite materials shield

Firstly, the specifications and requirements of the composite shields were collected, which were the 2D and 3D technical drawings for the respective references, the materials (glass-fiber reinforced polymer for the main body and PVC for some tubes glued to the body), the color code (white RAL9001) and the finishing (high-gloss). In Figure 20 is presented one of such shields.



Figure 20 - GFRP Shield (ASL0301FVMQ0002)

Compared to sheet metal services, there are considerably less suppliers and substitutes, and the manufacturing is relatively complex, so the supply risk is medium-high. As for financial impact, these items are a small fraction of the final machines' cost, so it is considered low. Thus, the GFRP shields are a bottleneck item, and the strategy is to ensure supply continuity and search for alternatives.

As was discussed in Section 3.3, the current supplier, for this purpose called CM-A, supplies the parts without the high gloss finishing and painting, so it is important to know the internal cost to perform those services. In Table 6, the data from the proposal of supplier CM-B is compared to CM-A, as well as the cost estimates of polishing and painting. The mold cost in supplier CM-B is a fixed cost incurred only once, to manufacture the parts.

Supplier CM-B was given one part for each part number to develop a more precise proposal. Unfortunately, it was not possible to send him part number ASL03, due to limited or inexistent stock at the time, but ASL05 is a good term of comparison, because it belongs to a larger machine.

Table 6 - Proposals for GFRP shields from suppliers CM-A and CM-B

Article code	Finishing Cost	CM-A	CM-B		
		Unit Cost	Unit cost (+Finishing)	Unit Cost	Mold cost
ADS3001FVMQ0002	7.85 €	45.90 €	53.75 €	70.00 €	216.00 €
ADS3001FVMQ0004	7.85 €	45.90 €	53.75 €	70.00 €	216.00 €
ASL0301FVMQ0002	8.63 €	83.80 €	92.43 €	N/A	N/A
ASL0501FVMQ0002a	10.16 €	136.70 €	146.86 €	112.00 €	330.00 €

As can be seen in Table 6, for articles ADS30, CM-B is more expensive, even when considering the finishing costs. For article ASL05, the unit cost is cheaper. A total cost analysis was developed for article ASL05 using Equations 4.1, 4.2 and 4.3:

$$\text{Total Cost} = \text{Fixed costs} + \text{Variable Costs} \quad (4.1)$$

$$\text{Total Cost (CM - A)} = \text{Unit Cost (incl. Finishing)} * \text{Quantity} \quad (4.2)$$

$$\text{Total Cost (CM - B)} = \text{Mold cost} + \text{Unit Cost} * \text{Quantity} \quad (4.3)$$

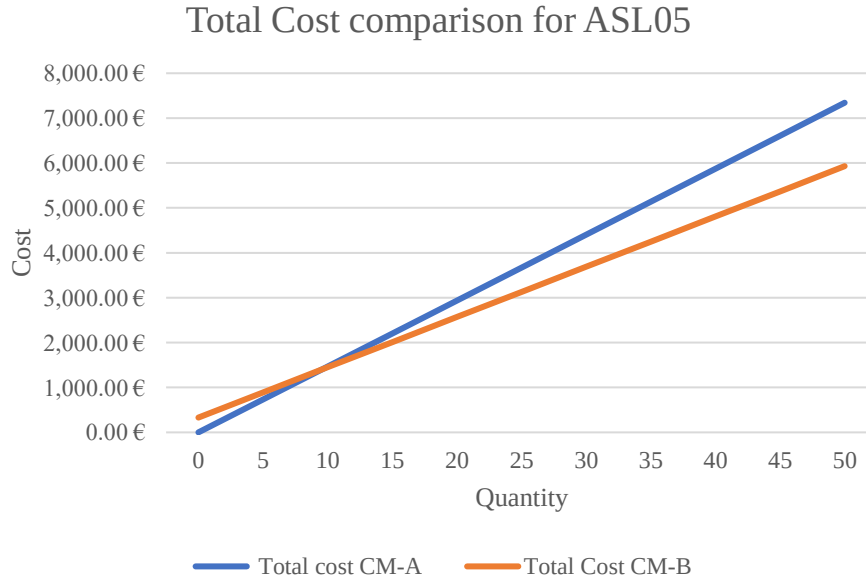


Figure 21 - Total cost analysis for ASL05 for suppliers CM-A and CM-B

As can be observed in Figure 21, the slope of the curves is dictated by the respective unit costs. They intersect at around 10 units. This means that if more than 10 units are ordered, it becomes cheaper to use supplier CM-B for item ASL05. Since the ADS are not worth it, but the ASL05 are cheaper, some sort of dual sourcing could be made to de-risk the supply situation and lower costs.

4.1.3 Stainless steel bowls

The stainless steel bowls are essential to the dough mixing machines and represent a large part of the cost of a machine. Their geometry also plays a big role in the dough quality, so any change in the dimension of a bowl requires lots of tests. The stainless steel bowls used in the bakery industry are very different from other bowls, so there are not many suppliers internationally, and the few suppliers who exist are highly utilized. For example, the current supplier, for this project called SS-A, has very long lead times (3 months) because they have many backorders and there are few alternatives. The problem worsened because of the need to make bowls that have a central cone, similar to the one in Figure 22. To make this bowl in a cost-effective way requires the investment in a mold for the cone, that is then welded to the other parts. Without a mold the production involves lengthy manual metal forming that increases the cost (labor hours) and also the production lead time.



Figure 22 - Stainless steel bowl with central tube/cone

Due to the strategic importance of this product, at the time the project started, FELINO was already in talks with suppliers. In the search for additional suppliers as part of this project, only one different supplier was found through a Chinese product directory, but the results were not satisfactory and it was not reliable and trustworthy, considering that FELINO requires a sample before fully committing to a new supplier and the difficulty in communication with the supplier in China.

4.2 Pilot cases

In this Section, three pilot cases will be analyzed. The first two are related to the aggregation of orders, while the third is related to the continuous review policy of stock management. When implementing inventory policies, Chopra et. al (2016) recommend starting with a pilot program that represents similar products from the entire set of products. By starting with a pilot, problems can be solved before a policy is implemented for all products.

4.2.1 Order aggregation

As was described in Section 2.2.3, aggregating orders means that several products or items can be aggregated in the same order, rather than being ordered independently, which allows for the spread of fixed costs to multiple items.

The first case is on the opportunity of order aggregation for individual protective equipment for the unit of Ermesinde, such as gloves and protective eyewear. This group was chosen due to the similarity and possibility of being ordered from the same supplier, as well as to the fact that they are items of relatively steady consumption throughout the year.

To calculate the optimal order frequency, n^* , (recall Equation 2.16) there are four inputs. The annual demand for each item, D_i , was obtained using the 2022 annual consumption Figures and assumed to be the same as 2022. This is the simplest time series forecast (Bozarth and Handfield, 2019), which assumes that the following year takes the same value as the previous year ($F_{t+1}=D_t$). The holding cost per year as a fraction of product unit cost, h , was assumed to be 20%. The item unit costs, C_i , were based on the most recent cost to date. The setup cost, S , was assumed to be 8€, which is an estimate of fuel costs, road tolls and other costs, to transport

the items from the supplier to Ermesinde by the company's own drivers. The results are summarized in Figure 23. The products internal code is used instead of their description.

h	20%						
S	8 €						
Product Code	NMGPROT00010038	NMGPROT00010065	NMGPROT00010029	NMGPROT00010027	NMGPROT00010028	NMGPROT00010042	NMGPROT00010031
Annual Consumption (D)	24	92	44	108	205	24	17
Unit Cost (C)	0.96	1.42	0.55	0.55	0.55	1.38	8.97
$D \cdot h \cdot C_i$	5.76	32.66	6.05	14.85	28.1875	8.28	38.1225
Optimal frequency (n*)	2.59	2.59	2.59	2.59	2.59	2.59	2.59
Optimal quantity (D/n*)	9	36	17	42	79	9	7
Average Inventory	5	18	9	21	40	5	3
Annual Holding cost	1.11 €	6.31 €	1.17 €	2.87 €	5.45 €	1.60 €	7.37 €
Annual Order cost	25.88 €						
Total cost (excl. materials)	51.75 €						

Figure 23 - Order aggregation for individual protective equipment

Given the assumptions, the optimal order frequency was 2.59 aggregated orders per year. If rounded to 3, then an order for these items can be made every four months. The quantities ordered are given by the annual consumption divided by the order frequency.

Considering that in 2022 there was a total of 21 orders for the same items, this system would reduce the number of orders by 18 (around 86%), while also reducing costs. For instance, assuming transportation costs of 8€ per order, this would result in a saving of 144€ per year $(= (21-3) \cdot 8)$ in this aspect. Additionally, the company's resources, such as the drivers, vehicles and time are also freed up for other tasks.

The calculation for the case of no order aggregation, that is, each product ordered independently, with the EOQ, which demonstrates the higher costs without aggregation, is presented in Appendix C.

The second pilot case illustrates another situation where order aggregation is possible in some electrical components, specifically wire end ferrules, which are small metal or plastic tubes used to terminate the ends of electrical wires and come in various sizes (measured by the tube cross-section area) and colors (Figure 24). They are ordered in very large quantities and have low unit costs.



Figure 24 - Wire end ferrules

The same assumptions to the first case were made in terms of the demand, holding costs, and set up costs. There is a difference, though, because these components were sourced from four different suppliers last year, so the suppliers' location and distance is different, which affects transportation costs. Thus, 8€ is assumed to be an average transportation cost for these items. If third party transportation is arranged, the cost can be higher. The results are summarized in Figure 25.

S	8 €				
h	20%				
Product Code	NMECNLI00010040	NMECNLI00030017	NMECNLI00010039	NMECNLI00020034	NMECNLI00040029
Annual Consumption (D)	3700	3210	800	1448	1100
Unit cost (C)	0.0149	0.027	0.02	0.024	0.0307
$D_i \cdot h \cdot C_i$	11.026	17.334	3.2	6.9504	6.754
Optimal frequency (n*)	1.68	1.68	1.68	1.68	1.68
Optimal quantity (D/n*)	2200	1908	476	861	654
Average Inventory	1100	954	238	430	327
Annual Holding cost	3.28 €	5.15 €	0.95 €	2.07 €	2.01 €
Annual Order cost	13.46 €				
Total cost (excluding materials)	26.91 €				

Figure 25 - Order aggregation for wire end ferrules

The calculated optimal order frequency, n^* , for the assumptions made, is 1.68. Therefore, the proposal is that 2 orders be made annually for the purchase of these components. Considering that in 2022, 11 orders were made for the same items, it would lead to an 82% reduction in orders for these components. For a setup cost (S) of 8€, it would lead to a 72€ annual saving in transportation. In addition to this, it is proposed that only one supplier is selected, leading to a reduction from four to one supplier. The aggregation of orders in one supplier could also lead to better prices, due to the possibility of quantity discounts.

4.2.2 Stock management pilot case

The third pilot case arises from the need to develop a theoretical approach to stock management, particularly in high consumption, low seasonality items, which have stable demand during the year. The most consumed tools for machining (milling or turning) match the criteria. Therefore, after analyzing the consumption data since 2021, and including the first four months of 2023, the most used cutting tool was selected for this case, with code NMGFERR00030100.

The inventory policy that is chosen is a continuous review system (recall Section 2.2.1), thus, the ROP, SS and EOQ parameters are calculated in this Section. The procedure followed was as below:

1. Calculation of the distribution of monthly demand based on historical data (2021-2023 year-to-date)
2. Calculation of the distribution of lead time
3. Calculation of safety factor based on desired service level
4. Safety stock calculation
5. Reorder point calculation

The analysis of the historical consumption of NMGFERR00030100 showed an outlier in October 2022 of 46 consumed items (see Figure 26). Therefore, the results were calculated for the situations both including and excluding the outlier. The outlier significantly increases the standard deviation, which increases the safety stock and, consequently, the ROP.

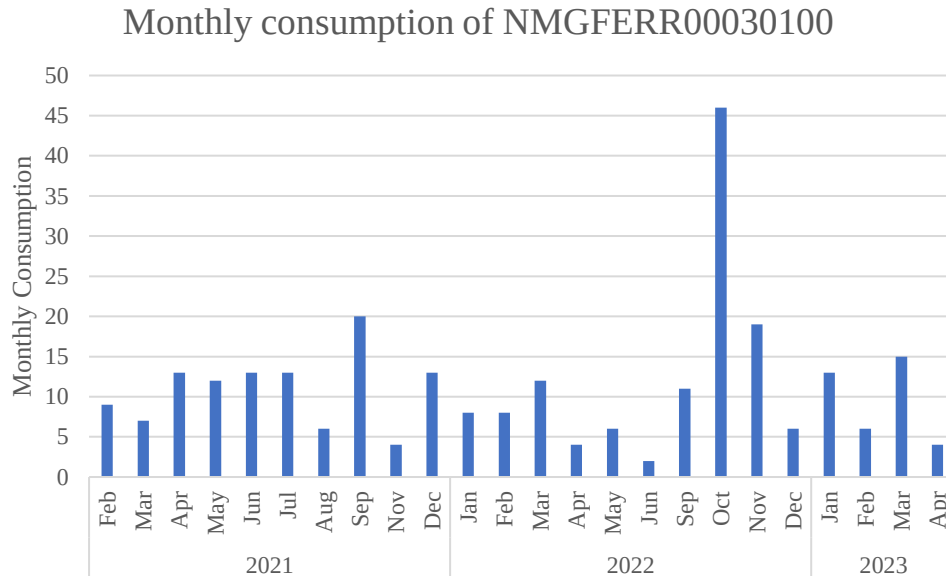


Figure 26 - Monthly consumption of NMGFERR00030100

As for the lead time a similar analysis was made. The lead time was calculated by subtracting the dates of delivery from the IR date for the specific supplier during 2022. In other words, it is the time interval since the IR is generated until it arrives at FELINO. The values above 33 days were considered outliers (see histogram in Figure 27). So, the calculations without outliers exclude both outliers from demand and lead time data.

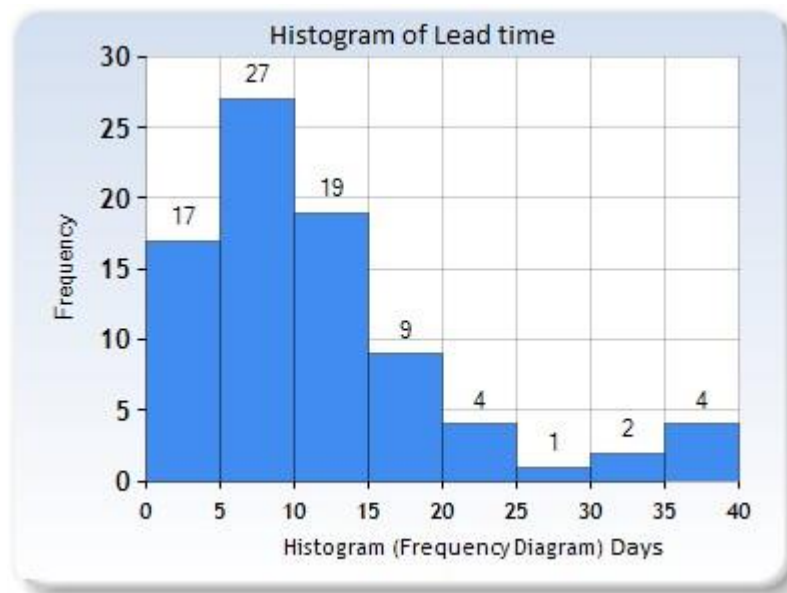


Figure 27 - Histogram of lead time

As for the safety factor, a service level of 97.7% was chosen, meaning that the probability of having an empty stock during the replenishment cycle is 2.3%, which, according to Table 1, equates to $Z=2$.

The SS and ROP were calculated, with all results presented in Table 7.

Table 7 - ROP calculations for NMGFERR00030100

NMGFERR00030100	Including Outliers	Excluding Outliers
Avg Monthly demand – D_{avg}	10.90	8.30
St. dev sample of demand – σ_D	11.15	5.67
Avg LT in months - LT_{avg}	0.38	0.31
St. dev. sample of LT - σ_{LT}	0.31	0.21
Service level – SL	97.7%	97.7%
Safety factor - Z	2	2
Safety stock - SS	15	7
Reorder point - ROP	20	10

As was expected, if the outliers are included in the computations, ROP is higher, in this case twice as much.

To conclude the continuous review system, the order quantity, EOQ, was also calculated (Table 8), using the last 12 months' Figures for demand, and recent unit cost.

Table 8 - EOQ calculations for NMGFERR00030100

Variables	Values
D (last 12 months)	144
h	20%
S	5 €
C	7.50 €
EOQ	31

5 Conclusions and future work

This dissertation project was conducted at FELINO, with the goal of improving the procurement function of the company, reducing the administrative load, increasing efficiency, and reducing costs.

To address these goals, firstly, the current procurement process was analyzed, which showed the delays and bottlenecks happening throughout the process, especially when the purchaser consults suppliers and waits for quotations. Then, a spend analysis highlighted the high fragmentation of suppliers and the potential for supplier concentration, that is, to focus the orders on less suppliers, for the purpose of obtaining commercial advantages and reducing administrative complexity. Afterwards, the supply problems with certain products were identified, to allow for new supplier research and selection.

The supplier research and analysis followed a structured method that starts by categorizing the products in a portfolio matrix (Kraljic matrix), which helps to understand the market dynamics and strategic importance to the company, supporting supplier selection strategy. Using various tools, such as the weighted-point evaluation system to analyze sheet metal services supplier proposals, and a total cost analysis for composite shields supplier proposals, the analysis of bids and decision making takes several factors into account, besides price.

Furthermore, the pilot cases on order aggregation showed concrete evidence on the possibility of cost reduction, supplier concentration and reduction of orders simultaneously. The last pilot case on inventory management developed a structured approach to determine continuous review policy system parameters. The most important is not the absolute savings value obtained by these cases, which are marginal for the total costs of the company, but rather to show the possibility that exists to extend the application to other products in order to significantly reduce the administrative load and an excessive number of orders and suppliers. For this reason, they are pilot cases. Continuous improvement requires small incremental improvements that, as a whole, have significant results.

During the project, some delays in the purchasing process were identified that have an impact on the total process lead time and administrative load. The following suggestions for future work can have a beneficial impact which are:

- Use preferred supplier and create preferred suppliers list
- Gradually remove need for three mandatory supplier consultations
- Focus on Total cost of ownership (TCO) versus price.
- Periodically assess supplier performance and update preferred supplier list

For recurrent and relatively standardized purchase items, the proposal is to use a preferred supplier and to gradually stop making three mandatory supplier consultations. One of the reasons why so many suppliers are used is related to the fact that the preferred supplier is not defined, with which there should be a greater commitment between both parties, namely in the definition of prices, order quantities and delivery times, among other conditions. Periodically, quarterly for example, market research to evaluate whether this supplier is still the most competitive can be made, consulting several suppliers again, or reviewing if the current supplier is problematic. It is important to increase intercommunication with the preferred suppliers, so that the supplier is aware of the quantities needed (if there is an estimate to do so), which could lead to a reduction in lead times. In turn, the lead time reduction leads to a reduction in inventory levels.

The preferred supplier should be documented and visible to everyone involved in purchasing, including the purchaser, so that he does not have to waste time consulting suppliers and asking for quotations, have to wait for their response, and only then place the order, which still needs validation.

Another reason for the creation of a preferred supplier list is that information does not rely exclusively on the employee's memory. So, if for some reason the employee is ill or changes, the knowledge is still available to others. If the preferred supplier is used, with the terms agreed between both parties, there is no need for validation, unless for checking errors or abnormal discrepancies, but order approval can become much faster.

Too high a focus on price increases the risk of quality and service problems. Thus, it is proposed that more performance dimensions are considered, and to shift focus to total cost of ownership, i.e., the total costs that the company will incur over the lifetime of the product that is purchased (van Weele, 2018), instead of mostly considering purchase price.

Whenever a delivery is completed, it would be useful to create data to then be able to evaluate the suppliers in terms of price, quality, and delivery and take note of problems that may arise. With this formal and objective evaluation, the company should then increase the volume of purchases with suppliers that perform well and reduce or eliminate troublesome suppliers altogether. This should reduce the supplier base over time.

The administrative load, being reduced, unlocks valuable time that can be used on higher value-added tasks such as prospecting new suppliers, supplier evaluation and continuous improvement initiatives, enhancing operational efficiency.

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Appendix A: FELINO's bakery and pastry equipment

FORK MIXER (FIXED BOWL)

FF



FORK MIXER (REMOVABLE BOWL)

FM



SPIRAL MIXER (FIXED BOWL)

SF



SPIRAL MIXER (WITH REMOVABLE BOWL)

SM



SPIRAL MIXER (WITH FIXED BOWL)

SL



PLANETARY MIXER

BT



DOUGH SHEETER

LM



BUN DIVIDER ROUNDER

DS



AUTOMATIC BUN DIVIDER

DA



BREAD MILL

RP

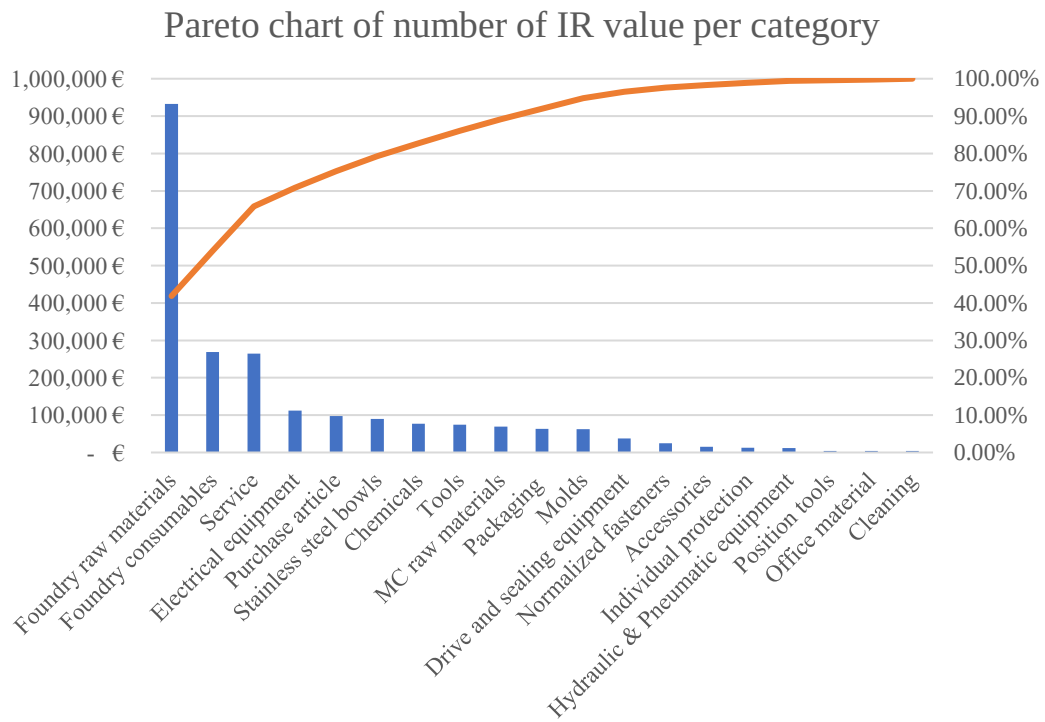
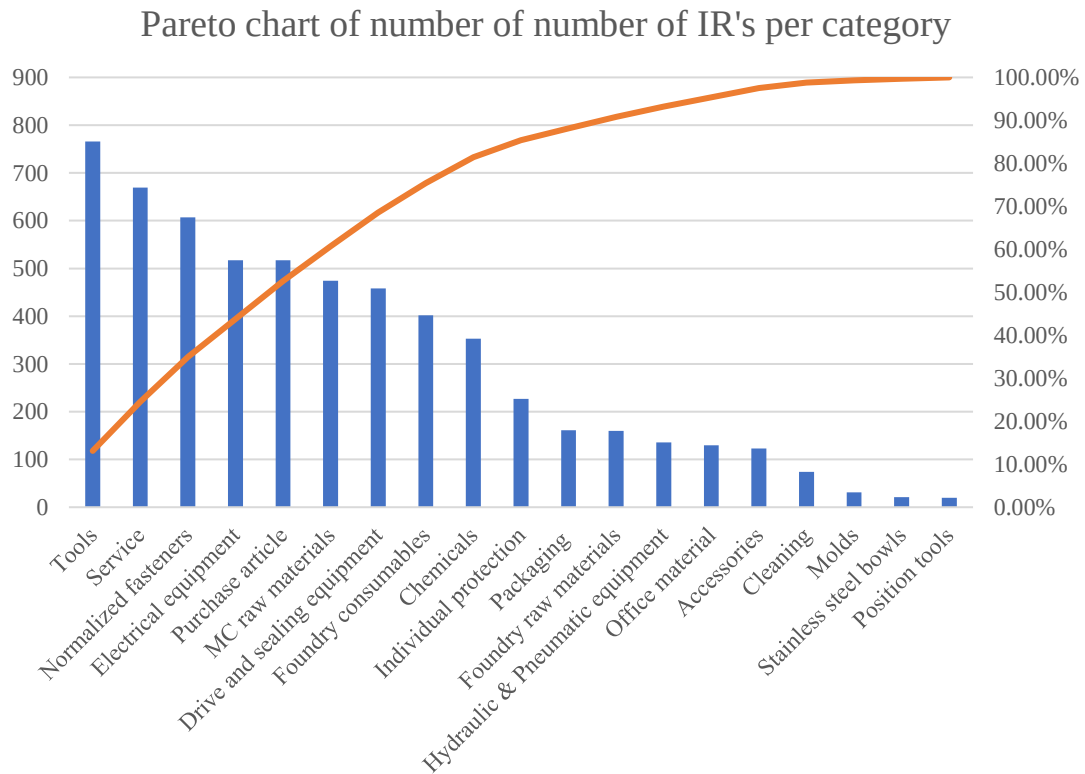


BOWL LIFTER

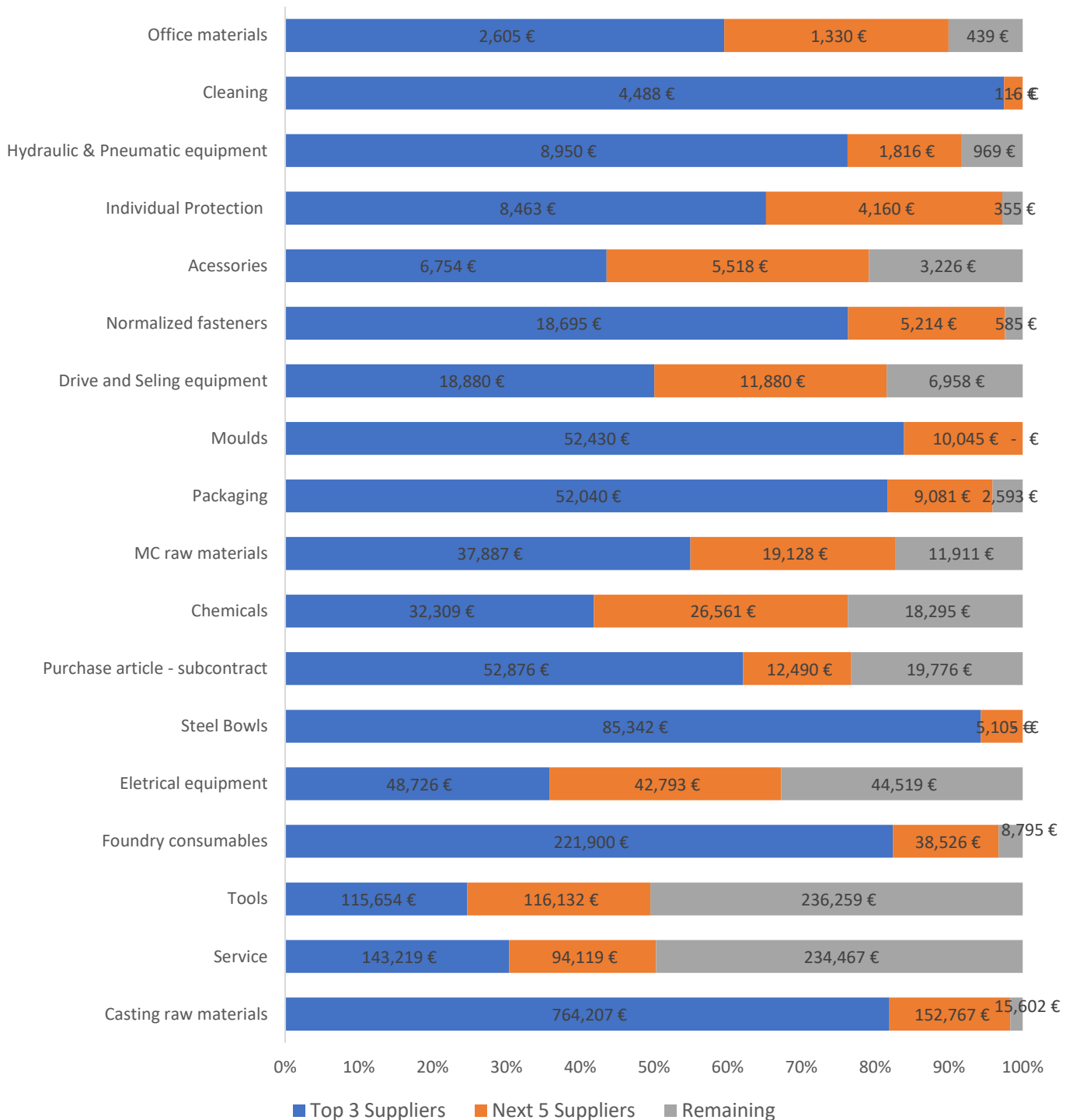
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Appendix B: Other charts from Spend Analysis



Supplier density chart for all categories



Appendix C: Products ordered independently

Ordering each product independently

Produto	NMGPROT00010038	NMGPROT00010065	NMGPROT00010029	NMGPROT00010027	NMGPROT00010028	NMGPROT00010042	NMGPROT00010031
Annual Consumption (D)	24	92	44	108	205	24	17
Unit Cost (C)	0.96	1.42	0.55	0.55	0.55	1.38	8.97
S	8	8	8	8	8	8	8
EOQ	45	72	80	125	173	37	12
Annual Frequency (D/EOQ)	0.54	1.28	0.55	0.86	1.19	0.64	1.38
Cycle Inventory	22	36	40	63	86	19	6
Annual Holding cost	4	10	4	7	9	5	11
Order Cost	4.29	10.22	4.40	6.89	9.50	5.15	11.04
Total cost (excluding material)	103.00 €						

Ordering each product independently

Produto	NMECNLI00010040	NMECNLI00030017	NMECNLI00010039	NMECNLI00020034	NMECNLI00040029
Annual Consumption (D)	3700	3210	800	1448	1100
Unit Cost (C)	0.0149	0.027	0.02	0.024	0.0307
S	8	8	8	8	8
EOQ	4457	3084	1789	2197	1693
Annual Frequency (D/EOQ)	0.83	1.04	0.45	0.66	0.65
Cycle Inventory	2229	1542	894	1098	847
Annual Holding cost	7	8	4	5	5
Order Cost	6.64	8.33	3.58	5.27	5.20
Total cost (excluding material)	58.03 €				