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Development of an Inventory Management Policy at Wurth Portugal

Francisco Manuel Canas Cardoso Durães Ferreira

Master in Management of Services and Technology

Supervisor:
Assistant Professor Ana Lúcia Henriques Martins, Department of Marketing, Operations and Management, ISCTE Business School

October, 2021

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BUSINESS SCHOOL

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Resumo:

O presente projeto é realizado numa empresa de venda de equipamento e prestação de serviços de manutenção desses equipamentos. O objetivo do projeto foi a redução do tempo de reparação dos equipamentos por via do incremento da disponibilidade de peças para realização dessas mesmas reparações. Tendo-se identificado que a falta de peças para reparação adia a conclusão das reparações, a política de gestão de stock em vigor foi estudada e tendo em conta a variabilidade na procura e abastecimento, foi proposta à empresa uma nova política de gestão de stock para combater as irregularidades atuais. Para além disso, também foram identificados os potenciais riscos de abastecimento relacionados com fornecedores e prazos de entrega e proposta uma política de mitigação do risco de abastecimento.

Foi analisada a atual política de gestão de stock de peças de substituição de máquinas e identificados os respetivos riscos de abastecimento. A avaliação dos dados foi feita através de observação, entrevistas e grupos focais nos departamentos de compras, logística e serviços técnicos da empresa.

As peças de substituição foram dividas por classes através da análise ABC (volume de vendas) com o intuito de selecionar as com maior grau de importância, as denominadas de classe A. Assim sendo, foi proposto uma sugestão de melhoria de gestão do stock de peças de substituição de classe A. Também foi elaborada uma proposta de mitigação do risco do abastecimento. As propostas foram implementadas, originando uma melhoria substancial ao longo do processo de reparação de máquinas.

Palavras chave: gestão de stock, risco de abastecimento, mitigação do risco

Classificação JEL:
M11: Administração de Empresas – Gestão da Produção
Y40: Categorias Diversas - Dissertações

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Abstract:

This project is carried out in a company that sells equipment and provides maintenance services for this equipment. The project's objective was to reduce equipment repair time by increasing the availability of parts to carry out these repairs. Having identified that the lack of parts for repair delays the completion of repairs, the current stock management policy was studied and taking into account the variability in demand and supply, a new stock management policy was proposed to the company to combat current irregularities. In addition, potential supply risks related to suppliers and delivery times were also identified and a supply risk mitigation policy was proposed.

The current stock management policy for machine substitution parts was analyzed and the respective supply risks were identified. Data evaluation was carried out through observation, interviews and focus groups in the company's purchasing, logistics and technical services departments.

The replacement parts were divided by classes through the ABC analysis (sales volume) in order to select those with the highest degree of importance, the so-called class A. Therefore, a suggestion for improving the management of the class A substitution parts stock was proposed. A proposal for mitigating the supply risk was also prepared. The proposals were implemented, leading to a substantial improvement throughout the machine repair process.

Keywords: stock management, supply risk, risk mitigation

JEL Classification:

M11: Business Administration - Production Management

Y40: Miscellaneous Categories – Dissertations

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1. Introduction

The environment of production and supply chain transactions has changed greatly in recent years. This change is due to increased complexity driven by globalization, delocalization, high transportation charges, poor infrastructure, weather-related disasters, and terrorist threats (Hamdi et al., 2018). Thus, managing a supply chain with a view to gaining a competitive advantage has become even more challenging and complex (Hamdi et al., 2018). In this context, stock management policy and supplier selection have become key elements for businesses to improve their market position (Chase et al., 1998).

The inventory management policy aims to calculate the quantity to be ordered of each material and to define the moment when each order must be placed to minimize costs and meet customer needs (Hamdi et al., 2018). Supplier selection is another concern of the modern manager who wants a supplier capable of delivering the right product to the right place at the right price and at the right time (Slack et al., 2019). Moreover, the product must be delivered in the right quantity, with the right information and particularly with a minimum of disruption (Hamdi et al., 2018). Thus, enterprises, when selecting suppliers, should evaluate all aspects of the performance of supply candidates, not only the price, product quality, product quantity and service, but also the risk factors of uncertainty, vulnerability and possible disruption of supply (Slack et al., 2019).

Wurth Portugal belongs to the Wurth Group, a multinational market leader in the field of professional fastening and assembly. In order to improve its market position, the company should focus on its inventory management policy and mitigate supply risk. Currently, machine substitution parts are only ordered when there is stockout, which sometimes leads to delays in repairs. That said, the opportunity arises to create an inventory management policy capable of improving these times.

1.1 Objective

This study aims to reduce the repair time of the machines by implementing a new stock management policy for machine parts capable of mitigating the risk of not being able to meet customer delivery times. In addition to the risk of not being able to provide the service when it is required, demand and supply variability are factors to be considered when implementing these policies. Therefore, the following tasks will have to be performed:

1. Investigate the company's current situation
2. Identify, classify and prioritize the area of intervention
3. Evaluate and prepare respective improvements
4. Implement the proposed suggestions
5. Monitor the effectiveness of established measures

1.2 Methodology

The current research has been structured following the case study paradigm, which is a social science research method, generally used to investigate a contemporary phenomenon in depth and in its real-world context (Yin, 2018). So, in this case study, the phenomenon of interest pertains to an event with the converged finding implicitly assuming a single reality. Use of evidence from multiple sources will increase confidence that this case study renders the event accurately (Yin, 2018). This case aims to contribute to the implementation of a new stock management policy capable of mitigating the risk of not being able to serve the customer when the order is received.

1.3 Scope

Wurth Portugal belongs to the Wurth Group, a multinational market leader in the field of professional fastening and assembly. The purchasing, logistics and technical services departments are the areas that will gain the most from this research. This research will focus on Wurth Portugal's machine substitution parts. Substitution parts will be divided into classes through ABC analysis (sales volume) to select those with the highest degree of relevance, called class A. All the data collected is from the year 2019, which is the year before the start of the COVID-19 pandemic to produce more reliable results.

1.4 Structure

This thesis will be subdivided into five chapters:

- Introduction - consists of a general context, objective, an initial approach to the methodology, scope and structure.
- Literature review - with the aim of providing the foundation for the research, this chapter provides a synopsis of the existing literature on stock management, ABC analysis and the continuous review policy taking into account the variability in

demand and supply. Furthermore, supply chain risk management and related models are also approached.

- Methodology - encompasses the description of the methods and principles applied to fulfill the overall aims of the study, structured around the several phases of the research.
- Company situation - analysis and description of the current stock management policy, as well as the variability in demand and supply. Identification of proposals of solutions to improve stock management and mitigate supply risk. The chapter ends with the implementation of the new policies accepted by the company and the improvements already achieved out of the implementation of the proposals.
- Conclusion - synopsis of results with validation as to whether the milestones proposed at the beginning of the study were indeed attained. Statement of the limitations of research and possible clues for future research.

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2. Literature Review

In eliciting the fulfilment of the objectives presented in the previous chapter, a literature review on the enunciated topics is required to ground the subsequent development of the research. The current chapter provides a synopsis of the existing literature on logistic system, stock management, ABC analysis and the continuous review policy considering the variability in demand and supply.

2.1 Logistic System

The mission of the logistic system is to create value for the customer (Ramos, 2020). On this way, countless activities are carried out to offer the right product to the customer, in the right place, at the right time, in the right quantity, at the lowest possible cost (Ramos, 2020). Storage activity does not add value to the product (Chase et al., 1998). The value of a product to the customer is the same when entering and leaving the warehouse (Ramos, 2020). Sometimes, the value may even be lower when leaving the warehouse due to the risk of obsolescence, breakage or deterioration (Ramos, 2020). However, the whole process of making the product available to the customer is based on a set of storage and transportation activities that allow it to comply with the value proposal previously established (Slack et al., 2019).

Although it does not add value to the product, the storage contributes to the fulfillment of the value proposal by the company's logistic system (Ramos, 2020). Its importance comes from the lack of totally reliable transport with short delivery times to quickly place the product with the customer (Slack et al., 2019). Therefore, on the one hand, there is an economic reason, in which the need for storage reduces the total costs of the logistic system and on the other hand, when owning a warehouse, the product is placed closer to the market which allows availability and faster response and, consequently an improvement of the service (Slack et al., 2019). A logistic system without storage would only be possible if production and consumption were perfectly synchronized, without variability, and if there were transports capable of carrying small loads to each customer in a short period of time (Chase et al., 1998).

The need for storage infrastructures results from the need to build up stock (Ramos, 2020). The need to build up stock arises when supply and consumption are not aligned over time. Consumption occurs continuously, while supply usually occurs in batches (order batch or manufacturing batch) (Ramos, 2020). On the other hand, consumption and supply may be out of step with time, leading to the need for stock accumulation (Ramos, 2020). Thus, the existence of stock means that the consumption process is not dependent on the supply process (Ramos, 2020). In addition to making these two processes independent, the creation of stock is important in the following measures (Ramos, 2020):

- Meet demand variations. The demand is not known in advance so, stock maintenance allows responding to unforeseen demand fluctuations.
- Meet variations on the supply side related to non-compliance with the delivery times practiced and the respective quantities delivered by suppliers whose effects can be mitigated through the constitution of stock.
- Allow economical buying. Each order has its costs, which means, ordering in small quantities means that the ordering costs are high due to the number of orders placed. The greater the quantity ordered, the smaller the number of orders, which leads to a greater stock build-up. On the other hand, due to the costs associated with the stock maintenance, it is necessary to order the appropriate quantity and able to minimize costs.

Stock management will make costs lower for a certain level of customer service (Chase et al., 1998).

2.2 Inventory Policies

Inventory management has a strong importance in the performance of the supply chain (Ramos, 2020). Its activity is linked to the management of the relationship with the supplier and the customer and plays an important role in the balance between supply and demand (Chase et al., 1998). Effective stock management in the supply chain can only be pursued through the implementation of a stock management policy (Chase et al., 1998).

The stock management policy implemented for each item makes it possible to determine the stock in the warehouse, which is necessary to carry out the sizing of the storage space (Slack et al., 2019).

Defining a stock management policy for each item implies knowing when and how much to order to minimize costs and at the same time satisfy the customer's needs (Ramos, 2020). There are several stock management models that present the most varied solutions and the chosen model should take into account the random behavior of supply and demand (Ramos, 2020). Regarding the supply, suppliers have variable delivery times and sometimes the quantity delivered is not correct, which implies a future delivery of the rest previously stipulated (Ramos, 2020). Concerning the demand, its unpredictability makes demand variable, since neither on the market side nor on the customer side the quantities demanded are known (Ramos, 2020).

The inventory management policy defines when to order and how much to order (Ramos, 2020). The order is placed to the supplier when the stock level reaches the reorder point. Regarding the order quantity, it must be the one that minimizes the total costs (Ramos, 2020).

2.3 ABC Analysis

Companies with a considerable dimension have a large stock which has the risk of being managed incorrectly by using too many resources on less important items and losing track of more important items (Cohen & Ernst, 1988). Therefore, companies intend to classify the items according to their importance and to find adequate control policies for each group of items (Cohen & Ernst, 1988). Several authors have studied the classification process and developed exact and heuristic methods for classifying inventories (Cohen & Ernst, 1988). The most used classification method was the ABC classification, which has only one condition of having an annual use value (Cohen & Ernst, 1988).

When the inventory has a high number of items, the company chooses to apply the ABC classification because it is not feasible for the company to implement a stock control system for each one of the items (Ernst & Cohen, 1990). The ABC classification is easy to implement and performed only with respect to one criterion (sales volume) but there is always a need to optimize the stock parameters of each class despite the fact that a large part of the investment is directed to class A items (Zhang et al., 2001).

ABC analysis is a method that allows differentiating a set of items into three classes: class A, class B and class C. Class A items are of greater importance, those of Class B are of intermediate importance and those of Class C are of less importance (Ramos, 2020). The ABC analysis is based on the Pareto rule (80/20 rule) (Ramos, 2020). As such, class A comprises about twenty percent of the total number of items representing approximately eighty percent of the quantity of items used (Ramos, 2020).

2.4 Continuous Review Inventory Policy

As this project will focus on class A items and, according to the literature review, it is recommended that these items be monitored through a continuous review inventory model, only the continuous review model will be further elaborated from this point forward.

The continuous review model can be applied when demand and supply behave uncertainly (Chase et al., 1998). To deal with this behavior on both sides, demand and supply, it is necessary to build a safety stock of items to absorb variations greater than the average values recorded (Chase et al., 1998). Constant monitoring of stock levels is carried out due to the need to place an order for the supplier when an item reaches the order point (Chase et al., 1998). If the order is not placed at that time, the risk of stockout increases considerably over time (Chase et al., 1998).

In a stochastic model of continuous review (Q, r), demand and lead time are random variables that follow a specific probability distribution (Ramos, 2020). Kim and Benton (1995) posit that the lead time can be controlled through some of its components such as lot size, unit cost of production, production time and preparation time. In addition, Al-harkan et al. (2007) concluded that when considering the lead time as a controllable factor, the lead time will be shorter and consequently there will be less risk and also a smaller safety stock. Therefore, most stock management policies follow a stochastic model in which lead times are dependent and controllable (Ramos, 2020).

In this model, the quantity to be ordered is fixed and the period between orders is variable because it is dependent on the pace of demand in the period between orders (Ramos, 2020). As demand and lead time are variable, there is a possibility of disruption (Ramos, 2020). During the order cycle, there is a possibility of stockout when the quantity in stock is lower than the reorder point, that is, during the supplier's delivery period (Ramos, 2020). There will be disruption if the demand during the supplier's delivery period is greater than the order point (Ramos, 2020).

The reorder point corresponds to the average demand during the delivery period, plus a safety margin because there is variability associated with demand during the delivery period. This safety factor corresponds to the safety stock. Therefore, the reorder point is calculated as follows (Ramos, 2020):

$$Safety\ Stock = z * \Sigma L$$

$$Reorder\ Point = d * L + safety\ stock$$

$z = service\ level$

$$\sigma L = \sqrt{L * \sigma^2 demand + d^2 * \sigma^2 lead\ time}$$

$L = monthly\ lead\ time$

$d = average\ monthly\ demand$

$\sigma d = standard\ deviation\ of\ monthly\ demand$

$\sigma L = standard\ deviation\ of\ monthly\ lead\ time$

The following equation corresponds to the order quantity that minimizes total costs and is called the economic order quantity. It is calculated as follows (Ramos, 2020):

$$Economic\ Order\ Quantity = \sqrt{2 * S * D \div (i * C)}$$

$S = order\ cost$

$D = annual\ demand$

$i = inventory\ holding\ cost$

$C = acquisition\ cost$

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3. Methodology

The current chapter encompasses the description of the methods and principles applied to fulfil the overall aims of the study, structured around the 4 phases passed throughout this study.

3.1 Case Study Approach

The current research has been structured following the guidelines for conducting a case study (Yin, 2018).

In this case, the phenomenon of interest pertains to an event with the converged finding implicitly assuming a single reality. Use of evidence from multiple sources would then help to structure this case study and clarify the events accurately (Yin, 2018).

During an informal interview, the Operations Director proposed that the chosen group for this study be the machine substitution parts, considered the most critical group. They were divided into classes through ABC analysis to select the ones with the highest degree of importance, called class A. The criterion used was the sales volume in order to satisfy the greatest number of customers.

3.2 Research Design

The research entails an empirical study and links directly with the literature review. The research design is a logical plan for getting from a starting point (now) to an improved point (desired scenario), where at the starting point may be defined as the set of questions to be addressed, and at the improved point is some set of conclusions about these questions (Yin, 2018). Between these two points are several major steps, including the collection and analysis of relevant data. Yin (2018) described a research design as "a plan that logically links the research questions with the evidence to be collected and then to be analyzed in a case study".

Direct observation and interviews are two of the most important techniques used in a case study (Yin, 2018). The case study relies on many of the same techniques as in a history, but it also relies heavily on two sources of evidence not usually available as part of the conventional historian's repertoire: direct observation of the events being studied and interviews with the persons who may still be involved in those events (Yin, 2018).

Another useful tool is focus group which is a discussion with a small group of persons about some aspect of a case study, deliberately trying to surface the views of each person in the group (Ryan et al., 2014). This technique is used because the group interaction encourages people to explore and clarify individual and shared perspectives.

Due to the nature of the investigation, these techniques will be used as data collection tools, and thus play an important role in the execution of this case study.

The company research is developed based on a five-step process:

Step 1 - Diagnosis of the current situation:

Observation - will be used to kick-start the project, as it best suits the aims and purposes of the study. Based on the internal analysis carried out (mainly data collection and informal interviews), the logistic system of Wurth Portugal and the company's headquarters, Wurth Germany should be analyzed in detail through direct observation and the area to be studied should be identified.

Output: Gathering of the current situation and identification of the area to be studied.

Step 2 - Identification and analysis of the main challenges entailed in the current procedure as they stand:

The machine repair department is the area chosen by the logistic department to be studied and for that reason, it is necessary to carry out a research of its stock management policy.

Output: Research of the stock management policy of the previously identified set of parts.

Step 3 - Analysis and development of the proposal:

Identification of the problem’s sources. Then, ways to overcome them will be developed, that is, through the proposal of a stock management policy that the literature considers more adequate for this case.

Not all parts are of equal importance. Therefore, an ABC analysis is performed to select the most appropriate inventory model for the class A materials.

Development of the stock management policy proposal, which includes the identification of the stock management model, the level of service that the company intends to offer its customers and the determination of the various operational parameters of the model.

Step 4 – Recommendation for procurement policy to reduce the supply risk.

Risk assessment of inventory management through lead time, a very relevant indicator when choosing a supplier.

Step 5 – Monitoring and adjustments:

Monitor the operationalization of the model and make adjustments if necessary.

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4. Company Situation

This chapter intends to present the project's target company as well as the project developed, in its different phases. Thus, and after a brief presentation of the company, the company's logistic system is approached, as well as all the main challenges entailed in current process. An ABC analysis relating to the items in the machine repair department is done to select the class A materials. Next, the following indicators will be calculated: monthly average demand and its standard deviation; monthly lead time and its standard deviation; service level; inventory holding cost and order cost; safety stock, reorder point and economic order quantity. The chapter ends with a risk assessment of inventory management through lead time, a very relevant indicator when choosing a supplier.

4.1 Wurth Group

The Wurth Group is world market leader in its core business: the production of assembly and fastening materials. It currently consists of over 400 companies in more than 80 countries and has more than 81,000 employees on its payroll (Wurth, 2021). More than 33,000 of these are permanently employed sales representatives (Wurth, 2021). According to the annual financial statement, the Würth Group generated total sales of EUR 14.41 billion in the business year 2020 (Wurth, 2021). A new record in sales.

In the core business, the Wurth Line, the product range for craft and industry comprises over 125,000 products: From screws, screw accessories and anchors to tools, chemical-technical products and personal protection equipment (Wurth, 2021). The Allied Companies of the Wurth Group, which either operate in business areas adjacent to the core business or in diversified business areas, round off the range by offering products for DIY stores, material for electrical installations, electronic components (e.g. circuit boards) as well as financial services.

3.9 million customers all over the world trust in Wurth today (Wurth, 2021). Human beings and a very special corporate philosophy are the driving forces of the long-standing success enjoyed by the Wurth Group. Wurth is a family business that was founded by Adolf Wurth in 1945. Prof. Reinhold Wurth, today’s Chairman of the Supervisory Board of the Wurth Group’s Family Trusts, took over the business at the age of 19 after his father had passed away and developed it further in the following years. Starting from the early years of the company in post-war Germany, he turned the former two-man business into a worldwide operating trading group.

Wurth Group has a clear business orientation: It is marked by a strong brand policy, future-oriented product strategy, closeness to the customer, clear quality offensive, thinking in terms of visions and not least by a strong corporate culture. Bettina Wurth, Reinhold Wurth's daughter and Chairwoman of the Advisory Board together with the members of the Central Managing Board see to it that these values are filled with life and developed further.

4.2 Current company situation

Wurth Portugal, which belongs to the Wurth Group, has 657 employees and had an annual turnover of 65.9 million euros in 2019 (Wurth, 2021). It currently has 23 stores at its disposal throughout the country where they only sell their products, including in Madeira and the Azores. In order to satisfy the needs of its customers, Wurth Portugal has a machine repair department capable of repairing any machine under and out of warranty. However, sometimes, due to the lack of inventory of a particular part, its repair may take longer. For that reason, during an informal interview, the Operations Director proposed that the chosen group for this study be the machine substitution parts, considered the most critical group.

4.3 Main challenges entailed in current process

Not all items are of equal importance to the machine repair department of Wurth Portugal. For each item, depending on its degree of relevance, the most appropriate stock management policy is applied. Basically, the objective is to manage resources according to the importance of each item for the company.

4.3.1 ABC Analysis

The ABC criterion used to calculate the importance of each item results from the respective number of units used during the year 2019. This criterion, as well as the time interval that is before the start of the COVID-19 pandemic, were chosen in order to present more reliable results.

ABC analysis is based on the Pareto rule (80/20 rule). Thus, class A comprises around twenty percent of the total number of items that represent approximately eighty percent of the quantity of items used; Class B comprises approximately thirty percent of the items that represent approximately fifteen percent of total quantity; finally, class C comprises about fifty percent of the items that represent five percent of total quantity.

In this context, ABC analysis will be used to filter class A items, define the most efficient stock management policy, which will be the continuous review policy, and the control level required for each one of these items. The amount used of one of the class A items, “pack 5 orings”, was calculated (Table 4.1).

Table 4.1 - Quantity used of “pack 5 orings”

Repair Code	Item Code	Item Name	Quantity Used	Date of use
219101	07071604230661	PACK 5 ORINGS	1	01-feb-19
219816	07071604230661	PACK 5 ORINGS	1	21-feb-19
220984	07071604230661	PACK 5 ORINGS	1	27-mar-19
222176	07071604230661	PACK 5 ORINGS	1	03-may-19
225739	07071604230661	PACK 5 ORINGS	1	30-jul-19
226263	07071604230661	PACK 5 ORINGS	1	19-aug-19
226364	07071604230661	PACK 5 ORINGS	1	28-aug-19
226928	07071604230661	PACK 5 ORINGS	1	18-sep-19
226932	07071604230661	PACK 5 ORINGS	1	18-sep-19
228500	07071604230661	PACK 5 ORINGS	1	07-nov-19
230013	07071604230661	PACK 5 ORINGS	1	30-dec-19

As previously said, class A comprises about twenty percent of the total number of items representing approximately eighty percent of the quantity of items used. Thus, 84 of the 417 items, which shows that the Pareto rule applies in this case (Table 4.2). Only 63 of the 84 items will be studied due to the lack of data on the system of the other 21 items and the impossibility of personally collecting data from the archives during COVID-19 pandemic.

Table 4.2 - Class A items

Item Code	Item Name	Quantity	Accumulated Quantity
07086514710901	DISCOS DE EMBRAIAGEM	300	9.53%
07071602580661	ORING	204	16.01%
07729551209611	BATERIA 12V - 23A PARA BOOSTER	168	21.35%
07071602040661	CONJUNTO DE 3 VÁLVULAS	149	26.08%
07071602200661	PERNE	66	28.18%
58004040099901	MOTOR	66	30.27%
07071602330661	INTERRUPTOR	64	32.31%
58001000129901	MOTOR	59	34.18%
…			
58091300280661	ESPAÇADOR	11	80.05%

4.3.2 Monthly Average Demand and its Standard Deviation

To have a uniform temporal unit to calculate the moments and quantities to be ordered of each item, it was necessary to convert all data, worked previously, to the monthly temporal unit. In this way and based on formulas presented in the literature review, the monthly average demand and respective standard deviation were calculated trough data collected regarding annual demand. The following tables (Table 4.3 and Table 4.4) demonstrate the steps to calculate these indicators of “pack 5 orings” item.

Table 4.3 - Annual demand and its standard deviation of “pack 5 orings”

Item Code	Item Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Demand	Standard Deviation
070716042306 6 1	PACK 5 ORINGS	0	2	1	0	1	0	1	2	2	0	1	1	11	0.79

Table 4.4 - Monthly average demand and its standard deviation of “pack 5 orings”

Item Code	Item Name	Annual Demand	Monthly Average Demand	σ Annual Demand	σ Monthly Demand
0707160423066 1	PACK 5 ORINGS	11	0.92	0.79	0.23

4.3.3 Monthly Lead Time and its Standard Deviation

In accordance with the demand data, it was also necessary to convert this data to the monthly time unit. Therefore, the monthly lead time and respective standard deviation were calculated. The following tables (Table 4.5 and Table 4.6) demonstrate the steps to calculate these indicators of “pack 5 orings” item.

Table 4.5 - Quantity ordered of “pack 5 orings”

Item Code	Item Name	Order Creation Date	Expected Delivery Date	Stock Entry Date	Expected Delivery (days)	Inventory Entry (days)
070716042 3066 1	PACK 5 ORINGS	06/03/2019	19/03/2019	25/03/2019	13	19
070716042 3066 1	PACK 5 ORINGS	30/04/2019	10/05/2019	13/05/2019	10	13
070716042 3066 1	PACK 5 ORINGS	01/04/2019	12/04/2019	16/04/2019	11	15
070716042 3066 1	PACK 5 ORINGS	24/05/2019	06/06/2019	19/06/2019	13	26
070716042 3066 1	PACK 5 ORINGS	11/07/2019	23/07/2019	19/07/2019	12	8
070716042 3066 1	PACK 5 ORINGS	03/06/2019	12/06/2019	19/06/2019	9	16
070716042 3066 1	PACK 5 ORINGS	25/06/2019	05/07/2019	05/07/2019	10	10
070716042 3066 1	PACK 5 ORINGS	01/08/2019	12/08/2019	12/08/2019	11	11
070716042 3066 1	PACK 5 ORINGS	25/11/2019	06/12/2019	09/12/2019	11	14
070716042 3066 1	PACK 5 ORINGS	30/09/2019	15/10/2019	11/10/2019	15	11

Table 4.6 - Monthly lead time and its standard deviation of “pack 5 orings”

Item Code	Item Name	Lead Time (days)	Monthly Lead Time	σ Lead Time (days)	σ Monthly Lead Time
0707160423066 1	PACK 5 ORINGS	13.00	0.59	4.33	0.92

4.3.4 Service Level

The service level is expressed as a percentage and corresponds to the expected probability of not hitting a stockout during the next replenishment cycle (Ramos, 2020). Through an informal interview with the Director of Operations, it was learned that the desired service level is 98% (z = 2.06), so customers can expect that out of 100 orders, 98 will be fulfilled in full and 2 will be out of stock, as the stock held is not enough to meet demand. The complement of the service level is the probability of failure and in this case it will be 2%. Therefore, the constitution of the safety stock depends on the service level defined by the company. The higher the level of service provided to customers, the greater the security stock.

The constitution of the safety stock will vary according to the variation in demand and supply in relation to the average values recorded. If an item presents a very marked variation, the company, in order to comply with the stipulated service level, will have to constitute a greater safety stock of that item. The items that present a reduced safety stock will be those with less variation in demand and supply.

4.3.5 Inventory Holding Cost and Order Cost

The inventory holding cost represents the cost that the company has to store items during a certain period. This cost includes the cost of storage, the opportunity cost of capital and the cost of obsolescence. Regarding storage costs, only costs that vary with the quantity of stock should be included. Thus, fixed costs, those that do not depend on the stock level, should not be part of the inventory holding cost. The inventory holding cost is expressed as a percentage and consists of the depreciation of the product over its useful life and the cost of financing with the bank. During an informal interview with the Operations Director it was clarified that, on average, items have five years of useful life with a constant depreciation of 20% per year. The cost of financing with the bank is 2%, so the total percentage will be 22% and the same for all items.

The order cost includes all costs related to the launch and receipt of the order. Thus, this item includes costs with human resources and maintenance of the computer system. The cost of transportation is not part of this cost because it is included in the cost of goods at the entrance to the warehouse (Ramos, 2020). During an informal interview with the Operations Director it was clarified that, an employee of the purchasing department costs 1100 euros per month to the company and an employee of the goods reception department costs 750 euros per month to the company, need an average of five minutes to perform their tasks related to the items of an order for the machine repair department. Each of the employees works 208 days a year (schedule from Monday to Friday not counting holidays and vacation days). Regarding the maintenance of the computer system, the Operations Director guarantees the cost represents 10% of the 70 thousand euros annually spent with the purchasing department. The computer system is an important item because it prepares future forecasts and allows to automatically place an order for an item when it reaches the point of order. In 2019, 1920 orders were placed. In this sense, the order cost will be the same for all orders by calculating the average order cost that will be estimated as follows:

*Purchasing Dept. = ((1100€ * 14 months) / 208 days) * (5 min / (8 h * 60 min) = 0.77€*

*Reception Dept. = ((750€ * 14 months) / 208 days) * (5 min / (8 h * 60 min) = 0.53€*

*Computer System Maintenance = (70000€ * 10%) / 1920 orders = 3.65€*

Average Order Cost = 0.77€ + 0.53€ + 3.65€ = 4.95€ per order placed

4.3.6 Safety Stock, Reorder Point and Economic Order Quantity

The company intends to minimize total costs, and for that it is necessary to determine the safety stock, the reorder point and the economic order quantity (EOQ) of the various items. Item “Conjunto de 3 Válvulas” will serve as an example to demonstrate all the steps to calculate the safety stock, the reorder point and the economic order quantity.

When the stock level reaches a pre-defined quantity, it is necessary to place an order with the supplier in order to minimize the probability of stock rupture. This pre-defined quantity is called the reorder point, as it is the point at which the need to place an order is signaled. The reorder point corresponds to the average demand during the delivery period, plus a safety margin due to the variability associated with the demand during the delivery period and the delivery period itself. This safety factor corresponds to the safety stock. In addition to the calculation of the reorder point, the economic order quantity to be launched in the pre-defined quantity will have to be determined. In order to simplify the calculations, the time unit chosen was the monthly one. The delivery time is counted in working days, with an average of one month having 22 working days. The value of the safety stock, such as that of the reorder point, is rounded up to the nearest integer. All values below are in accordance with the final document attached in the annexes (Appendix A).

$$Safety\ stock = z * \sigma L = 2.06 * \sqrt{0.55 * 2^2 + 12.42^2 * 1.13^2} = 29.01 = 30\ units$$

$$Reorder\ Point = d * L + safety\ stock = 12.42 * 0.55 + 30 = 36.81 = 37\ units$$

z = service level

$$\sigma L = \sqrt{L * \sigma^2 demand + d^2 * \sigma^2 lead\ time}$$

L = monthly lead time

d = average monthly demand

σ_d = *standard deviation of monthly demand*

σ_L = *standard deviation of monthly lead time*

$$Economic\ Order\ Quantity = \sqrt{(2 * S * D) \div (i * C)} = \sqrt{(2 * 4.95 * 149) \div (0.22 * 4.77)} = 37.49 = 38\ units$$

S = order cost

D = annual demand

i = inventory holding cost

C = acquisition cost

Therefore, when the stock of item “Conjunto de 3 Válvulas” reaches 37 units, an order of 38 units must be placed with the supplier. The safety stock to be maintained is 30 units.

4.4 Procurement policy

The company intends to mitigate the risks involved, but in relation to demand, the task is quite challenging (Ramos, 2020). The company has no control over demand and only through forecasts is it possible to minimize the influence that demand variation has on stock management (Ramos, 2020). As for the lead time, it risk can be mitigated by performing an assessment to the supplier (Ramos, 2020). If the current supplier is not meeting all requirements, a selection of a new supplier must be studied (Ramos, 2020).

Table 4.7 - "bateria 12V - 23A para booster" data and "conjunto de 3 válvulas" data

Supplier	Item Name	Annual Demand	Average Monthly Demand	σ Monthly Demand	Monthly Lead Time	σ Monthly Lead Time	Acquisition Cost	Safety Stock	Reorder Point	EOQ
850002	BATERIA 12V - 23A PARA BOOSTER	168	14.00	1.78	2.11	2.78	89.88	81	111	9
850001	CONJUNTO DE 3 VÁLVULAS	149	12.42	2.00	0.55	1.13	4.77	30	37	38

Regarding "Bateria 12V - 23A para Booster" and "Conjunto de 3 Válvulas" items (Table 4.7), the lead time is a very relevant indicator in the risk assessment of the stock management of these two items. "Conjunto de 3 Válvulas" item presents very reasonable values regarding the lead time and respective standard deviation, which makes it safety stock and therefore it reorder point, smaller than those of "Bateria 12V - 23A para Booster" item. This last item as it presents less interesting values, the change of supplier should be studied.

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5. Conclusion

In order to gain an understanding of the results found in the previous chapters, it is necessary to discuss the results, as well as their contribution to the company and to the literature. In addition, the limitations that affected this study and some suggestions for future topics are also addressed here.

Regarding the results, it can be said that the application of this stock management policy in this department of the company in order to improve its performance would produce successful results in an unpredictable environment, both in terms of volume demand and lead time. Thus, this project would lead to an effective practical contribution to the department of the analyzed company.

In terms of contribution to theory, it is possible to state that this research contributes to filling the gap identified at the beginning of the project. However, in a theoretical context, more studies would be needed to assess the real effectiveness of this stock management policy applied to other departments of the company. Furthermore, it would still be necessary to implement other policies to verify that they would have the same success as the policy implemented here.

Throughout this research, some constraints arose that affected and influenced the analysis of the study, limiting some conclusions that could be reached. One of the major limitations of the study that impacted the analysis of each process was the absence of more recent data due to lack of credibility in data after the start of the COVID-19 pandemic.

Regarding future topics, it would be advisable to periodically reformulate the reference values so that the management policy remains efficient. In addition, it would be interesting to expand the analysis, that is, what was done to items of class A to be done to items of classes B and C.

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Appendix

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Appendix A

Item Name	Annual Demand	Average Monthly Demand	σ Monthly Demand	Monthly Lead Time	σ Monthly Lead Time	Aquisition Cost	Safety Stock	Reorder Point	EOQ
DISCOS DE EMBRAIAGEM	300	25.00	5.81	1.21	5.48	2.99	283	314	67
ORING	204	17.00	2.94	0.65	1.54	1.28	55	67	85
BATERIA 12V - 23A PARA BOOSTER	168	14.00	1.78	2.11	2.78	89.88	81	111	9
CONJUNTO DE 3 VÁLVULAS	149	12.42	2.00	0.55	1.13	4.77	30	37	38
PERNE	66	5.50	0.92	0.65	1.38	0.54	16	20	74
MOTOR	66	5.50	1.37	0.65	1.30	33.55	15	19	10
INTERRUPTOR	64	5.33	0.53	0.57	0.55	10.72	7	11	17
MOTOR	59	4.92	0.92	0.55	0.68	11.47	7	10	16
BOCAL	51	4.25	0.71	0.70	1.42	4.69	13	16	22
CONJUNTO REPARAÇÃO	51	4.25	0.52	0.60	1.38	9.25	13	16	16
ANILHA	50	4.17	0.97	0.55	0.52	8.76	5	8	16
VÁLVULAS	49	4.08	0.67	0.62	1.35	13.99	12	15	13
ORING	44	3.67	0.82	0.73	1.75	1.26	14	17	40
EMBRAIAGEM	38	3.17	1.07	0.56	0.46	22.67	4	6	9
BATERIA P/0827940126	37	3.08	0.69	0.68	0.30	7.58	3	6	15
PISTÃO	37	3.08	0.53	0.52	0.47	12.58	4	6	12
PLACA P/0827940126	35	2.92	0.68	0.77	2.05	7.33	13	16	15
GATILHO	31	2.58	0.61	0.55	0.31	27.29	2	4	7
INTERRUPTOR	29	2.42	0.58	0.81	2.38	8.54	12	14	13
BUCHA	29	2.42	0.81	0.54	0.60	18.4	4	6	9
JUNTA	27	2.25	0.66	0.56	0.29	0.51	2	4	49

Appendix A

Item Name	Annual Demand	Average Monthly Demand	σ Monthly Demand	Monthly Lead Time	σ Monthly Lead Time	Aquisition Cost	Safety Stock	Reorder Point	EOQ
FUSIVEL BOOSTER WPS 1224-700 500A	27	2.25	0.54	1.94	0.69	2.85	4	9	21
CARREGADOR PARA BOOSTER WPS 12/24-700	22	1.83	0.30	1.81	1.65	37.38	7	11	5
PECA P/MAQUINA	21	1.75	0.30	1.69	1.34	1	5	8	31
CARCAÇA	21	1.75	0.65	0.62	0.93	45.99	4	6	5
MOTOR	20	1.67	0.45	1.43	1.15	88.58	5	8	3
CONJUNTO ESCOVAS	20	1.67	0.57	0.57	0.55	3.76	3	4	16
EMBRAIAGEM	19	1.58	0.51	0.54	0.21	30.12	2	3	6
ESCOVA	18	1.50	0.48	0.67	1.29	4.32	5	6	14
RESISTENCIA	18	1.50	0.53	0.60	0.36	23.57	2	3	6
MOTOR	18	1.50	0.42	0.49	0.38	35.88	2	3	5
O-RING P/VIDRO DE EXTRACTOR OLEO	17	1.42	0.36	0.98	1.93	1.39	6	8	24
INTERRUPTOR (ANTES DE 2016)	16	1.33	0.41	0.58	0.22	4.12	1	2	14
PORCA	16	1.33	0.40	0.60	1.47	13.39	5	6	8
KIT PLACA	16	1.33	0.43	1.56	2.88	15.99	8	11	7
CABO 2x1 MM HO5RN-F IEC 60245 4 MT	15	1.25	0.33	0.71	1.77	5.45	5	6	11
ORING FUNIL MAQ. ESPUMA	15	1.25	0.49	1.77	0.00	0.18	2	5	62
ÓLEO PARA MÁQUINA HDR 160	15	1.25	0.22	0.65	1.13	6.56	3	4	10
PLACA PARA BOOSTER 0772950	14	1.17	0.34	1.68	0.00	18	1	3	6
INTERRUPTOR ON/OFF 24V	14	1.17	0.46	1.35	4.72	45.23	12	14	4
CABO 2X1 MM HO7RN-F IEC 60245 4 MT	12	1.00	0.33	0.50	0.39	6.74	1	2	9
PéS DE APOIO	12	1.00	0.52	1.31	2.00	0.64	5	7	29

Appendix A

Item Name	Annual Demand	Average Monthly Demand	σ Monthly Demand	Monthly Lead Time	σ Monthly Lead Time	Aquisition Cost	Safety Stock	Reorder Point	EOQ
INDUZIDO	12	1.00	0.35	1.51	0.80	18.29	2	4	6
PACK 5 ORINGS	11	0.92	0.23	0.59	0.92	1.66	2	3	18
ANILHA	11	0.92	0.42	1.05	0.00	7.65	1	2	8
BUCHA	11	0.92	0.29	0.48	0.33	18.3	1	2	6
ESCOVAS	11	0.92	0.36	0.48	0.58	9.16	2	3	8
INTERRUPTOR PARA 0772960	11	0.92	0.26	2.14	2.00	21.74	4	6	5
ROLAMENTO 608 2RS	10	0.83	0.41	0.55	0.00	3.45	1	2	12
TRANSFORMADOR PARA GAMBIARRA	10	0.83	0.24	0.82	2.04	18.77	4	5	5
BOCAL ROTATIVO P/HDR 160 PREMIUM	10	0.83	0.30	0.53	1.23	37.41	3	4	4
TAMPA SUPERIOR	10	0.83	0.21	1.86	0.00	6.09	1	3	9
TAMPA INFERIOR	9	0.75	0.18	1.65	2.38	6.13	4	6	8
PARAFUSO BUCHA	8	0.67	0.22	0.53	0.18	1.11	1	2	18
CABO ALIMENTAÇAO	8	0.67	0.19	0.91	0.00	13.48	1	2	5
MOTOR	7	0.58	0.23	0.47	0.49	7.37	1	2	7
INTERRUPTOR PARA CONVERSOR	7	0.58	0.15	1.68	1.89	9.9	3	4	6
ELECTRÓNICO	7	0.58	0.23	0.66	0.72	48.48	1	2	3
MOLA	6	0.50	0.26	1.15	4.49	1.71	5	6	13
ESCOVAS	6	0.50	0.26	1.04	5.03	3.69	6	7	9
CORREIA	6	0.50	0.26	1.64	0.00	5.65	1	2	7
INTERRUPTOR	6	0.50	0.15	2.36	0.00	8.04	1	3	6
ESPAÇADOR	6	0.50	0.19	0.79	1.09	8.21	2	3	6