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Sara Filipa Costa Teixeira

ANÁLISE E MELHORIA DO PROCESSO DE COMPRAS NUMA STARTUP BIOTECNOLÓGICA

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia e Gestão Industrial, realizada sob a orientação científica do Doutor José António de Vasconcelos Ferreira, Professor Associado do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro.

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agradecimentos

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À família, por serem o meu pilar, incondicionalmente.

palavras-chave

Compras; Processo de Compras; Digitalização; Compras 4.0; Gestão de Informação Lean; Seleção de Fornecedores; Técnica de ordenação de preferência de acordo com a semelhança à solução ideal;

resumo

O aumento da pressão competitiva levou as empresas a adotar estratégias diferenciadoras de modo a obterem vantagem sobre os seus concorrentes. As compras, outrora vistas como uma função meramente operacional, representam agora uma fonte de vantagem competitiva, tendo-se tornado uma função estratégica que merece cada vez mais atenção.

O projeto descrito neste relatório visa analisar e melhorar o processo de compras de uma start-up biotecnológica, ainda numa fase muito preliminar da sua atividade. De modo a facilitar a análise do processo de compras atual, usou-se a linguagem *BPMN 2.0* para mapear os mesmo e identificar tanto as ferramentas em que os dados são armazenados, mas também os principais fluxos de informação. Identificaram-se dois principais problemas: os desperdícios presentes no fluxo de informação e a falta de um método consistente para a seleção de novos fornecedores.

De modo a combater os problemas relacionados com a gestão de informação, e mitigar os riscos que isso pode trazer para a empresa, foi desenvolvido um software de apoio ao processo de compras. Foi seguida a metodologia *Rational Unified Process* (RUP) e a linguagem *UML* foi usada para modelar o software a ser desenvolvido. O desenvolvimento foi conseguido através da integração do Microsoft Power Apps, com o Microsoft Power Automate, e o SharePoint. Neste software desenvolvido, toda a informação relativamente às compras da empresa deve ser registada e consultada. Para resolver os problemas relacionados com a seleção de novos fornecedores, foram definidos critérios e subcritérios alinhados com a estratégia da empresa para uma seleção correta. Foi, posteriormente, aplicado o método *TOPSIS*, um algoritmo que compara uma série de fornecedores alternativos.

O desenvolvimento desta plataforma permitiu à empresa integrar várias fontes de dados num só sistema de informação. Desta forma, os documentos em papel e os ficheiros Excel não estruturados foram completamente eliminados, favorecendo o fluxo de dados e informação da empresa, consequentemente permitindo uma tomada de decisão mais eficaz e eficiente. Isto contribuiu para uma maior consistência do conhecimento organizacional na empresa, uma vez que foi criado um repositório de informações mais ágil e simples.

Keywords

Procurement; Procurement Process; Digitalization; Procurement 4.0; Lean Information Management; Supplier Selection; Technique of Order Preference Similarity to the Ideal Solution;

Abstract

The increasing competitiveness on the market influenced companies to adopt diferentiating strategies that bring advantage over their competitors. Procurement, which used to be seen as an operational function, is now seen as a strategic activity that deserves increasing attention.

The project characterized on this report aims to analyze and improve the procurement process in a biotech startup that is still in the early stages of its life-cycle. To facilitate the analysis of the as-is process, BPMN 2.0 was used to model the process and identify how and where the data is stored, as well as the main informations flows. Two main issues were highlighted: the wastes present on the information flows and the lack of a consistent new supplier selection method.

To strike the identified issues related to the information management, and mitigate its associated risks, a procurement software was developped. The Rational Unified Process (RUP) methodology was followed through the development of the software and the UML language was used to model its structure and functions. The software development entailed the integration of Microsoft Power Apps, Microsoft Power Automate and SharePoint. The developped software aggregates all the information regarding the procurement process, and allows the user to register new information as well as consult stored data. To solve the lack of a supplier-selection method issue, new criteria and subcriteria, that are alligned with the company's strategy, for the selection of vendors were defined. Later, the TOPSIS method, which compares a set of different alternative suppliers, was applied.

The development of this platform allowed the company to integrate several data sources in one complete and structured information system. This way, the paper documents, as well as the old-fashioned disorganized excel files could be completely eliminated, favoring company's flow of data and information, which enabled a much more efficient and effective decision making. This contributed to a greater consistency of organizational knowledge in the company, since a more streamlined and agile repository of information was created.

Table of Contents

List of figures

List of Tables

1. Introduction

This document intends to present the work performed during a 9-month internship at the Company X, a biotech new venture based in Portugal.

1.1 Contextualization

This dissertation project is within the scope of the Integrated bachelor's and master's degree in Industrial Engineering and Management at the University of Aveiro. The project was developed during a curricular internship at Company X, a medical-tech startup based in Porto and addresses the company's procurement processes.

1.2 The project

1.2.1 Company X's activity

Company X is a startup founded in 2019 and has already been highlighted as one of the most disruptive new ventures in Europe on its operating field. Company X has its headquarters in Portugal, in a medical research center. The facilities include a laboratory for either biological and photonics fields, and an office space for all the other desk jobs. Here is where nearly all collaborators and all the equipment are located, thus it is also the place where all the product development activities are performed, as well as the productive process. Company X has another strategic office in the United Kingdom, where normally the COO is based.

Company X has developed a patented and innovative technique that combines photonics with artificial intelligence (AI), and is utilized to analyze human plasma samples (or human serum samples) of neurodegenerative disease patients (see **Figure 1**). The analysis is performed using an innovative hardware, which is developed and produced by the company, and uses photonics to capture a new type of disease biomarkers (also referred to as optical fingerprints). Later, the collected data are processed through AI techniques and a detailed and tailored profile is created for each patient. The data are stored in an innovative cloud-based library of biomarkers.

This fast and cheap technique has the potential to solve the biggest bottleneck of some cureless neurodegenerative disease medicine clinical trials: the recruitment process. The current recruitment process for these clinical trials is long, expensive, and inaccurate for the clinical companies, and evasive for the volunteers. Company X's technique solves all those obstacles, being a cheap and fast solution for patient screening and later stratification.

As mentioned above, Company X developed a preliminary hardware to perform and support the developed technology. The company built a prototype of the hardware and verified its performance, having obtained great results: depending on the biomarker, the system detects relevant neurodegenerative diseases biomarkers with an accuracy of 84%-100%.

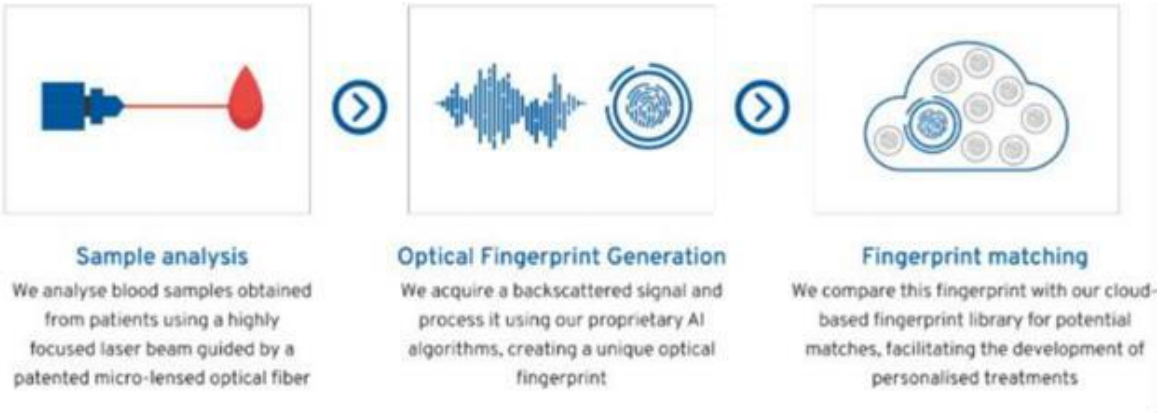


Figure 1- Company X's technology

Anyhow, the go-to-market strategy established by Company X and its advisors entails the construction and validation of a new hardware device, which must be compact and portable, and is intended to substitute the initial prototype. A new prototype (see **Figure 2**) is currently on development phase and validation process, in which its accuracy is being tested and possible improvements are being experienced and analyzed.

The production scenario at Company X is, therefore, different than what it is usually encountered in industry. The entire production process of the prototypes happens in Company X's facilities, at the Porto's laboratory. The production is not in mass nor continue since the product is still in the development phase and trying to reach its commercial readiness. There is no need to produce several unities, but instead the focus is on the development and improvement of the current prototype so that it meets all the requirements of a business sector as demanding as the medical device industry.

Figure 2 – Company X's hardware prototype

1.2.2 Company X's organizational Structure

The company has currently more than 20 collaborators, including effective employees and interns. Company X's structure is based on Board Structure. This structure encompasses either the Board of Directors and the Advisors of the company (see **Figure 3**).

The Board of Directors is composed by the Chief Executive Officer (CEO) and the Chief Technology Officer (CTO). The CEO coordinates its own associate and the Senior Leadership Team, composed by the Chief Strategy Officer (CSO), the Chief Operating Officer (COO) and the Head of Intellectual Property (IP) and Legal. On the other hand, the CTO coordinates both the Data Science lead and the Biophotonics Lead.

The other component of the Board Structure is mainly composed by investors.

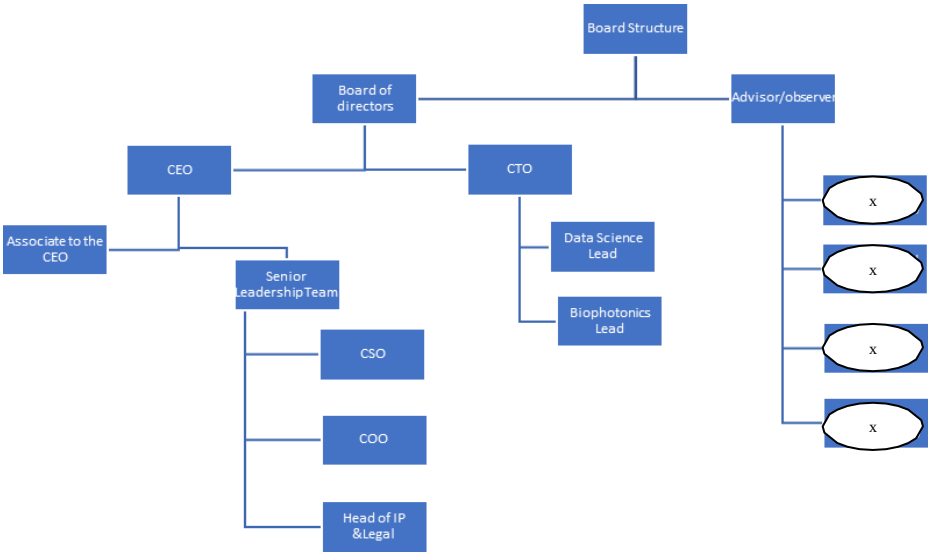


Figure 3 – Company X's organizational structure

1.2.3 Project's motivation and objectives

As a part of the process towards reaching the commercial readiness, there is an important stage regarding the certification and market approval, in which the company must certify its Quality Management System (QMS) in accordance with the international standard **ISO 13485:2016**, which specifies requirements for a QMS that can be used by an organization involved in one or more stages of the life-cycle of a medical device (W.J. Linders, 2020). Being Company X such a young company, and being in such a pilot phase, it is harder to define processes, procedures, and workflows. Anyhow, there is an effort in that direction and the company is now starting its long journey towards the certification of it QMS.

Through the present project, it is intended to **analyze the current procurement processes at Company X**, aiming to understand what is bought and how it is bought. Afterwards, improvement strategies will be proposed and implemented, always considering ISO 13485 requirements.

To sum up, this project must accomplish the following objectives:

- Understanding and mapping of the current Procurement process and its information flows.
- Development of an IT application in which the user can register and consult all the procurement-related data in real-time - The current documentation and information flow concerning the procurement process must be analyzed and enhanced. All the data related to procurement is currently registered in several Excel files, leading to numerous issues that directly affect efficiency of the process. It is aimed to develop an application, using Microsoft Power Apps and Power Automate, in which buyers will be able to register and to consult the information regarding purchases. The data will be stored in the cloud-based platform Share-Point.
- Definition of criteria for selecting and evaluating suppliers - since selecting appropriate suppliers is critical for the success of procurement, the current criteria used at Company X must be analyzed, discussed, and improved. Then, a Supplier Selection System must be developed.

Each of these objectives will be part of a consistent and regulated Procurement Process that will be defined and documented at the end of the project.

1.2.4 Methodology

Towards the achievement of the previously proposed goals, a methodology must be pursued throughout the project.

The **first stage** included an understanding of the company's dynamic, analyzing its main processes, as well as its major challenges and existing issues. This resulted in the definition of the problem in which this project will focus on. The aim of this project is analyzing and improving the procurement processes at Company X, mitigating its associated risks, and enhancing its performance, always in the light of ISO 13485's requirements.

In the **second stage**, a bibliographic review must be conducted, so that the theoretical background regarding the present subjects is fully understood and concepts are successfully integrated. Also, the ISO 13485's requisites regarding procurement processes must be explored and examined.

Afterwards, at the **third stage**, the new venture's current procurement processes ought to be fully understood and described. This task includes the following sub-steps:

1. Direct observation of procurement processes.
2. Informal and semi-structured interviews to the processes' stakeholders.
3. Process mapping and analysis using BPMN 2.0.
4. Issues and improvement opportunities identification.
5. Develop a plan of actions needed to conduct to reach the project's goal

Then, in the **fourth stage** of this project, a Supplier Selection System must be developed. A Multi-Criteria Decision Making (MCDM) approach will be used.

The **fifth stage** involves the development of Information System (IS) that supports procurement and in which all information must be compiled. This solution must be cloud-based, so data is always available and updated. This phase encompasses the following sub-steps:

1. Examine the current information flows and understand the current issues - wastes.
2. Using Microsoft PowerApps and Microsoft Power Automate to develop a solution in which users may request purchases, register quotes, register approved suppliers, register purchase orders, register invoice receipts and

order's receipts. The procurement process owners may approve or decline the purchase requests by using the application, or through an e-mail that will be automatically sent when a purchase request is placed. The information inserted on the system will be stored in SharePoint, so it is always available and updated in real-time.

3. Model the user's functionalities diagram of the developed application, using Unified Modelling Language (UML).

Finally, to conclude, the new Procurement process will be defined and documented through procedures.

1.3 Structure of the document

This report is structured in 5 chapters.

In the present chapter, a project's context was presented, as well as the company in which it was developed. Moreover, the methodology used, and the expected objectives were also outlined.

In chapter 2, a theoretical background is given. This section is essential to evidently explain the concepts and matters that support the work performed throughout the project.

In chapter 3, the aim is to clearly explain the current procurement processes of the company and identify issues and improvement opportunities.

In chapter 4, the improvements proposed on the chapter 3 are developed and explained.

In chapter 5, the key conclusions and limitations are reviewed. Future work suggestions are also summarized.

2. Bibliographic Support

2.1 Supply Chain Management

The term Supply Chain Management (SCM) was introduced on the early 1980s and has consequently gained an increasing awareness (Chen and Paulraj, 2004). As the global competition between organizations grew, Supply Chain Management became a source of competitive advantage (Anand and Grover, 2015). The practice of SCM is considered to be a crucial part of a company's success, since it comprises a set of interrelated activities that are both internal and external to a firm and share a common main goal: provide maximum value to customers. This represents a significant paradigm shift of modern business management, by acknowledging that business no longer compete as individual entities, but as supply chains (Lambert and Cooper, 2000; Chen and Paulraj, 2004).

There are several definitions regarding the concept of Supply Chain Management. According to (Monczka *et al.*, 2009), SCM encompasses proactively managing the two-way movement and coordination of the various flows (i.e., goods, services, information and funds) across boundaries, that is from raw material through end costumer. The Council of Supply Chain Management Professionals (CSCMP) stated that SCM comprehends either the planning and management of the activities implicated in sourcing, procurement, conversion, and all logistics management activities, including coordination and collaboration with channel partners (i.e., suppliers, intermediaries, service providers and customers) (CSCMP, 2013). Hereupon, the same source views SCM as "an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model.".

A large set of activities are part of SCM, but they all have one feature in common – they are a part of a network that will define how efficiently goods and information flow across a supply chain. These activities include procurement, inbound transportation, quality control, demand planning, materials handling (i.e., receiving and storage), inventory control, order processing, production planning, warehousing/distribution, shipping, outbound transportation, and customer service (Monczka *et al.*, 2009).

2.2 Procurement

In a supply chain, each corporation buys materials from upstream suppliers, adds their own value, and sells them to downstream customers. This buying and selling activities make the materials move through the supply chain since the trigger that initiates each move is a purchase (Waters, 2003).

As companies struggle to increase costumer value by improving its performance, many companies are turning their attentions to supply chain, purchasing and its strategic role. Purchasing has evolved from a mere buying function into a strategic function and has recently been recognized as a critical driving force in the strategic management of supply (Paulraj, Chen and Flynn, 2006).

The purchasing and procurement activities are usually confused and mistaken. According to Waters (2003), **purchasing** is about the events associated with acquiring products or services. On the other hand, **procurement** has a broader meaning, since it includes a wider range of activities that can vary between organizations. It can include different types of acquisition (purchasing, rental, contracting, and so on) as well as the associated work of selecting suppliers, negotiating, agreeing terms, expediting, monitoring supplier performance, materials handling, transport, warehousing, and receiving goods from suppliers. Lambert, Stock and Ellram (1998) state that procurement results from the addition of a strategic side to purchasing activities. That said, the overall aim of procurement is to guarantee that an organization has a reliable supply of materials, while linking the organizations in the supply chain, coordinating the flow of materials between them (i.e., customers and suppliers).

Hughes and Ertel (2016) consider that procurement is at the intersection between a company and its external suppliers, being able to play a key role in the expansion of company's competitive advantage, while minimizing the associated risks to a company's operations. These authors state that procurement can and must focus on maximizing the total value obtained from suppliers but consider that it is only possible if the procurement paradigm changes (see **Table 1**). The primary value of procurement must be solving business problems, while delivering competitive advantage, instead of the traditional cost reduction and external supply securing. Companies must view the collaboration with suppliers as the key value of procurement, instead of the leverage over suppliers and competitive pressure. The internal focus of the new procurement paradigm is on being a trusted advisor to the business, while the traditional paradigm's focus is on stakeholder compliance. New procurement must focus on managing long-term relationships instead of

simple transactions, and the emphasis on analytic skills must be replaced for soft skills and business expertise. Lastly, procurement employees must do more than own and execute, by facilitating and enabling.

Table 1 – The change of Procurement's Paradigm (Adapted from (Hughes and Ertel, 2016))

Traditional procurement paradigm	New procurement paradigm
Primary value is cost reduction and securing external supply of goods and services	Primary value is solving business problems and delivering competitive advantage
Competitive pressure and leverage over suppliers are the keys to achieve value	Collaboration with suppliers and balanced dependence are the keys to achieve value
Internal focus is on stakeholder compliance	Internal focus is on being a trusted advisor to the business
Manage transactions	Manage relationships
Analytical skills	Business expertise and soft skills
Own and execute	Facilitate and enable

The procurement process will vary between companies and according to the type of products to be bought. According to Smeltzer, Manship and Rossetti (2003), the procurement process encompasses two sides: the operational one, which is purchasing, and the strategic one, which is known as sourcing. Sourcing includes the management of suppliers, as a way of obtaining value and achieving company's goals.

Van Weele (2005) divides procurement in two phases and six major activities (see **Figure 4**). Initially, there is the tactical phase, also known as **sourcing**. This stage encompasses three activities. First, the specifications and requisites of the needed product are discussed and defined and once this task is completed, the supplier selection begins. Here, quotations must be requested and the most capable supplier for the given product must be chosen. It is necessary to find out whether the purchase need is met by one of the current suppliers, or whether it is necessary to find a new one:

- If the company has already an established relationship with the chosen supplier, the second phase begins (**ordering/operational** phase) by placing the order.

- If the chosen supplier has no established relationship with the company, this relationship must be contracted. As soon as it is done, the **ordering/operational** phase must begin, and the purchasing order must be placed. The order is then tracked until it is received, and the supplier performance is evaluated.

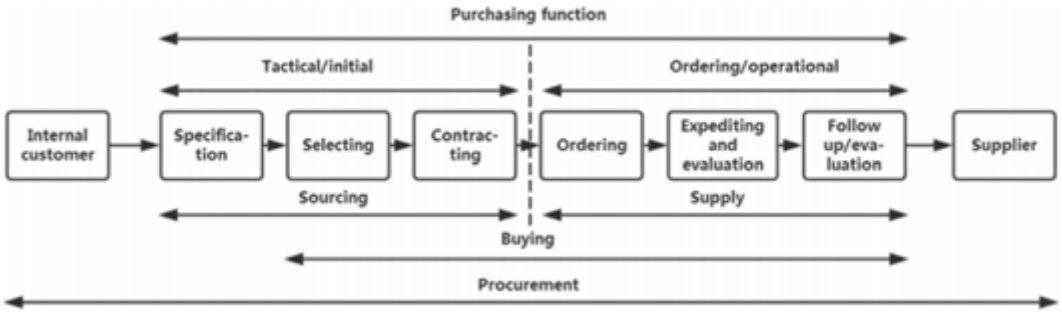


Figure 4 – Procurement process (Source: (Van Weele, 2005))

2.3 Supplier selection and evaluation

The evaluation, selection, and continuous measurement of supplier's performance are getting increased importance today in the success of procurement processes.

There are several risks that must be assessed when choosing a new supplier and developing a relationship with it. According to Ruhrmann, Hochdörffer and Lanza (2014), there are exogenous and endogenous risks. The exogenous risks may be market risks (i.e., Currency risks, demand risks, price risks) or microeconomic risks (i.e., country-specific risks). On the other hand, the endogenous risks are specific supplier risks (i.e., capability, motivation, quality, communication).

A prudent selection decision can reduce and help mitigating the above-mentioned risks, especially since its overall aim is to reduce the purchase risk and maximize the overall value (Monczka et al., 2009).

The goal of supplier selection processes is to assess which is the best supplier for a particular situation. For that ending, the influencing factors/criteria must be defined, assessed, and weighed. Usually, the supplier selection process involves three fundamental steps (Ristono *et al.*, 2018):

- The **identification and selection of criteria** that will be considered in the selection of suppliers.
- The **determination of methods for the assessment of suppliers** based on these criteria – decision making techniques.
- The **selection of suppliers** based on the assessment results.

2.3.1 Identification and selection of criteria

Purchasers must evaluate suppliers across multiple categories using their own selection criteria with assigned weights (Monczka et al., 2009). The same source states that most evaluations rate suppliers on three primary criteria: cost or price, quality, and delivery. For critical items needing an in-depth analysis of the supplier's capabilities, a more detailed supplier evaluation study is required.

According to (Ho, Xu and Dey, 2010),the most popular applied measure is quality, followed by delivery and then, by price/cost. The most popular criteria and sub-criteria considered by the decision makers for evaluating suppliers, according to the same source, are compiled in **Table 2**.

2.3.2 Decision-making techniques applied to the selection of suppliers

There are several techniques that can be applied to the selection of suppliers, making the process easier and more consistent.

According to (Chai, Liu and Ngai, 2013), there are three categories of decision-making techniques, namely Multicriteria decision making (MCDM) techniques, Mathematical programming (MP) techniques, and Artificial intelligence (AI) techniques.

MCDM techniques aim to help decision makers, by providing a recommendation among a set of alternatives, while being evaluated from multiple perspectives (Chai, Liu, and Ngai, 2013). The selection of a supplier problem is usually regarded as a MCDM, in which a set of alternative suppliers are evaluated from multiple criteria and the framework provides a knowledgeable recommendation of the best one.

The **Technique of Order Preference Similarity to the Ideal Solution**, also known as TOPSIS, is a multi-criteria decision-making (MCDM). The main idea behind this method is that the best solution is the one closest to the ideal solution, and furthest from the anti-ideal solution (see **Figure 5**) (Ishizaka and Nemery, 2013).

Table 2 - Most popular criteria for evaluating suppliers (Source: (Ho, Xu and Dey, 2010))

Criteria	Sub-criteria
Quality	acceptable parts per million
	compliance with quality
	continuous improvement programs
	corrective and preventive action system
	documentation and self-audit
	inspection and control
	ISO quality system installed
	low defect rate
	percentage of products or items not rejected upon inspection”
Delivery	appropriateness of the delivery date
	compliance with due date
	delivery conditions
	geographical location
Price	appropriateness of the materials price to the market price
	competitiveness of cost
	cost reduction capability-quantity discounts etc.
	cost of shipments

This algorithm will be fully explained since it is one of the most important methods and will be applied to the project.

TOPSIS is used to compare a set of alternatives on previously defined criterion, to assess which, one is the best solution for a given problem. Once we have defined the criteria to-be used, as well as our alternative-solutions, the method is based on five easy steps that will be detailed (Ishizaka and Nemery, 2013):

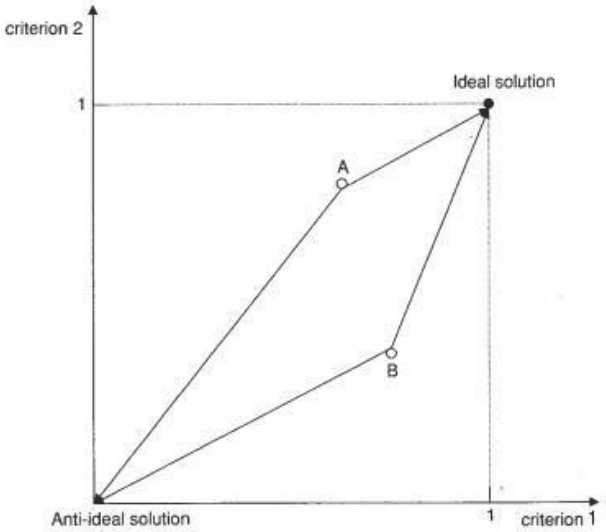


Figure 5 – TOPSIS method (source: Ishizaka and Nemery, 2013))

1. The performances of n alternatives a with respect to m criteria are collected in a decision matrix $X = (x_{ia})$, where $i = 1, \dots \dots m$ and $a = 1, \dots \dots n$. After, the performances of the different criteria are normalized, so that they can be compared. Several normalization methods can be used for this ending, but the chosen one was the distributive normalization, in which the performances of each alternative are divided by the square root of the sum of each squared element in a column:

$$r_{ia} = \frac{x_{ia}}{\sqrt{\sum_a^n x_{ia}^2}} \text{ for } a = 1, \dots \dots n \text{ and } i = 1, \dots \dots m.$$

2. In this step, a weighted normalized decision matrix must be constructed by multiplying the normalized scores by their corresponding weights : w_i

$$v_{ai} = w_i * r_{ai}$$

3. The weighted scores obtained will be used to compare each solution to an ideal (zenith) and anti-ideal (nadir) virtual solution. The first step is to define the ideal and anti-ideal virtual solution and there are several ways to do so. The chosen procedure was to collect the best and worst performance on each criterion of the normalized decision matrix (step 2). For the ideal solution, we have

$$A^+ = (v_1^+, \dots \dots, v_m^+),$$

and on the other hand, for the anti-ideal solution, we have

$$A^- = (v_1^-, \dots \dots, v_m^-),$$

where $v_i^+ = max_a(v_{ai})$ when the criterion i is to be maximized and $v_i^- = min_a(v_{ai})$ if the criterion i is to be minimized.

4. The distance between each possible solution and the ideal solution must be calculated,

$$d_a^+ = \sqrt{\sum_i (v_i^* - v_{ai})^2}, \ \ a = 1, \dots \dots, m$$

and then, the distance between each possible solution and the anti-ideal solution must also be calculated

$$d_a^- = \sqrt{\sum_i (v_i^- - v_{ai})^2}, \ \ a = 1, \dots \dots, m.$$

The used approach was the Euclidean distance, but another metric could be adopted.

5. Lastly, the relative closeness coefficient must be calculated, for each possible alternative:

$$C_a = \frac{d_a^-}{d_a^+ + d_a^-}$$

The closeness coefficient is always between 0 and 1, where 1 is the preferred alternative. If an alternative is closer to the ideal that to the anti-ideal solution, then C_a approaches 1. The best alternative will be the one presenting the higher C_a.

2.3.3 Selection of suppliers

After a careful selection of criteria and appliance of a decision-making technique, the buyer will be provided with a knowledgeable recommendation of the best supplier-option. The recommended supplier must be the selected one.

2.4 Procurement in the Digitalization Era

The fourth industrial revolution, namely **Industry 4.0**, is ongoing and was first introduced in Germany, in 2011 (Lu, 2017). Industry 4.0 is the superposition of several technological developments, incorporating both products and processes, therefore it shall be defined as the embedding of smart products into digital and physical processes (Schmidt *et al.*, 2015). According Hermann, Pentek and Otto (2016), there are four key components of the current industrial revolution; **Internet of Things (IoT), Cyber-physical systems (CPS), "Smart Factory"** and **"Smart Products"**.

Digitalization or digitization is about converting a captured analog signal into a digital form, for the purpose of generating a digital representation that can be electronically stored and/or processed (Ornig, 2016; Kayikci, 2018). The better information is captured and processed, the more systems get equipped with a certain level of intelligence, and the more these systems communicate with each other, increasing the level of digitalization of a network (e.g., a supply chain) (Kayikci, 2018). This way, digitalization delivers the availability of communication and information anywhere, anytime, in any context, and for any user using any device and type of access (Kayikci, 2018). Guo *et al.*, (2017) state that digitalization has an important impact in organizational performance. Therefore, it has a significance as a source of value creation (Amit and Zott, 2001; Martinez, 2019). This situation assigns digitalization as a critical matter to develop. Organizations must start immediately introducing components of the digital era to continue competitive in their markets or to take advantage of the opportunities that digitalization provides and become leaders (Martinez, 2019).

Digitization can play a leverage role to align existing sourcing strategies as well as to design new sourcing strategies, helping organizations to grow and achieve competitive advantage (Bienhaus and Haddud, 2018). The changes brought by Industry 4.0 and its associated technologies (e.g., CPSs, IoT, Big Data, Cloud Computing, etc.) directly affected production, as well as managerial and operating systems, changing the way processes are executed, and therefore, Supply Chains have to adapt (da Silva, Kovaleski and Pagani, 2019). Thus, the concept of **Supply Chain 4.0** or **Digital Supply Chain (DSC)** arises, indicating a supply chain based on web-enabled capabilities, relying entirely in synchronization, system integration and "smart" information-producing capabilities (Tawfik, Cherrafi and El Hassani, 2021). Mohammed and Ahmed (2017) define Supply Chain 4.0 as a contemporary system with interconnected processes that expands from isolated applications to a broad relationship, integrated and efficient between stages of the

supply chain (da Silva, Kovaleski and Pagani, 2019). Managing a Supply Chain 4.0 implies moving traditional relations between the stages of the chain (from supplier to manufacturer and end costumer) to a data connection network, using the available technologies, systems and personnel (Szozda, 2017; da Silva, Kovaleski and Pagani, 2019). The different parties involved, from supplier to costumer, are now more likely to interact with each other.

A Supply Chain 4.0 includes hardware, software and communication networks systems that enable interaction among organizations, coordinating supply chain activities (i.e., buying, storing, moving and selling) (Bhargava, Ranchal and Ben Othmane, 2013; Tawfik, Cherrafi and El Hassani, 2021). According to Alicke, Rexhausen and Seyfert (2016), Supply Chain 4.0 will affect all areas of supply-chain management (see **Figure 6**). This is evident in the way the main Supply Chain 4.0 improvement levers map to six main value drivers. In the end, improvements enable a step change in service, cost, capital, and agility.

SC 4.0 value drivers	**Enablers**
Supply Chain Planning	Big Data; Machine Learning; Advanced analytics; Automation of knowledge work
Physical Flow	Connectivity between supply chain stages; Additive manufacturing; Advanced automation; Autonomous and smart vehicles
Performance management	Control systems; performance indicators; Big Data and data mining techniques; machine learning
Order management	the processing of orders performed by digital means; re-planning, in real time
Collaboration	Cloud technology
Supply Chain strategy	Big Data

Service
Cost
Capital
Agility

Figure 6 – Supply Chain 4.0 enablers and its enabling technologies

The use of information technologies (IT) is not new on procurement processes. Since the 1970s, demand for production material was structured using a simple electronic system named Material Requirement Planning (MRP) that connects different internal departments of a company with each other (e.g., production and procurement) (Glas and Kleemann,

2016). Later, stronger cross-company IT integration systems came up, also known as Enterprise Resource Planning (ERP), providing a common basis for all major business functions, from sales over finance and including procurement (Glas and Kleemann, 2016). ERP systems are still focused on administrative and assistance for operative tasks, following the already mentioned traditional paradigm of procurement.

Later, **E-Procurement** emerged and is now a well-established concept, that is defined as the use of Internet technology for facilitating operative procurement processes such as ordering, as well as sourcing tasks (e.g., web-based supplier search) (Monczka *et al.*, 2009). These systems are used to facilitate tasks that previously required heavy manual work, such as the connection of suppliers with the ordering company by means of electronic data interchange (EDI) systems (Glas and Kleemann, 2016). E-procurement consists of four aspects: **e-design, e-sourcing, e-negotiation, and e-evaluation** (Croom and Johnston, 2003; Chang, Tsai and Hsu, 2013). Each of these aspects focus on different functions, even though they counterpart each other in terms of the advantages for SCM. These e-procurement tools are widely used in companies and present an attractive value propositions for greater organizational efficiency and reduced costs and cycle times (Davila, Gupta and Palmer, 2003). E-procurement contributes to different processes, including enabling partner relationships (mainly influenced by e-negotiation), facilitating the flow of information (mainly influenced by e-sourcing) and activity coordination among supply chain partners, enabling supply chain integration (mainly influenced by e-evaluation) (Chang, Tsai and Hsu, 2013). Information exchange between partners can reduce uncertainty, and therefore increase supply chain performance by improving the level of trust between the different business partners. On the other hand, and accordingly to the same source, partner relationships and information sharing influence supply chain performance through its integration, reaching higher levels of coordination. E-procurement is considered to be the state-of-the-art and this is closely connected with the new paradigm of procurement that, as mentioned before, changed the focus of procurement: now, it is a function seen as capable of solving business problems as well as a source of competitive advantage, enabling collaboration between all parties of the supply chain.

Procurement 4.0 is a fundamental element of the digital paradigm since it connects the different supply chain partners and enables a dynamic and quick cooperation and coordination beyond organizational boundaries. The new technologies encompassed in industry 4.0 can potentially impact further developments in procurement, creating new levels of transparency and visibility across tiers in the supply chain, enabling faster

information exchange in the relationships between the different involved parties (Bienhaus and Haddud, 2018; van Hoek *et al.*, 2020). Procurement 4.0 represents a set of solutions that can support managers and buyers at all stages of the procurement process, since the supplier selection, up to the monitoring of expenditure, offering a better vision of procurement: more agile, integrated, and responsive (Nicoletti, 2020).

It is important to understand what the actual differences between e-procurement and Procurement 4.0 on practical terms are. One key aspect is the emphasis on “smart” IT systems, which may actually automate all procurement processes (e.g., automatically recognizing demand and, from that, independently generate an order that is sent to the respective supplier without any necessary human interference) (Schmidt *et al.*, 2015).

E-procurement already had an impact in information exchange between different parties. The advances in technology brought by Industry 4.0 have increased the potential of doing this. The key change is the step from “exchanging information” to the “free flow of information” between connected products, services and consequently, organizations (Schlick *et al.*, 2014; Glas and Kleemann, 2016). This “free flow” implies a higher level of exchangeability of data, a higher level of automation of the information exchange and even the possibility of using the data under the concept of “big data analytics” (Lee, Kao and Yang, 2014; Glas and Kleemann, 2016).

Lastly, it will be discussed the “collaboration productivity” boosted by either e-procurement or Industry 4.0. E-procurement triggered a decrease of transaction as process costs, converting paperwork into electronics software systems, and endorsing strategic tasks like the supplier relationship management process. The concept just focuses on simple process-efficiency. On the other hand, Industry 4.0 facilitates production development processes, new product-service functions and improves the organizational supply chain set up. Its goals are extended to increased productivity and performance to meet highly tailored requests (Glas and Kleemann, 2016).

Figure 7 outlines the evolution of system used in procurement from MRP until today. The improvements happened in two dimensions: the degree of functional and cross-company integration; and the degree to which systems reduced manual work in the procurement tasks. Procurement 4.0 clearly exceeded e-procurement in both aspects, standing for the ultimate digitalization and automation of the function within its company and supplier environment.

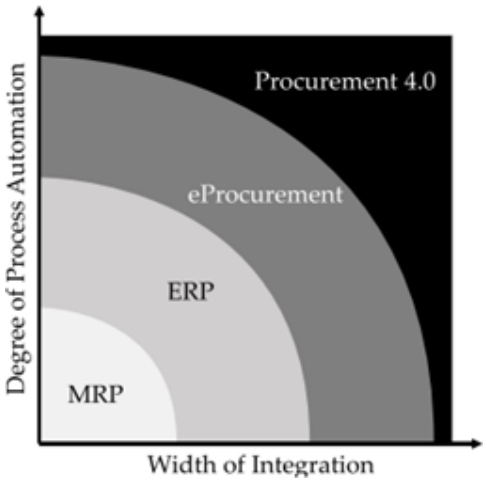


Figure 7 - The evolution of Procurement IT Systems towards Procurement 4.0 Source: (Glas and Kleemann, 2016)

Nicoletti (2020) identifies six key-aspects of Procurement 4.0, the 6C's **(**see **Figure 8).**

1. The first key-aspect is **Cybernetics.** Through smart-machines and computer software, it is possible to link all the organization's functions. Procurement 4.0 is based on a large network in which all parties involved in procurement (costumers, distributors, and partners) have access. This is made possible by an internet platform that handles all information exchanges in real-time, creating a whole process much more optimized and transparent.
2. The second key-aspect is **Communication**. While e-procurement supports the operational work, Procurement 4.0 solutions go further (i.e., automatically recognizing the demand for a specific material). Thus, they can generate an order, which is transmitted to the respective partner without human intervention.
3. The third key-aspect is **Control**. Procurement 4.0 accelerates communication and requires the re-organization of procurement with a comprehensive and global approach.
4. The fourth key-aspect is **Cooperation**. E-procurement allows an organization to turn paper documents into digital applications, while supporting key activities such as the process of managing relationships with partners. The driving factors of industry 4.0 collaborative productivity are improvements in terms of procurement, production, and engineering. Industry 4.0 enables the development of production processes to be radically shortened. An organization can activate new product-service functions and improve procurement. E-procurement is focused on process efficiency, while the objectives of procurement 4.0 are increased productivity, flexibility, and performance that meet the highly tailored needs of customers.

5. The fifth key-aspect is **Connection**. By optimizing external transport and internal handling processes, it is possible to impact on the structure of procurement costs. If automatic operation, robots, and similar autonomous control solutions are introduced, they can solve some of the problems in traditional solutions such as slowness.
6. The last key-aspect is **Cognition**. Data analytics is one of the most important enablers for procurement 4.0, allowing the aggregation, processing, and analysis of large volumes of data from many sources. Big data analytics can improve the decision-making, can support an organization's partners in improving the design and performance of their components and can support predictive analysis maximizing procurement opportunities.

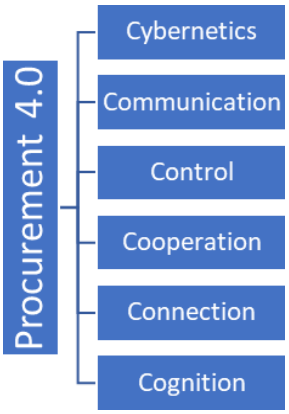


Figure 8 – Procurement 4.0 6C's (adapted from Nicoletti (2020))

2.5 Information Management

2.5.1 Lean Information Management

Lean thinking is a method for managing an organization, an improvement approach, a strategy, and a philosophy to either minimize waste and enhance a company's performance (Womack, Jones and D., 1990; Bevilacqua, Ciarapica and Paciarotti, 2015). It states that all activities can be classified as value added, necessary non-value added, and non-value added (i.e., the activities which a customer is not willing to pay for) (Womack and Jones, 1996; Bevilacqua, Ciarapica and Paciarotti, 2015). The primary goal of lean thinking is eliminating non-value-added activities, also referred to as waste or Muda. There are **seven types of waste**: overproduction, waiting, transporting, over processing, inventory, motion, and defects (Ohno, 1988; Bevilacqua, Ciarapica and

Paciarotti, 2015). To achieve a lean company, there are **five lean principles** that must be followed: specify value, identify value streams, make value flow, let the customer pull value and pursue perfection by continuous improvement (Womack and Jones, 1996; Bevilacqua, Ciarapica and Paciarotti, 2015).

Over the last decade, lean philosophy has been widely and successfully applied to manufacturing activities and production environments (Hicks, 2007). Anyhow, to achieve a total lean approach, lean thinking should also be applied to other business processes, such as the administrative processes.

With the exponential growth of several disruptive technologies, organizations are incessantly crossed by huge amounts of information generated by numerous technological tools. Therefore, the concept of **Information Management** arises, since managing the information the right way is crucial to take advantage of it, and create either financial and business benefits (Bevilacqua, Ciarapica and Paciarotti, 2015). According to the same source, information management is even used to improve processes' efficiency, since it connects the company's different functions and their members, therefore it is important to ensure that the information flowing is accurate, updated, complete and self-consistent. Anyhow, there are several problems usually identified: information is inaccurate, the needed information is sometimes not generated and the flow of information through the organizations is difficult (Bevilacqua, Ciarapica and Paciarotti, 2015).

Lean Information Management (LIM) is an approach to improve organizational systems through the reduction of waste and the drive-up value of information (Bevilacqua, Ciarapica and Paciarotti, 2015). As cited in (Hicks, 2007), Womack and Jones (1996) identified **five key principles** of a lean approach for information management:

1. **Value** – Information and functionality must supply value to the customer (end user). Only valuable information (that supports core business activities) must be managed. User's benefit from systems must be considered.
2. **Value stream** – The processes and activities that deliver information must be mapped, including the processes that support the capture, representation, exchange, organization, retrieval, and visualization of information. All these processes must be integrated.
3. **Flow** – Information must be available on real time (as soon as it is generated). All information processes must occur in the shortest possible time. The processes

must be as simple as possible to facilitate its performance. The duplication of information must be minimized. The amount of outdated or unnecessary information must be minimized. The duplication of efforts regarding information management should also be minimized.

4. **Pull** – Information mut only be delivered as it is demanded by its users. To make this pull efficient, the interfaces and procedure must be consistent across the organization. Users must be involved on the development of systems, so the dependency on IT staff is minimized.
5. **Continuous improvement** – Information systems and business processes must be reviewed regularly so that opportunities for improvement are identified.

Identifying intangible wastes and value-flows in information management is a much more subjective task. Hicks (2007) identified four fundamental causes of wastes in information flow, and four corresponding **types of waste**, as explained on **Table 3.**

Table 3 – The Information Management wastes and its causes (Adapted from (Hicks, 2007))

Cause	Waste
Information that cannot flow because it has not been generated.	**Failure demand**: the resources and activities that are necessary to perform to overcome the lack of information generated (i.e., generating new information).
Information is unable to flow because it cannot be identified.	**Flow demand:** the time and resources spent trying to identify the information elements that need to flow.
Excessive information is generated and maintained so the accurate information is hard to identify and access.	**Flow excess**: the time and resources that are necessary to overcome excessive information.
Inaccurate information flows resulting in inappropriate downstream activities.	**Flawed flow**: the resources and activities that are necessary to correct or verify information, or unnecessary/inappropriate activities that result from its use.

2.6 Tools

Power Apps is a suite that offers a quick and low-code application development environment and allows users to build tailored business applications according to your business needs (Microsoft, 2021c). These apps may run either in browser or mobile devices. Besides, business apps built using Power Apps may be connected to business

data stored either in Microsoft Dataverse or in several online and on-premises data sources like SharePoint, Dynamics 365, SQL Server, and so on (Microsoft, 2021c). Overall, this tool can transform manual business processes to digital and automated ones.

Power Automate, on the other hand, is a service that allows users to generate automated workflows between apps and services, allowing the automation of repetitive manual tasks (Microsoft, 2021a). This tool may be integrated with power apps' applications.

SharePoint is a platform for shared access, allowing interaction and collaboration. This tool allows its users to create dynamic and productive team and share files, data, news, and resources (Microsoft, 2021b). It can be easily integrated with either Power Apps, Power BI and Power automate. In this project, this platform will be used to store and organize data.

2.7 Business Process Model and Notation (BPMN)

The main goal of BPMN is to provide a notation that is readily understandable by all business users, ranging from the business analysts who sketch the initial drafts of the processes to the technical developers responsible for actually implementing them, and finally to the business staff deploying and monitoring such processes (White, 2004). BPMN was originally published in 2004 by the Business Process Modelling Initiative as a graphical notation (partially inspired by UML Activity Diagrams) to represent the graphical layout of business processes. The ever-increasing number of adoptions from companies and the growing interest in this notation caused the adoption of BPMN as OMG standard in 2006. The BPMN 2.0 is the newest version of BPMN (Chinosi and Trombetta, 2012). This notation is composed of four categories of elements: flow objects, connecting objects, swim lanes, and artifacts.

There are three types of flow objects, which are the core elements of a Business Process Diagram: events, activities, and gateways. The connecting objects are sequence flows, message flows, and associations. There are two types of swim lanes: pools and lanes. Lastly, there are three types of artifacts, which are data objects, groups, and annotations (White, 2004).

An important part of SCM and Procurement is creating and managing healthy relationships with suppliers. This is a key issue in achieving business success and competitive advantage. Indeed, working across organizational boundaries is required to accomplish effective responses to customers' needs (Pradabwong *et al.*, 2015).

2.8 Rational Unified Process

The RUP (Rational Unified Process) is a software engineering process that provides a structured approach to ensure the development of high-quality software that meets the need of its users (Rational, 1998). This process encompasses six best practices: develop software iteratively; manage requirements; use component-based architectures; visually model software; verify model software; verify software quality; and control changes to software. The RUP divides de development cycle in four consecutive phases: inception phase; elaboration phase; construction phase; and transition phase (see **Figure 9**). Each phase is concluded with a well-defined milestone (Rational, 1998).

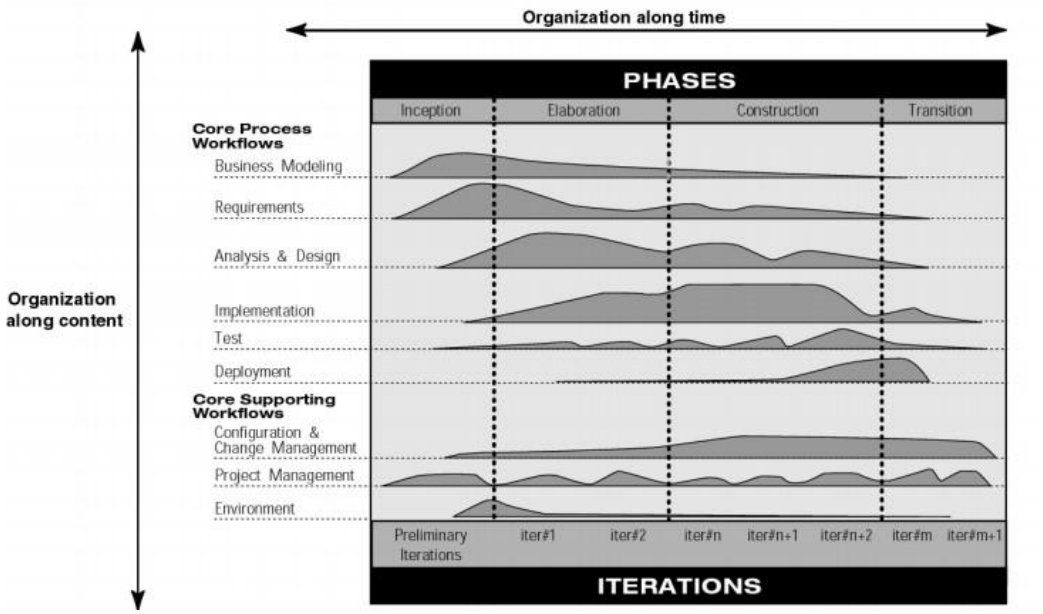


Figure 9 - Rational Unified Process (source: Rational, 1998)

2.9 UML

Enterprise applications, which assure the execution of business processes, must be structured in a way that enables scalability, security, and robustness (*What is UML | Unified Modeling Language*, 2005). Modelling is the designing of software applications before coding and represents an essential part of software projects. Using a model, those responsible for a software development project's success can assure that business functionality is complete and correct, while end-user needs are met, and program design supports requirements for scalability, robustness, security, and

extendibility before implementation in code (*What is UML | Unified Modeling Language*, 2005).

The Object Management Group is an international consortium that creates and maintains software interoperability specifications (Mellor et al., 2003). The Unified Modelling Language (UML) emerged in the mid-1990s through the combinations of previously competing object oriented (OO) software engineering methods (Dobing and Parsons, 2006). UML is now an OMG standard visual language for modelling software systems. UML 2.0 defines thirteen types of diagrams, divided into three categories: **Structure Diagrams** represent static application structure and include the Class Diagram, Object Diagram, Component Diagram, Composite Structure Diagram, Package Diagram, and Deployment Diagram; **Behavior Diagrams** represent general types of behaviour and include the Use Case, Activity Diagram, and State Machine Diagram; and **Interaction Diagrams**, which represent different aspects of interactions, all derived from the more general Behavior Diagram, and include the Sequence Diagram, Communication Diagram, Timing Diagram, and Interaction Overview Diagram (*What is UML | Unified Modeling Language*, 2005). These models capture knowledge about a system at various abstraction levels, ranging from requirements and analysis models to design models (Mellor *et al.*, 2003).

The **Use Case Diagram,** being a behavior model, aims to show the functionalities of the software, highlighting how each actor is allowed to interact with the system and each functionality.

The **Class Diagram,** being a structure diagram, is used to portray the composition of the database in which all the relevant information registered on the software will be stored.

2.10 ISO 13485:2016

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies) (International Organization for Standardization, 2016).

The International Standard 13485:2016 states the requirements for a quality management system that must be used by an organization that needs to demonstrate its ability to provide medical devices and related services that meet costumer and regulatory requirements. (International Organization for Standardization, 2016).

The adoption of a quality management system is a strategic decision of an organization. The design and implementation of an organization's quality management system may be influenced by several different motivations, such as the organizational environment, changes in that environment, and the influence that the organizational environment has on the conformity of the medical devices; the organization's varying needs; the organization's particular objectives; the product the organization provides; processes the organization employs; organization's size and organizational structure; and the regulatory requirements applicable to the organization's activities (International Organization for Standardization, 2016).

This International Standard is established on a process approach to quality management. Any activity that receives input and converts it to output can be considered as a process. For an organization to function effectively, it needs to identify and manage numerous linked processes. The application of a system of processes within an organization, together with the identification and interactions of these processes, and their management to produce the desired outcome, can be referred to as the "process approach." When used within a quality management system, such an approach emphasizes the importance of:

a) understanding and meeting requirements.
b) considering processes in terms of added value.
c) obtaining results of process performance and effectiveness.
d) improving processes based on objective measurement.

The organizations involved in one or more stages of the life cycle of a medical device must document its quality management system and maintain its effectiveness in accordance with the requirements of this International Standard and applicable regulatory requirements. Companies shall determine the processes needed for the quality management system and the application of those processes throughout the organization considering the roles undertaken by the organization. Also, they must apply a risk-based approach to the control of the appropriate processes needed for the quality management system, determining the sequence and interaction of these processes (International Organization for Standardization, 2016).

Regarding purchasing processes, the ISO states that the organization shall document procedures to ensure that purchased product conforms to specified purchasing information. The organization shall establish criteria for the evaluation and selection of suppliers. The criteria shall be based on the supplier's ability to provide product that meets

the organization's requirements; based on the performance of the supplier; based on the effect of the purchased product on the quality of the medical device; proportionate to the risk associated with the medical device. The organization shall plan the monitoring and re-evaluation of suppliers. Supplier performance in meeting requirements for the purchased product shall be monitored. The results of the monitoring shall provide an input into the supplier re-evaluation process. Non-fulfilment of purchasing requirements shall be addressed with the supplier proportionate to the risk associated with the purchased product and compliance with applicable regulatory requirements. Records of the results of evaluation, selection, monitoring and re-evaluation of supplier capability or performance and any necessary actions arising from these activities shall be maintained.

When it comes to purchasing information, the organization shall describe or reference the product to be purchased, including as appropriate: product specifications; requirements for product acceptance, procedures, processes, and equipment; requirements for qualification of supplier personnel; quality management system requirements. The organization shall ensure the adequacy of specified purchasing requirements prior to their communication to the supplier.

Regarding the verification of the purchased product the organization shall establish and implement the inspection or other activities necessary for ensuring that purchased product meets specified purchasing requirements. The extent of verification activities shall be based on the supplier evaluation results and proportionate to the risks associated with the purchased product.

When the organization or its customer intends to perform verification at the supplier's premises, the organization shall state the intended verification activities and method of product release in the purchasing information. Records of the verification shall be maintained.

3. Procurement at Company X – "As-Is"

The procurement process encompasses numerous tasks since the identification of a need of a material/service until the receipt of the order. This section aims to describe the current procurement practices at Company X. Later, the existing practices will be analyzed, and improvement opportunities will be outlined.

3.1 Organization

Company X was founded in 2019 but it was in 2020 that started its significant growth. The first step towards understanding the procurement procedures of the company was analyzing either what does Company X buy and how much does it buy. Since Company X is still a relatively small company, it does not use any Enterprise Resource Planning (ERP) system. Hence, all the information regarding company's purchases was not organized nor centralized in one platform and, as a result, this step entailed collecting and analyzing several Excel files, SharePoint libraries and paper documents files. Afterwards, a structured Excel file compiling all the available information and data was developed. Later on, these data were exported to **Power BI**, and relevant data visualization tools were used so that it was simpler to obtain some insights regarding the Procurement at Company X through a **dashboard** created with the data available.

The purchasing volume referent to each year (2019 and 2020) mirrors the growth that the company experienced during 2020: while in 2019, Company X only kept record of 12 purchases (see **Figure 10**), in 2020 the company has registered 209 purchases (see **Figure 11**) which represents a growth of approximately 1641.67%. On the other hand, the purchasing volume of the company went from 19290 € in 2019 (see **Figure 10**) to 121970 € in 2020 (see **Figure 11**) representing a growth of 532.3%. The number of suppliers that collaborated with Company X between 2019 and 2020 also grew from 9 to 97, reinforcing the growing significance of investing in structured procurement practices at the company, not only to avoid wastes, but also to take advantage of procurement's strategic role.

The items bought were categorized in different groups, according to their type, so that it became easier to understand the scope of each purchase. In 2019, the items purchased were mainly equipment for the lab and the office. This logically happened due to the fact that 2019 was a year of establishment for the new venture X. On the other hand, during 2020 the paradigm changed, since the company started operating: equipment's for the lab and office kept being bought but a considerable slice of the purchasing volume was referring to consumables (which are spent during signal acquisitions), and to the prototypes that were developed and built (Company X is developing its product in order to

achieve the Minimum Viable Product (MVP) that will later be commercialized and produced in a larger scale).

Figure 10 - Procurement dashboard 2019

Figure 11 - Procurement dashboard 2020

Company X is currently growing rapidly, consequently its purchasing volume is also very likely to increase, therefore the current procurement processes must be analyzed and improved to prevent wastes, mistakes and to take advantage of the strategic role of procurement. Moreover, as a part of the process towards reaching the commercial readiness, there is an important stage regarding certification and market approval, in

which the company must certify its Quality Management System (QMS) in accordance with ISO 13485:2016. Being Company X such a young company, and being in such a preliminary phase, it is harder to define processes, procedures, and workflows. Anyhow, there is an effort in that direction since the company is now starting its long journey towards the certification of it QMS.

Sections 4.1 and 7.4 of ISO 13485:2003, require organizations like Company X to control products and services obtained from suppliers, so the analysis and improvement of these processes must be carried out in the light of the ISO's requirements, which will be done during this project.

3.2 Purchase-to-pay process

3.2.1 Process characterization

The daily purchases were observed, and semi-structured and informal interviews were conducted. Since the process is not centralized and any full-time employee can place purchases at Company X, interviews were conducted with at least two employees of each team. According to the gathered information, the purchasing macro-process was mapped (see **Figure 12**).

The process always begins with the identification of a need for a supply. Company X does not plan its needs ahead (i.e., monthly, or yearly) and instead, the planning is done project by project or whenever a need is sensed. The same person who identifies the need (from now on called "buyer") must then define the requirements that the needed product must present. Currently, these requirements are not registered in any document.

Afterwards, the buyer must check if the needed item has already been purchased before, and if there is an already approved supplier:

- ⇒ If the **item has already been purchased**, a purchasing order must be created by communicating with the supplier and requesting the needed item. The document proving that the purchasing order was placed must be saved.
- ⇒ On the other hand, if the **item has never been purchased** before and there is no approved supplier, the buyer must evaluate the value of the purchase in order to assess the procedure that must be followed:

- if the value is **up to 100 euros**, a supplier must be chosen according to the delivery time or the location of supplier's facilities. In these cases, the sooner Company X gets the product, the better. Afterwards, the buyer may place the purchasing order.

- alternatively, if the value of the purchase is **greater than 100 euros**, the buyer should request at least three quotations. Nevertheless, one of the suppliers must be Portuguese and there must be at least one more European supplier. When all the quotations are received, the information gathered must be saved in an Excel document and the quotation's request process ends. The As-Is BPMN diagram of the subprocess "Request quotation" is presented in **figure 13.**

After the quotations are received, the buyer must analyse them, and then, use the supplier selection criteria of the company to pick the best option. Currently, the only supplier selection criteria used at Company X is related to the price, so the cheapest product is constantly the selected one.

Once the supplier is chosen, the process ends. The As-Is BPMN diagram of the subprocess "Select suppliers" is presented on **Figure 14**.

Afterwards, the buyer must create the purchasing order (PO). The purchasing order must be sent to either the Company X's Chief Executive Officer (CEO) or Chief Technology Officer (CTO). One of them will check the order and approve it or decline it. If the request is declined, the process ends. If the purchase is successfully approved, the approver will proceed to the payment of the order. After this, the buyer will receive the purchase's invoice, and later, the product.

When the order arrives at Company X's facilities, the buyer receives it and must check if it is complete:

⇒ If yes, the items received are stored.

⇒ If not, the buyer contacts the supplier.

The As-Is BPMN diagram of the subprocess "Receive products" is presented on **Figure 15**.

When the product's received, the purchasing process ends.

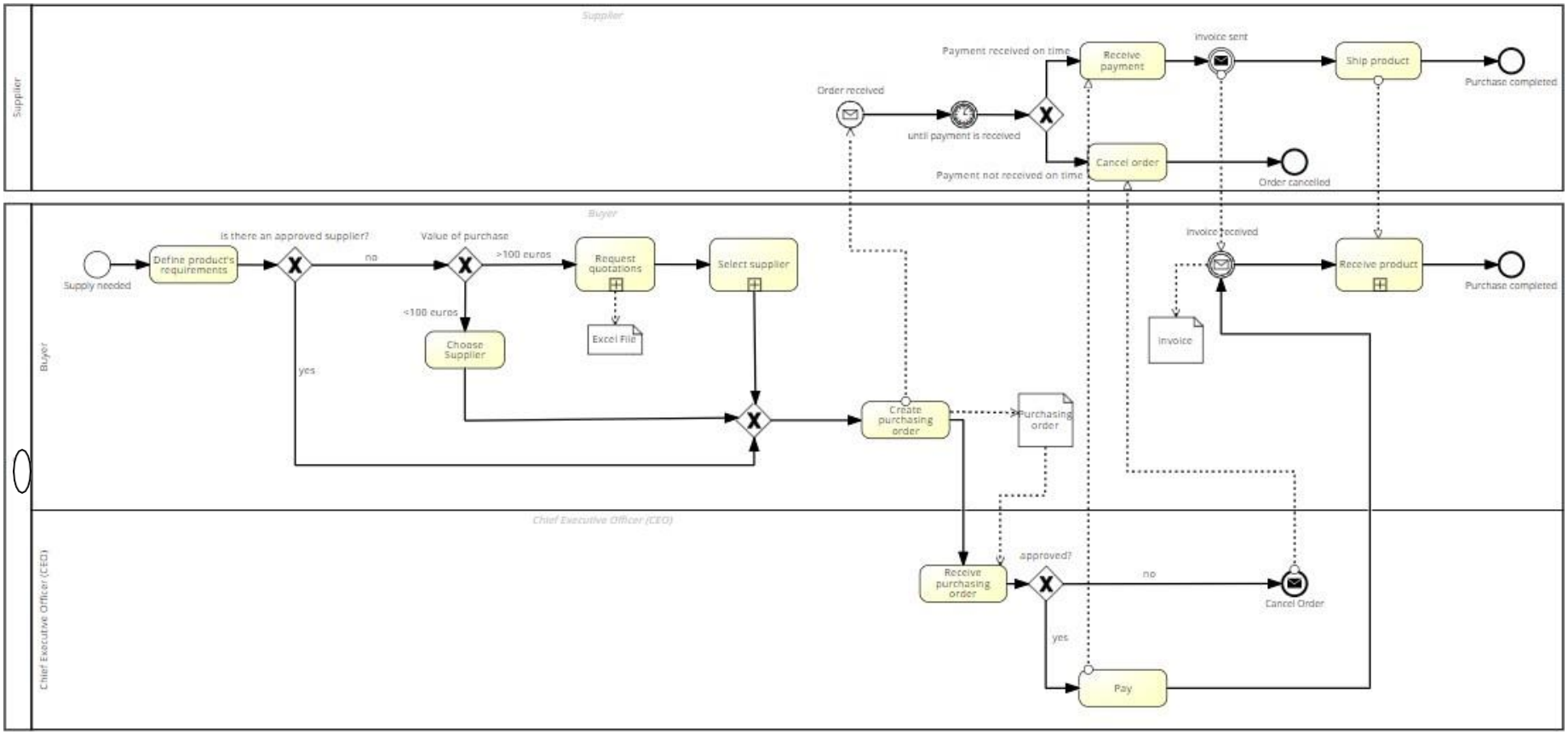


Figure 12 - Procurement Process at Company X

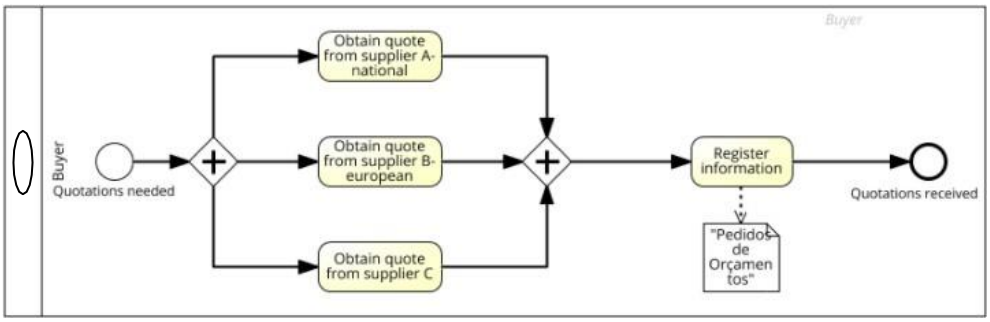


Figure 13 - Quotations Request at Company X

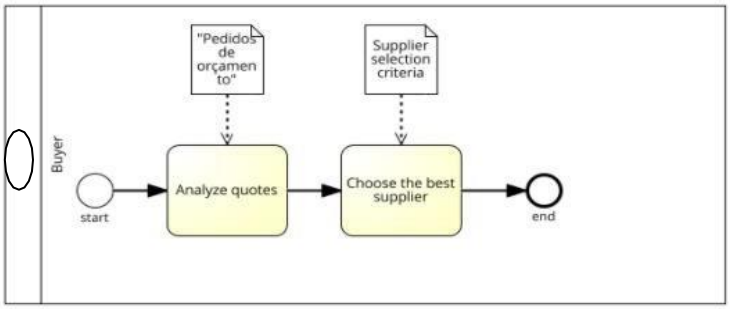


Figure 14 – Supplier Selection at Company X

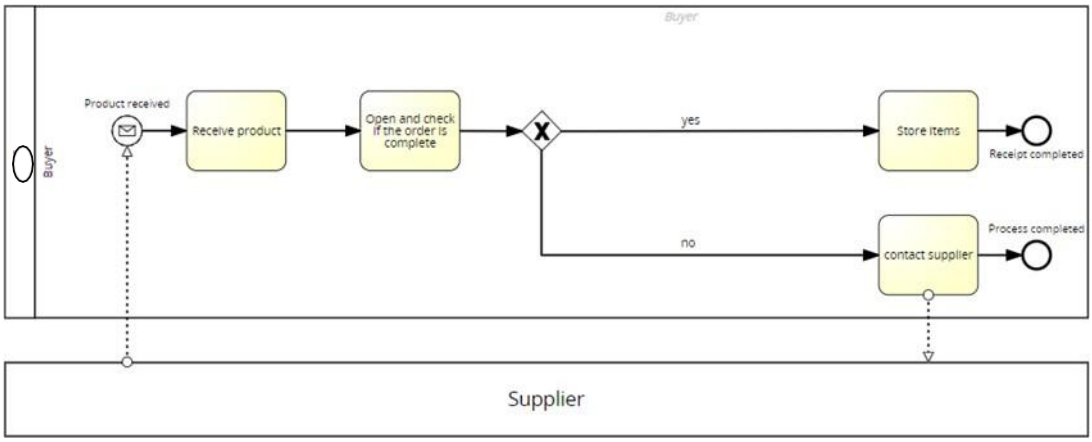


Figure 15 – Order's receipt at Company X

3.2.2 Processes' analysis and improvement opportunities identification

After careful observation and the elaboration of BPMN models referent to the procurement processes at Company X, the models developed were thoroughly analyzed so that wastes and improvement opportunities could be identified and outlined. As stated above, the ISO 13485:2016 clause 7.4's requirements were always considered throughout the assessment.

Issues identified:

1) Lack of consistent, clearly defined, and documented procedures

The first problem identified was a clear lack of standardization. At Company X, every full-time employer may execute the procurement processes. Since there are no documented procedures to the procurement processes, employees tend to perform it differently, leading to mistakes. Also, when new employees join the company, they do not get any training regarding the way they should carry out these processes since there are no defined procedures to teach new joiners. To be ISO 13485 certified, Company X must document its procurement procedures. The verification of the received orders must be incorporated on the new procedure. Hereby, this project aims to improve and define a new procedure for the procurement process, also referred to as the "To-Be" model, therefore solving this issue.

2) Absence of a Process Owner

Since Company X is still a small company, there is not a purchasing department nor an entity responsible for the procurement process's performance. This leads to several communication issues (i.e., if any employee has an issue regarding a purchase, the employee must contact the managing team, which is a slow process since the managing team has other responsibilities to address). If there were an employee (or group of employees) responsible for the process, problem solving would be faster, easier, and more effective. Furthermore, these employee(s) should be responsible for analysing the procurement data and evaluating the processes' overall performance, either to correct mistakes and to improve the efficiency of the process. Currently, this control is not performed. To address this problem, a process owner should be designated.

3) Lack of Supplier's Management

There were identified problems either on the selection of new suppliers and on the evaluation of the current supplier's working with Company X.

Currently, the only criteria used to select a new supplier is the price. The supplier offering the cheapest option is the chosen one, regardless. This is prone to lead to severe issues long-term. Particularly, since Company X is growing rapidly, it becomes even more important to carefully chose the suppliers with which the company will establish commercial relationships, to ensure service reliability, quality but price competitiveness as well. Furthermore, the company does not manage its relationship with its current suppliers, that meaning supplier's performance is not measured nor monitored, so the company does not assess or mitigate risks associated with supplier's performance.

These two issues require the development of a supplier selection system, which makes the selection of new supplier's more structured and accurate, and the development of a supplier rating system which monitors the performance of the current suppliers.

4) Information Management Issues

Several major problems related to the way information flow through the company and its management were observed. The company stores all the data regarding the Procurement Process in several, unorganized and unstructured Excel files or paper files. All the data is, therefore, dispersed, and disorganized, which makes it impossible for the company to take advantage of the data that is being stored. Moreover, a lot of crucial information is not even being registered and stored (i.e., when an order is received at the office, the information regarding the receipt is currently not registered: it becomes impossible to assess whether the order's lead time was fulfilled, weather the order's quality standards were met or not, …)

Also, the information cannot be consulted by all the employees at real time – the Excel files are not cloud-based, so they are constantly not updated, and the physical files cannot be consulted by more than 1 employee at the same time. Also, it is a huge waste of employee's time to be forced to look for information in so many different sources.

The mentioned issues lead to wastes thar may result in serious problems such as loss of information, impossibility of accessing to updated information when it is needed and difficulty in tracking the performance indicators measurements. The issues were further an

analysed, and each of them was classified according to the type of waste it provokes (see **Table 4**).

These problems could be addressed by defining, mapping, and describing a new procurement process and by creating a new IS that meets the above-stated requirements.

Table 4 – Information flow issues at Company X

Issue – "As-Is" scenario	Waste	"To-Be" alternatives
Information is stored in several unconnected sources such as Excel, Share-Point and even paper files. Therefore, it is impossible to automatically exchange updated information and enable value to flow across the company.	Flow demand	By implementing a cloud based and centralized Information System, in which all the information can be registered and consulted, this waste would be eliminated.
Lack of information generated – several information crucial do monitor the procurement processes is not being generated, which makes it impossible to identify mistakes and improvement opportunities.	Flow demand	By clearly defining procedures and state which information must be registered and how, this waste would be eliminated.
The fact that information is stored on so many systems lead to duplication of information.	Flow demand and flawed flow	By creating a single IS, and defining clear procedures, this waste would be eliminated.
Some information is stored on offline files, so outdated and inaccurate information is sometimes consulted as if it was updated.	Flawed Flow	By creating a cloud based IS, this waste would be eliminated.
As processes are not defined, each employee registers the information he considers necessary – it leads to mistakes and the need to sometimes verify and correct information.	Flawed Flow	By mapping and clearly defining procedures, this waste would be eliminated.
Inability to perform certain functions that require the flow of information to support management due to the lack of resources (i.e., flows of approval).	Failure demand	Some IS can provide tools that enable users to create flows of approval. By using it, this waste would be eliminated.

5) Lack of processes' monitoring

What cannot be measured, cannot be improved. There are currently no performance measures regarding the Procurement processes to assess its performance: the overall performance is not measured nor monitored; and, as mentioned before, supplier's performance is also not quantified nor monitored. Therefore, it is not possible to track and solve issues or even identify improvement opportunities that will lead to a better performance.

3.2.3 Improvement Plan

After the process' discovery, mapping and analysis, the issues related to procurement at Company X are already recognized. The **fifth issue** above identified, the lack of monitoring of the process, will not be addressed. This issue is the last stage of the improvement, and due to time constraints, the project did not get to this phase but instead focused on the development of new solutions that will be implemented and incorporated in a new procurement process.

The **first issue** identified was the lack of a defined procedure for the procurement process. This issue will be addressed, as stated before, by re-designing the "As-Is" BPMN models. The process will be re-thought and the improvement solutions to-be developed will be incorporated. Then, the BPMN "To-Be" models will be designed. This is a simple and intuitive way to present and document the procedure. These documents must be shared inside the Company X, so that all the employees, and future ones too, are familiar with the process.

The **second issue** outlined, was the absence of a procurement process owner. This issue was exhaustively discussed inside the Company X. Informal interviews were conducted either with the management and the rest of the teams involved in purchasing activities. Regarding this topic, it was unanimous that the company would benefit from naming one person to be responsible for the purchases. Therefore, when re-designing the process, a process owner will be considered.

The **third issue** identified to be addressed is the lack of a structured supplier-selection system. This project intends to solve this problem following the subsequent steps:

- First, the most suitable **criteria for the selection of new vendors** for Company X must be established. These criteria must align with company's strategy, while mitigating risks associated with purchases.
- Secondly, a **supplier-selection system** must be developed, using the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) algorithm.

It is important to outline that the supplier-rating system need, also identified on the third issue, was considered to be a monitoring action, so it was not address in this project.

The **fourth issue** identified outlined various Information Management issues. To solve them, a **procurement-support business application** must be developed, using the Power Platform and SharePoint. This software will offer employees a user-friendly

environment in which they may register all the relevant information about Company X's purchases. This will allow the company to condensate the all the information on a single platform. By doing that, the company will be able to treat and analyse data, taking advantage of relevant insights.

4. To-Be

4.1 To-Be Procurement Process

The procurement process incorporating these improvements was re-designed and the BPMN “To-Be” models were created to clearly show how the procurement processes will look like once the proposed improvements are implemented (see **Figure 16, Figure 17,** and **Figure 18**).

Firstly, it is important to highlight that the stakeholders of the to-be procurement process, are the buyers (which are the employees who identify the need) and the process owner, instead of the CEO. This change makes the communication between stakeholders easier, and more effective.

The to-be process (see **Figure 18**), similarly to the as-is one, begins with the identification of a need for a supply. The buyer must identify the requirements of the needed product and register them on a proper document. From now on, the process will be different from the as-is one since the buyer will now use the procurement software to-be developed. The buyer must open the software and check if the needed item was already purchased. This can be done my assessing all items requests and searching for the wanted item:

- ⇒ If the item was already requested before, the user must check the request’s information and then, check if the supplier that provided that item is still approved. To do that, the buyer must access the approved supplier’s list on the software. If the supplier is still approved, the buyer can go back to the item request and re-order it. A new item request will be generated and sent for approval. On the other hand, if the supplier is not approved anymore, the buyer must choose a new supplier, which is a sub-process that will be later described. Afterwards, the buyer must update supplier’s information and send the item request for approval.
- ⇒ If the item has never been requested before, the user may register a new items request, by filling the form on the software, and must attach the document that states the specifications that the wanted product must present. Afterwards, the buyer must choose the best supplier for this purchase, which is a sub-process that will be later described. When this task is completed, the buyer is able to send the item request for approval.

The process owner has permission to analyse and approve or decline requests. If he approves it, the buyer will be notified, and the purchasing process must go on. On the other hand, if the request is declined, the buyer will also be notified but the purchasing process will end.

Then, the buyer must place the Purchasing Order to the supplier and register it on the system. The next step is paying for the order. If this is not done on time, the process will end, the suppliers will cancel the order and the purchase will not be completed. If the payment is performed on time, the supplier will send the invoice to the buyer, who may register its information on the software, and attach the received document.

The last step on the macro-process is order's receipt, which will later be described in detail.

The Supplier selection sub-process (see **Figure 16**) begins with the need a supplier for a certain product. Afterwards, three or more quotes must be requested. Each of the quotes must be registered on the procurement-software. Then, the TOPSIS method must be applied, also using the software, and the supplier with the highest Ca must be the chosen one. This supplier will now be a part of the company's approved suppliers list, so its information must be registered on the system. Now that the supplier is chosen and registered on the system, the buyer must go back to the item's request, update the information, and the supplier selection is complete.

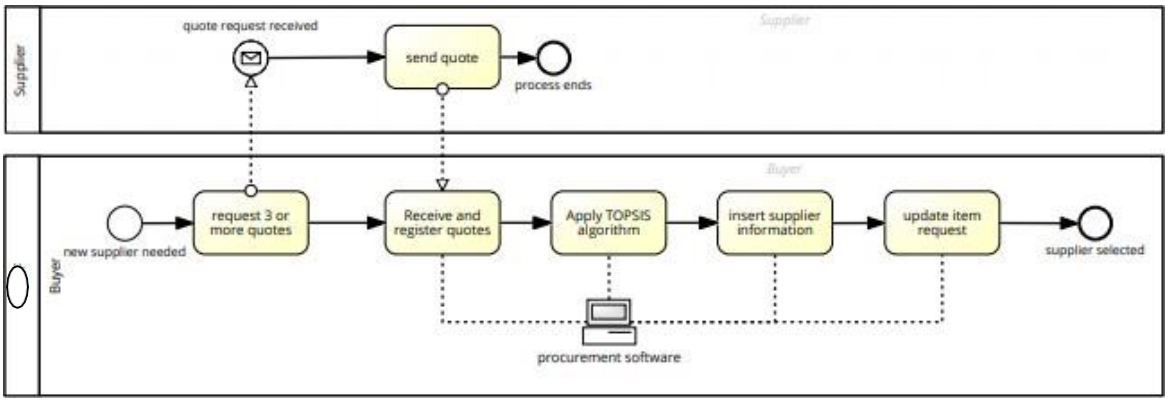


Figure 16 – To-Be supplier selection at Company X

Regarding the order's receipt (see **Figure 17**), the process begins when an order arrives at company's facilities. The buyer must open it and check if it is complete. If it is not

complete, the supplier must be contacted, and the process ends. On the other hand, if the order is complete, a quality check of each product received must be performed, always taking the required specifications into account. If product's quality is not validated, the supplier must be contacted, and the process ends. On the other hand, if the quality is validated, the items must be stored, and its receipt must be registered on the software, finishing the process.

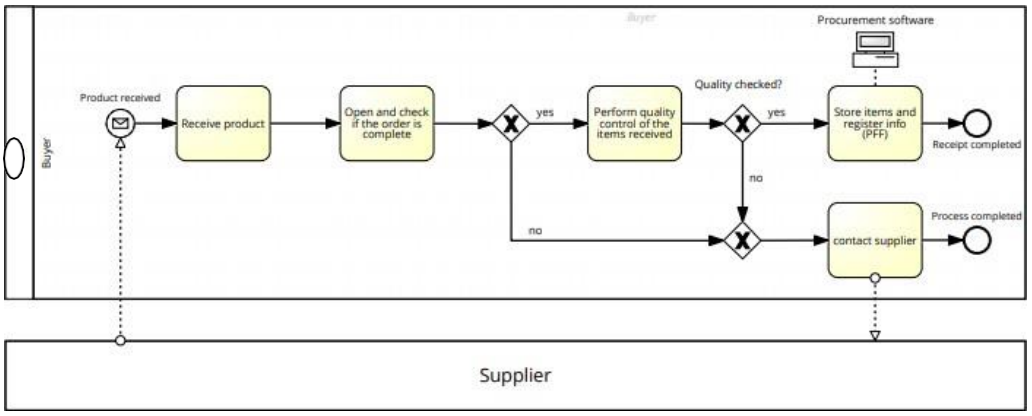


Figure 17 – To-Be order's receipt at Company X

4.2 Suppliers Selection System

4.2.1 Criteria and sub-criteria for the selection of new suppliers

As mentioned above (see **Section 3**), the only criteria used at Company X to select new suppliers was related to the price: the supplier providing the cheapest product would be the chosen one. In the long run, this may cause severe issues so it became essential and urgent to assess which are the criteria and sub-criteria that the company must consider when selecting new suppliers. This is an important step to assure that the suppliers selected are the ones that offer the best conditions. Furthermore, when Company X grows and scales its production, the company may need to establish strong and long-term relationship with its suppliers, so it is important to properly evaluate the options on the market, avoiding possible supply chain issues.

To wisely choose a set of criteria and sub-criteria that contemplate Company X's current strategy and needs, information was collected through a bibliographic review, and through several informal interviews with Company X's employees. Afterwards, a focus group was organized in which several members of the management team were able to attend, along with other employees.

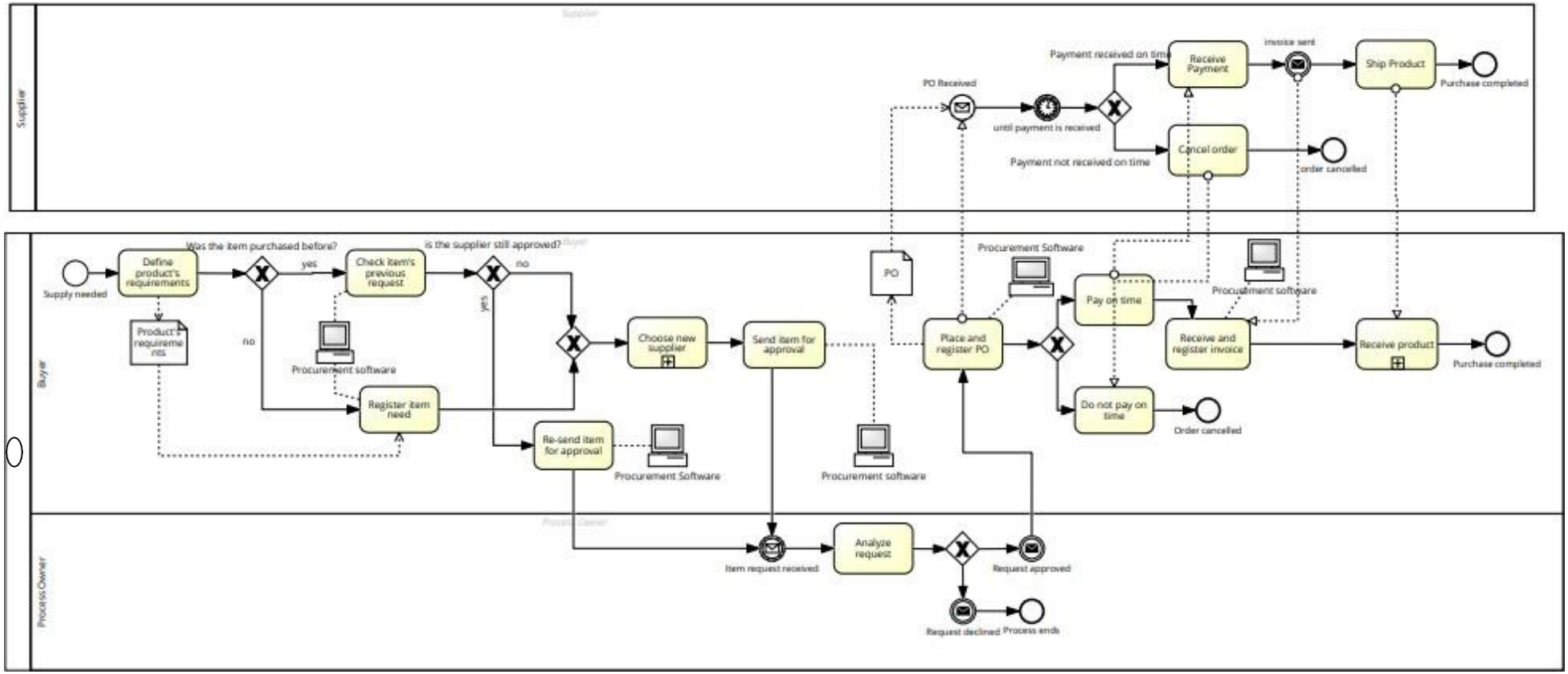


Figure 18 – To-Be procurement process at Company X

The first step was a presentation of the bibliographic review that was conducted, in which the most common criteria was presented. Later, a brainstorming session was conducted, in which all presents had the opportunity to state which are the criterion that they considered more or less important, and why. This discussion resulted in the definition of a set of criteria that will be further explained. To decide the weights of each criterion, each member purposed an alternative, and a weighted average of the different alternatives was made. The final results were presented and validated by the different stakeholders.

Since Company X is growing rapidly, one of the main goals when selecting new suppliers is ensuring that they will be able to keep up with production's scale-up, while not compromising quality and still providing competitive prices. The chosen criteria were mainly related to **Quality**, **Price** and **Delivery and Service**. To each criterion, there are several sub-criteria associated, as shown in **Table 5.**

Regarding the Quality criterion, it is relevant that supplier's quality procedures are regulated and that is ensured by the ISO's certification. Besides, the product provided by a certain supplier must be compliant with Company X's requirements.

Table 5 – Criteria for the selection of new suppliers

Quality	**Q1** – ISO quality certification (9001, 13485)
	Q2 – Product's specifications match the requirements
Price	**P1** – Price competitiveness
	P2 – Shipping and handling costs included
	P3 – Availability to negotiate
Delivery and Service	**D1** – Lead Time
	D2 - Reliability
	D3 – Corrective Action System
	D4 - Responsiveness
	D5 – Financial Stability
	D6 – Geographic location

On the other hand, concerning the **Price** criterion, it is valued that a supplier provides a competitive price when comparing to its competitors. It is also important that the shipping and handling costs are included on product's price, so it does not add up to an order's cost. Besides, it is valued that a supplier is available to negotiate (i.e., quantity discounts, collaboration projects).

Contemplating the "**Delivery and Service"** criterion, it is relevant that the supplier's service is fast, providing a low lead time between the product's order and its receipt at Company X's office. It is also important that a supplier shows reliability, by having safety stock and being able to successfully fulfil urgent orders, for instance. It is also appreciated that a supplier has a good correction action system, being fast on the response of complaints, solving problems effectively. Moreover, the supplier must be responsive, providing a good customer service (i.e., fast send of quotes, fast and correct invoicing). The financial stability is also important, so it is valued that the supplier company has a stable financial position on the market, and no problems regarding cash flows. Finally, the geographical location must also be considered: the closer supplier's facilities are, the better.

4.2.2 TOPSIS application

To clearly explain how the TOPSIS method is applied, an example will be presented, in which it must be assessed which of the alternative suppliers (A, B, C and D) is the best alternative for Company X, considering the above-mentioned criteria.

The first step is to define how each criterion will be measured and its weight. A questionnaire was developed and later sent to several employees. After the analysis of the responses, the results were presented in a meeting with the management team and an agreement was reached, as presented on **Table 6.**

The next step is assessing the performance of each alternative supplier and rate them, according to the predefined scale, as shown in **Table 7**.

Then, the performance of the different criteria must be normalized, so it is possible to compare the measures in different scales/units. The chosen method was **distributive normalization (section 2.3)**. The results were shown in **Table 8.**

Table 6 – Criterion weight and measurement

		Weight	Measurement
Quality	**Q1** – ISO quality certification (9001, 13485)	**0.15**	Yes – 10 points No – 0 points
	Q2 – Product's specifications match the requirements	**0.15**	0 -10 points
Price	**P1** – Price competitiveness	**0.15**	0 -10 points
	P2 – Shipping and handling costs included	**0.05**	Yes – 10 points Depending – 5 points No – 0 points
	P3 – Availability to negotiate	**0.1**	Yes – 10 points No – 0 points
Delivery and Service	**D1** – Lead Time	**0.1**	0 -10 points
	D2 - Reliability	**0.1**	Min 0; Max 10 points
	D3 – Corrective Action System	**0.1**	Min 0; Max 10 points
	D4 - Responsiveness	**0.05**	Min 0; Max 10 points
	D5 – Financial Stability	**0.025**	Min 0; max 10 points
	D6 – Geographic location	**0.025**	Min 0; max 10 points

Table 7 – TOPSIS Performance Matrix

TOPSIS	Q1	Q2	P1	P2	P3	D1	D2	D3	D4	D5	D6
Weight	0,15	0,15	0,15	0,05	0,1	0,1	0,1	0,1	0,05	0,025	0,025
A	10	2,5	10	10	10	7	10	7	6	10	10
B	10	5	2	0	0	5	8	7	2	10	10
C	0	10	7	10	0	9	10	7	2	10	10
D	10	8,5	4	0	0	3	5	7	2	10	10

Table 8 – TOPSIS Normalized Performance Matrix

TOPSIS	Q1	Q2	P1	P2	P3	D1	D2	D3	D4	D5	D6
Weight	0,15	0,15	0,15	0,05	0,1	0,1	0,1	0,1	0,05	0,025	0,025
A	0,58	0,18	0,77	0,71	1,00	0,55	0,59	0,50	0,87	0,50	0,50
B	0,58	0,35	0,15	0,00	0,00	0,39	0,47	0,50	0,29	0,50	0,50
C	0,00	0,70	0,54	0,71	0,00	0,70	0,59	0,50	0,29	0,50	0,50
D	0,58	0,60	0,31	0,00	0,00	0,23	0,29	0,50	0,29	0,50	0,50

Afterwards, it is necessary to take the weight of each criterion into account. For the normalized scores presents in the table above, the following weighted scores are obtained, as in **Table 9**.

Table 9 – TOPSIS Weighted normalized matrix.

TOPSIS	Q1	Q2	P1	P2	P3	D1	D2	D3	D4	D5	D6
Weight	0,15	0,15	0,15	0,05	0,1	0,1	0,1	0,1	0,05	0,025	0,025
A	0,09	0,03	0,12	0,04	0,10	0,05	0,06	0,05	0,04	0,01	0,01
B	0,09	0,05	0,02	0,00	0,00	0,04	0,05	0,05	0,01	0,01	0,01
C	0,00	0,11	0,08	0,04	0,00	0,07	0,06	0,05	0,01	0,01	0,01
D	0,09	0,09	0,05	0,00	0,00	0,02	0,03	0,05	0,01	0,01	0,01

The next step entails defining the ideal (A+) and the anti-ideal (A-) solution, as following in **Table 10.**

Table 10 – TOPSIS ideal and anti-ideal solutions

A + (Ideal)	0,09	0,11	0,12	0,04	0,10	0,07	0,06	0,05	0,04	0,01	0,01
A- (Anti-Ideal)	0,00	0,03	0,02	0,00	0,00	0,02	0,03	0,05	0,01	0,01	0,01

Afterwards, the weighted scores will be used to compare each score with the ideal and the anti-ideal one. The results obtained are the ones shown in **Table 11**.

Table 11 – TOPSIS distance matrix

TOPSIS	A	B	C	D
d+	0,080	0,156	0,140	0,142
d-	0,173	0,094	0,118	0,110

The last step entails the calculation of the relative closeness coefficient (Ca) to each alternative, as in **Table 12**.

Table 12 – TOPSIS relative closeness coefficient matrix

TOPSIS	A	B	C	D
d+	0,080	0,156	0,140	0,142
d-	0,173	0,094	0,118	0,110
Ca	**0,683**	0,374	0,457	0,435

This closeness coefficient varies between 0 and 1, being 1 the preferred alternative, which is closer to the ideal solution than to the anti-ideal. In this example, the preferred supplier would be A, which presents the highest Ca.

4.3 Procurement Software

This project aims to develop a software that supports the procurement process at Company X. The software development is an iterative process. Hereby, the Rational Unified Process methodology was followed.

The Inception Phase is the first one. Here, the scope of the software was defined - it was important to understand what were the issues that the software should address. Next, it was needed to identify how the software should address those issues: the intervening actors were identified, as well as the main use-cases. A preliminary prototype was also developed, considering employee's needs and concerns. After all this information was gathered, a small presentation was conducted to the management team, which validated the project, its viability and value.

Next, the Elaboration Phase was completed. On this phase, all the use-cases of the software had already been identified and most of them were already described on a user-manual. The class structure was fully defined. By the end of this stage, an executable architecture prototype was built, using several iterations.

Construction Phase encompassed the integration of the software with all the needed platforms. Here, the software was exhaustively tested and improved. The final user-manual was also completed, as well as an exhaustive description of all the software's use-cases.

Transition Phase entails the transition of the developed software to the user community, which in this case, are the Company X's employees. The software was tested by several different employees, but its use was fully not implemented yet. This phase was not fully completed due to time limitations.

4.3.1 Procurement Software Modelling

To model the software to-be developed, the **use case diagram** and **the class diagram** were used. Both diagrams employ the **UML notation**.

The **Use Case Diagram** was used during the requirements capture, and also during tests – Inception, Elaboration and Construction Phases.

As shown in the use case diagram (see **Figure 19**), there are two actors interacting with the system: the employee and the process owner. A login system was created, and two types of users were defined according to the different allowances each actor must have. Therefore, the interaction between each actor and the system begins with the insertion of its own login credentials and the executions of the login ("Login"). If the username and password are invalid, an error message will show. On the other hand, if they are valid, the user will access the main menu of the system.

Both actors are now entitled to register information about a supplier ("Register Supplier") and to search for a certain supplier and accessing its information ("Search for Supplier Information"). During the search, the user may also edit this information if needed ("Edit Supplier Information") or delete the supplier ("Delete Supplier").

Both actors are also allowed to register information about a quote request ("Register Quote"), to search for a certain quote and accessing its information ("Search for a Quote Information"). During the search, the user may also edit this information if needed ("Edit Quote Information") or delete the quote ("Delete Quote").

When any user identifies a need for a supply, he must register it on the system. This can be done in two different ways:

1. If all the information needed for the request placement is already gathered, the user may create a new Item's Request ("Register Item's Request). This request will be automatically submitted to an approval flow. Only the process owner is able to approve or decline the request and this can be done either by email or using the system ("Approval").

2. If the user does not have all the needed information for the request placement gathered, the user may create a new Draft Item's Request ("Register Draft Item's Request"). The user is able to search for a certain draft ("Search for a Draft Item's Request") and edit its information ("Edit Draft Item's Request Information") or delete it ("Delete Draft Item's Request"). Once the draft is completed and ready for

approval, it must be sent for approval (“Send for Approval”) and the approval flow described above will start.

Both actors are also allowed to apply the TOPSIS algorithm on the system (“Apply TOPSIS algorithm”). This method allows users to compare different alternative suppliers and find out which is the best option, in the light of the chosen criteria.

Both actors are also allowed to register information about a purchasing order (“Register Purchasing Order”), to search for a certain purchasing order, accessing its information (“Search for a Purchasing Order”), registering invoices associated to that Purchasing order (“Register Invoice”), and delete the purchasing order (“Delete Purchasing Order”).

Both actors are also allowed to register information about a purchase final file (“Register Purchase Final File”), to search for a certain purchase final file, accessing its information (“Search for a Purchase Final File”), and edit (“Edit Purchase Final File Information”) or delete the Purchase Final File (“Delete Purchasing Order”).

Both actors may also register information about travels (“Register Travel”). The user is also able to search for a certain travel (“Search for Travel”) and edit is information (“Edit Travel Information”) or delete that travel (“Delete Travel”). Then, the user is able to associate one or more expense to a certain travel (“Register Expense”). The user may also search for a certain expense (“Search for an Expense”) and edit its information (“Edit Expense information”) or delete a certain expense (“Delete Expense”).

Both actors are able to search for the stored information, according to the date in the following way (“Search by date”):

- The user can search for suppliers according to the registration date (“Search for suppliers by registration date”).
- The user can search for quotes according to the registration date (“Search for quotes by registration date”).
- The user can search for item requests according to the placement date (“Search for item requests by placement date”).
- The user can search for purchasing orders according to the placement date (“Search for purchasing orders by placement date”); the user can add the due date filter to the search (“Search for purchasing orders by due date”).

- The user can search for purchase final files according to the date of receipt ("Search for purchase final files by date of receipt").
- The user can search for invoices according to the invoicing date ("Search for invoices by invoicing date").

The **class diagram (**see **Figure 21)** encompasses several processes such as the register of suppliers, the request of items and its approval, the register of quotes, of purchasing orders, of invoices, of travels and of expenses.

The "draft_item" table contains the information regarding an item that needs to be purchased, which will be called item request from now on. This table is connected to the "employee" table, which contains information regarding the employee who is the responsible for the request. The "quote" table is also connected to the "draft_item" because it is the table that stores the information regarding the two or more quotes that must be asked for each item request. There must be an employee responsible for each quote, so this table is connected to the "employee" table.

If the item request is approved, it will generate a purchasing order ("PO" table). There is always an employee responsible for each PO, so this table is connected to the "employee" table. The information regarding the supplier that will provide each purchasing order is stored at "supplier" table. It is important to refer that one PO may be referring to one or several items requested and already approved. The tables "PO" and "quote" are also connected because the quote (or quotes) that was (or were) asked to the chosen supplier may be associated to the purchasing order.

After a purchasing order is placed, the supplier that will provide it will send the invoice(s) corresponding to the order. This information is stored at the "invoice" table, which is therefore connected to the "PO" table and the "supplier" one.

Each employee may also register information regarding its own travels at the "travel" table. Furthermore, employees are also able to associate expenses ("expense" table) to each travel.

In addition to the class diagram presented, a view was created above the level of the data structure presented in **Figure 20**. In this view called "Purchase Final File", all the data regarding a purchase is saved, so that it can be easily consulted.

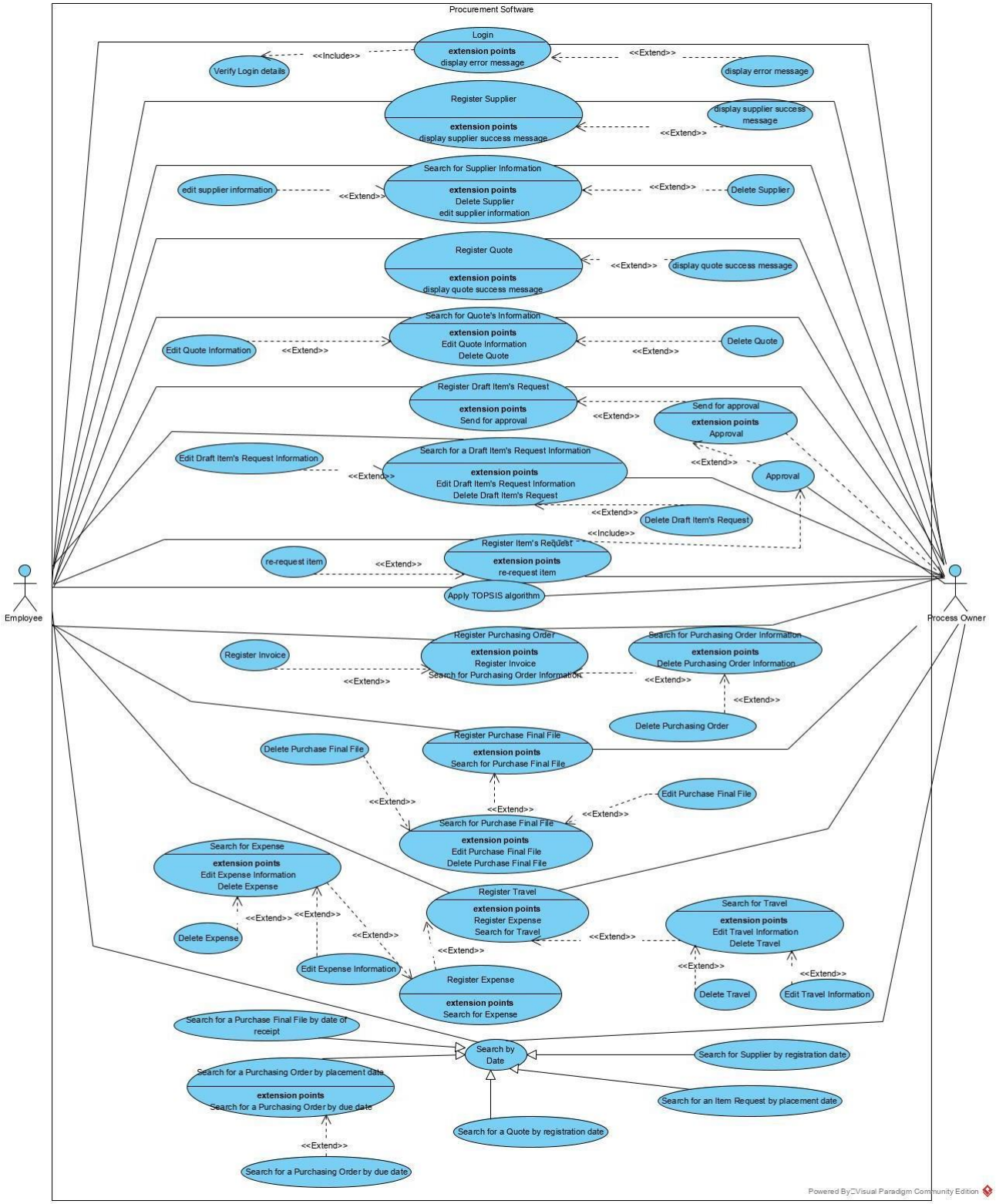


Figure 19 – Procurement Software Use-Case diagram

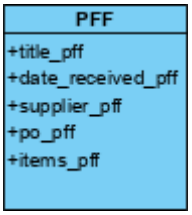


Figure 20 – PFF View

The software architecture that is presented and proposed here, integrates all the procurement processes at the company, solving several problems previously identified: it decreases paper documents, enables a proper flow of information, and allows users to easily register and save the correct information in a proper database, so that the data can further be analyzed, and useful insights can be obtained.

4.3.2 Procurement Software Development

The software architected was developed using **Power Platform** integrated with **SharePoint**. **Powers Apps** provided the environment in which the software was developed and **Power Automate** was used to automate tasks, and to create flows of approval, which will be described further. The information was stored in **SharePoint'**s lists. The final procurement-support software prototype will now be presented:

1. As shown on the use-case diagram (see **Figure 19**), there are two types of users interacting with the software – employees and process owners, and each user-type has different permissions on the software. For that reason, the first step when entering the application is **logging in** using a valid personal username and password (see **Figure 22**). The entered username has an associated type, which defines the permissions that the user will have access to.

2. If the log in information is validated by the system, the user will get into the **main menu** (see **Figure 23**). Through this menu, it is possible to access all the use-cases of the application. Each use case will be further explained.

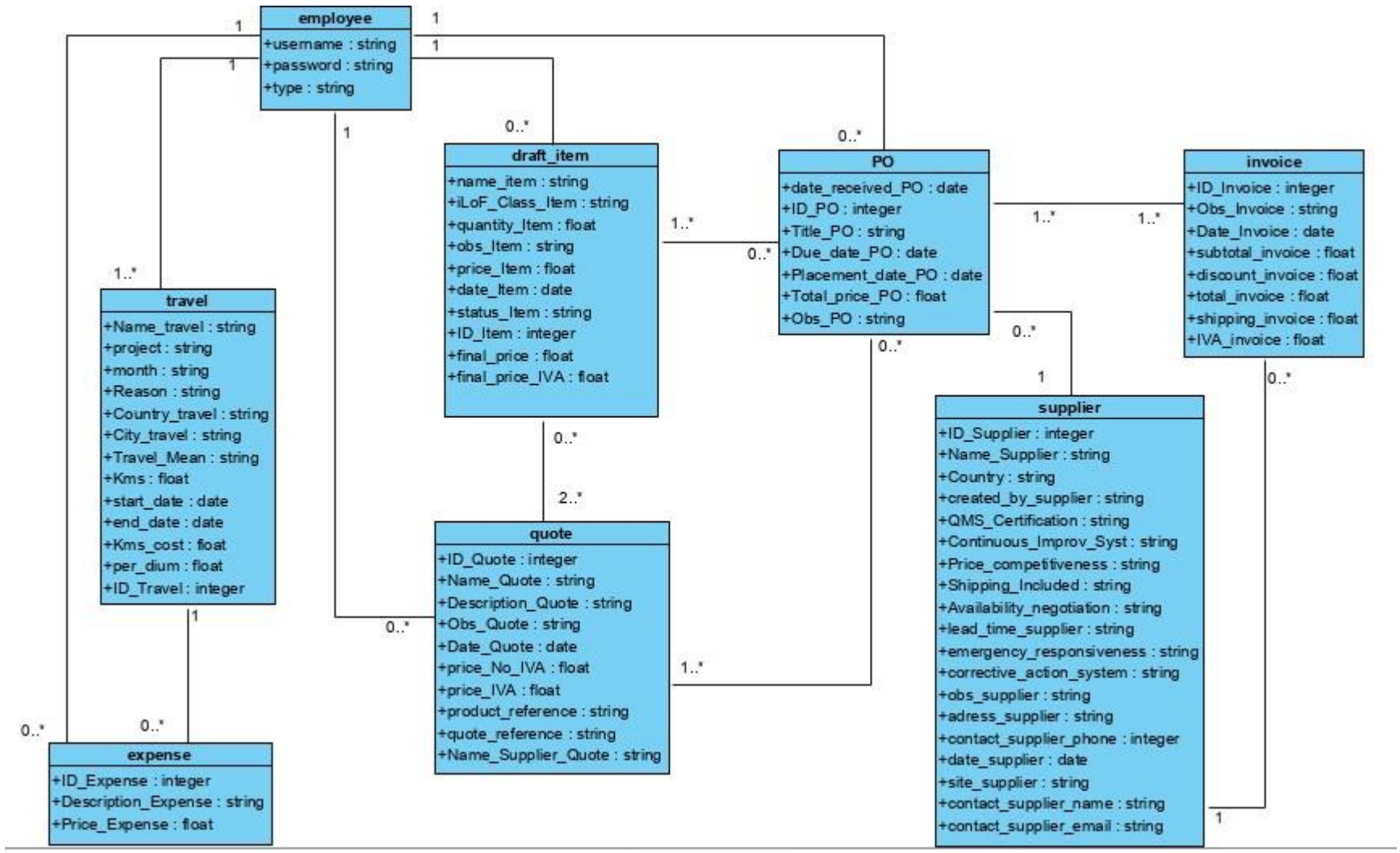


Figure 21 – Procurement Software Class Diagram

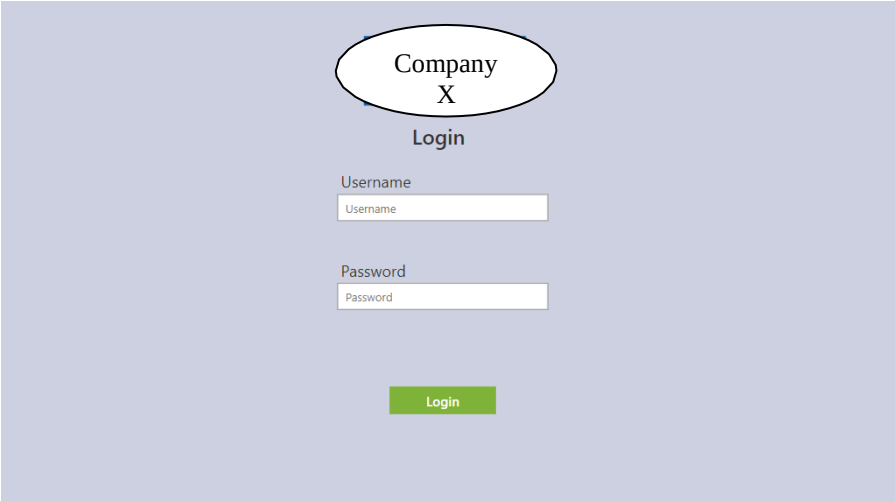


Figure 22 – Login Screen

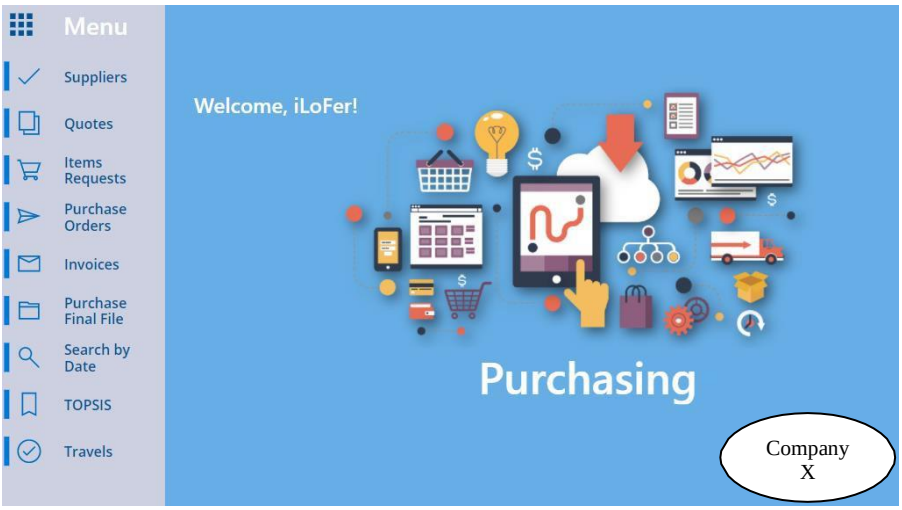


Figure 23 – Main Menu Screen

3. When a need is identified, the user may register it on the system. By clicking on **"Items Request",** the third button of the main menu (see **Figure 23**), the user will get into the Item Request's screen (see **Figure 24)**.

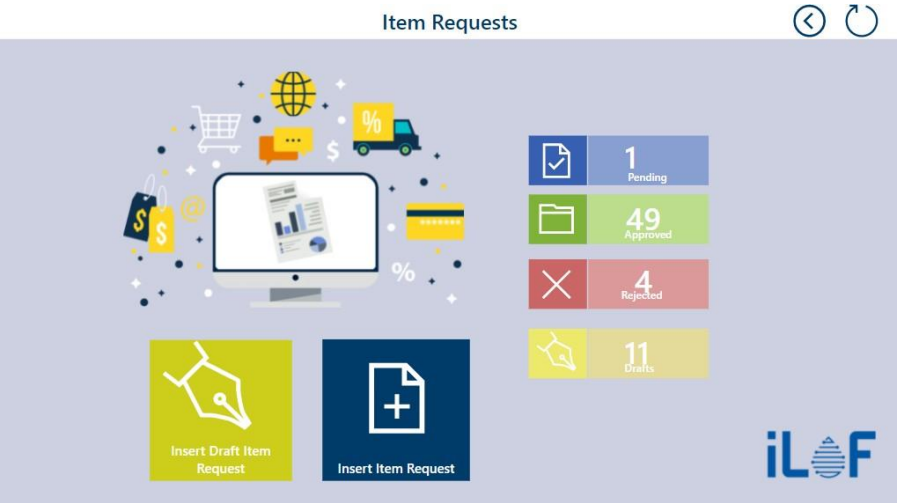


Figure 24 – Items Requests Screen

Figure 24 shows the screen through which the user can access to all item requests: either the approved, declined, pending and draft items. This is automatically updated every time a flow of approval is completed (see **point 12**). **Figure 24** also shows that the user can either **register an item request directly for approval (I.)** or **create a draft which can be later updated and sent for approval (II.)** (Only when all the needed information is available).

I. **Figure 25** shows the form in which the user must enter all the information regarding the needed item. The user must state a title ("**Title**") for the purchase, select the class of the item to be requested ("**Company X_Class_Item**") (i.e., furniture, lab consumables, prototype components, etc.) and select at least 3 quotes requested ("**Quotes_requested**"). It is important to note that these quotes ought to be inserted on the system previously (see **point 4**), so that the user is able to add them to an item request. In the "**Quotes selected**" field, the user must select the chosen quote. In the "**Quantity_item**" field, the user must state the number of unities needed. By doing that, and using the information saved on the selected quote, the system will automatically calculate the final price of this purchase, with IVA ("**Final_Price_IVA**") and without IVA ("**Final_Price**"). In the "**Obs_Item**" field, the user must enter TOPSIS results (explained in **point 11**). If needed, the user can also add attachments to the request. When all the information is completed, the item must be sent for approval by clicking on the

"**Submit**" button. The "**Reset Form**" button deletes all the fields so the user can re-enter the information.

The requested Item will be approved or rejected by the Process Owner, and the Item must only be bought after the approval (explained further on **section 12**).

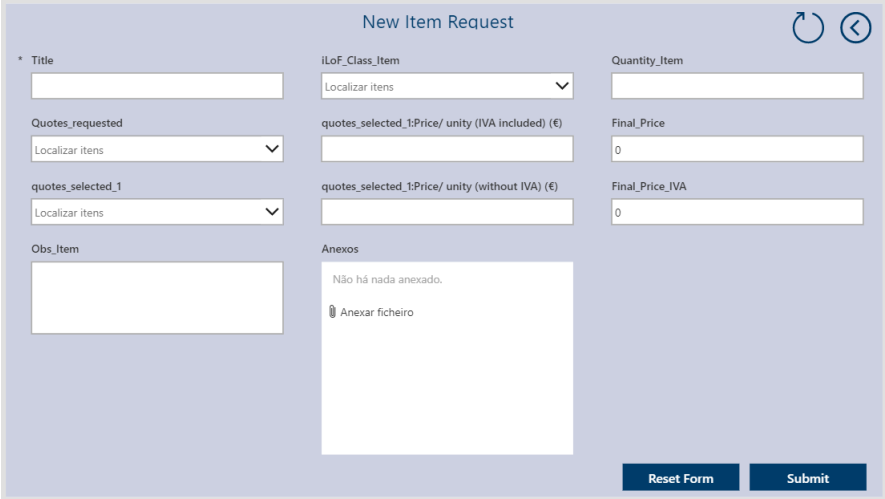


Figure 25 – Item Request Form Screen

II. On the other hand, if the user does not already have all the information needed to submit the request, he must click "**Insert Draft Item Request**" (see **Figure 26**).

The form's fields are identical to the previous one. The item request will be saved as a draft, and the user is able to later complete de information and send the item for approval. To do that, the user must access the items request's screen (see **Figure 24)**, and by clicking on "**Drafts**", a list of all the draft items will reveal (see **Figure 27**). By pressing on any item, a screen with the item's information will show up (see **Figure 28**). The information may be edited, and when all the needed data is gathered and registered, the item can be submitted for approval, by clicking on "**Submit for approval**". The item can also be deleted by clicking on "**Delete draft**".

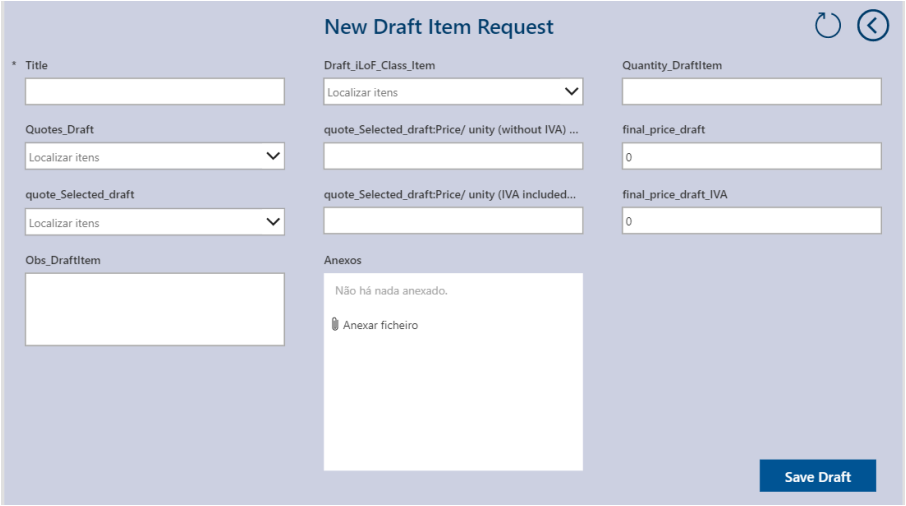


Figure 26- Draft Item form

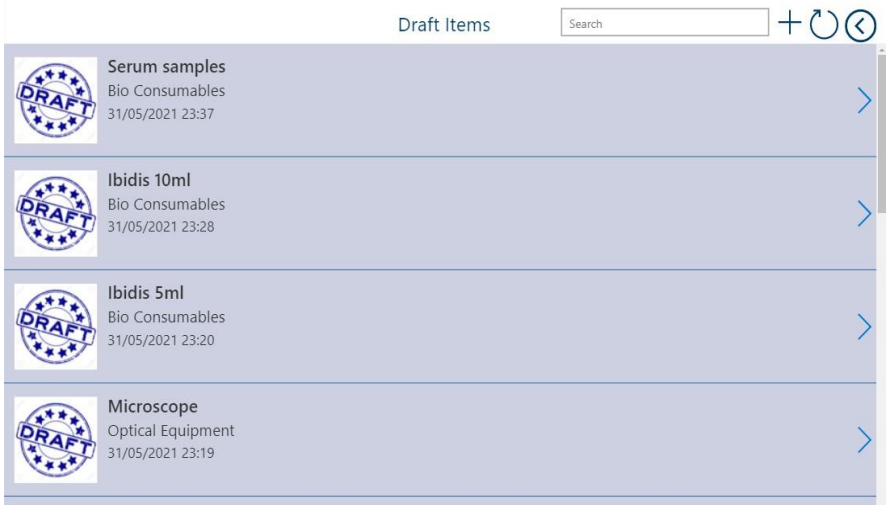


Figure 27 - Draft Item Requests

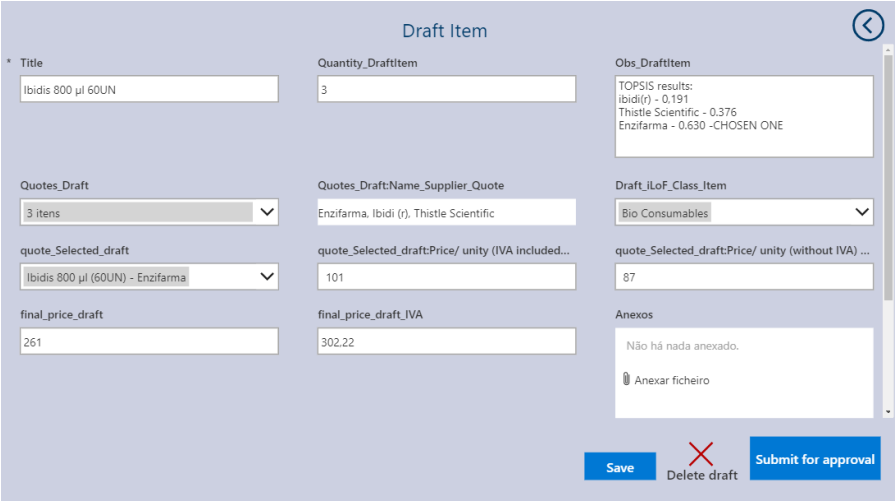


Figure 28 – Draft Item View

When the user sends a draft item for approval it will move from the "**Drafts**" list to the **"Pending"** list (see **Figure 29**). The items on this list are waiting for approval from one of the process owners.

Figure 29 – Pending Item Requests

If the user that is logged in the system is defined as "Process Owner", when clicking on a pending item request, he will be able to approve or decline it (see

Figure 31). On the other hand, if the user is defined as “employee”, this option will not be available (see **Figure 30**).

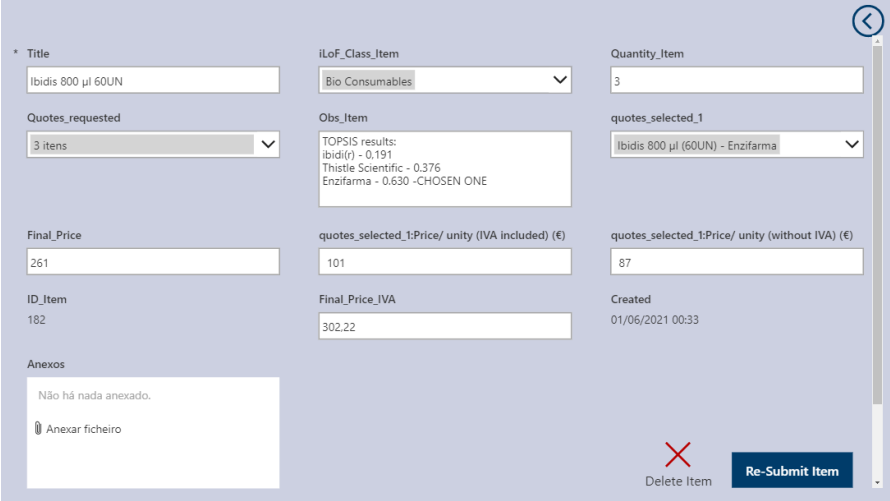


Figure 30 – Employee’s view of pending Item Requests

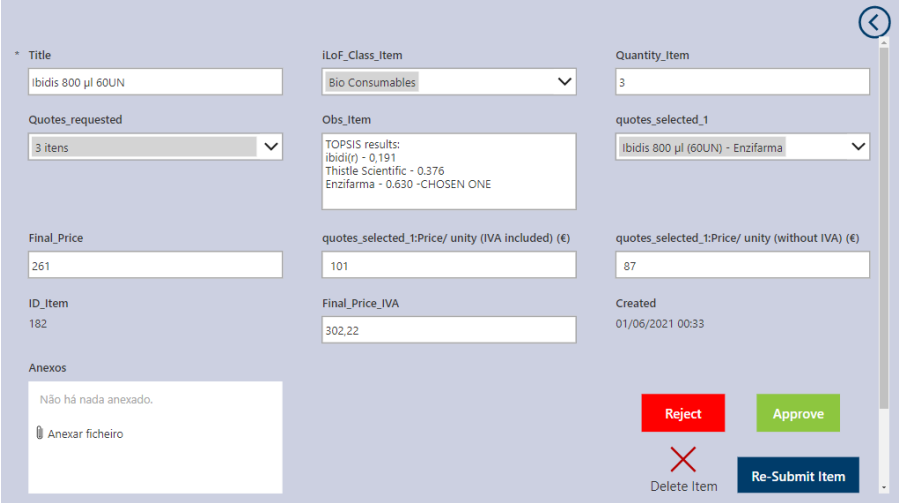


Figure 31 – Process Owner’s view of pending Item Requests

4. After the identification of a need, several quotes must be requested and registered on the software. To access quotes’ screen, the user must open the main menu screen (see **Figure 23**) and click on “**Quotes**”, which will lead to a screen where all the quotes registered on the system show up. Here, the user is able to search for a

certain quote, and by clicking on any of them, its information will appear. The quote can be edited or deleted. The user is also able to register a new quote by filling a form in which all the information regarding a quote must be registered.

5. After analyzing the requested quotes, the best supplier will be chosen. The preferred supplier's information must be registered on the system as well. This can be done by accessing the main menu (see **Figure 23**) and pressing the "**Suppliers**" button, which will initiate the supplier's screen (see **Figure 32**).

Figure 32 – Supplier's Screen

By clicking on the "**Approved**" button, the user will access a list of all the approved suppliers. It is possible to search for a certain supplier and, by clicking on any of them, its information will show up (see **Figure 33**). Supplier's data can be edited or deleted. All the Purchase Final Files associated with that supplier, will show up on that screen, and by clicking on them, the user is able to access its information.

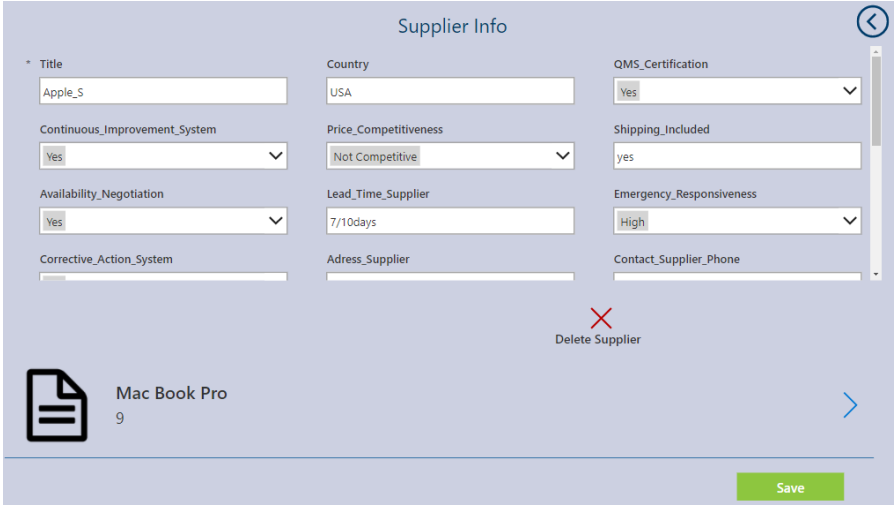


Figure 33 – Supplier's Information Screen

The user is also able to register a new supplier by filling a form in which the data about the supplier must be registered.

6. Once an item's request is approved, the item can be purchased. Purchase Order's information also ought to be registered on the software. This can be done by accessing the main menu (see **Figure 23**) and pressing the "**Purchase Orders**" button, which will lead to the purchase order's screen where all the PO registered on the system appear. On this screen, the user is able to search for a specific PO, and by clicking on any of them, its information will show up (see **Figure 34**). There, the information can be deleted. By pressing "**Add Invoice**", the user is able to add information about invoice(s) referent to the order. The user is also able to generate a PDF, by clicking on "Create PDF", in which all the information regarding the purchasing orders is compiled on a structured PDF file (see **Figure 35**). The document is automatically saved on a proper OneDrive file.

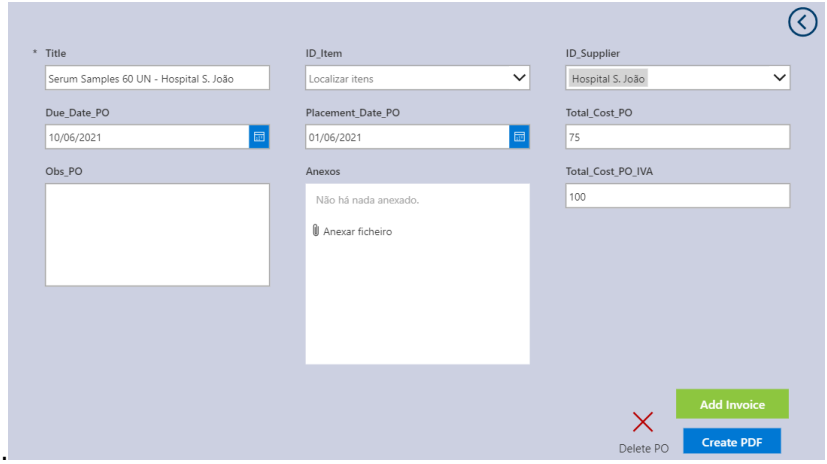
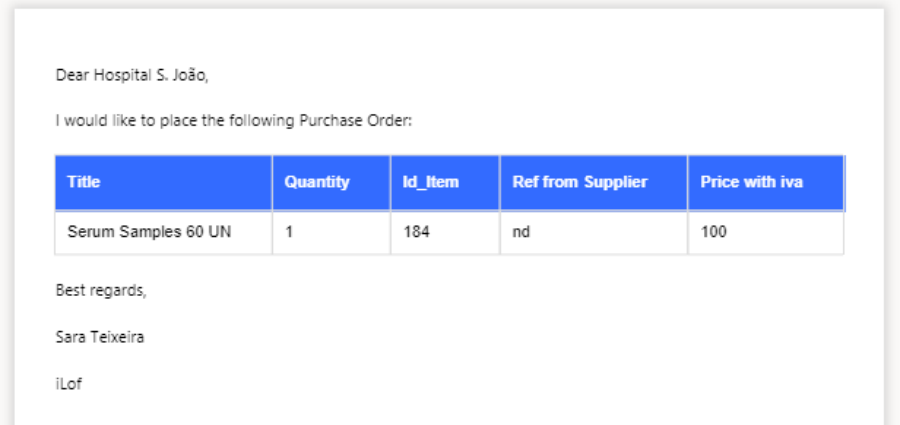


Figure 34 – Purchase Order's Information Screen

It is also possible to insert a new Purchase Order by filling a form.



Dear Hospital S. João,

I would like to place the following Purchase Order:

Title	Quantity	Id_Item	Ref from Supplier	Price with iva
Serum Samples 60 UN	1	184	nd	100

Best regards,

Sara Teixeira

iLof

Figure 35 – PDF Purchasing Order

7. After the PO is placed, the supplier will send the invoice(s), which should be registered on the system too. To do that, the user may access the main menu (see **Figure 23**) and press "**Invoices**", which will lead to the invoice's screen. Here, the user is able to consult all the invoices registered, search for a specific one, open it information and delete it. To register a new invoice, the user may fill the new invoice form.

As mentioned before, by selecting one specific PO, its Purchasing Order's Information screen (see **Figure 34**) will appear, and there is the "**Add Invoice**" button, which will lead to the new invoice form. When the user does it, the "**PO_invoice**" field is automatically filled, and the invoice is immediately associated to the PO that was previously opened.

8. A Purchase Final File (PFF) is a register in which all the information regarding a purchase is compiled. When an order is received, the user must create a new PFF. To access the PFF's screen, the user must go to the main menu (see **Figure 23**) and click on "Purchase Final File". Afterwards, a list of all the PFFs will show and the user is able to search for a specific PFF, and by clicking on any of them, its information will appear. On that screen, the user is able to edit the information. The user is also able to register a new PFF by filling the new PFF form.

9. The user may also register Travels and its associated expenses on the app, by going on the main menu (see **Figure 23**) and press the "Travels" button, which will open the travel's list screen (see **Figure 36**).

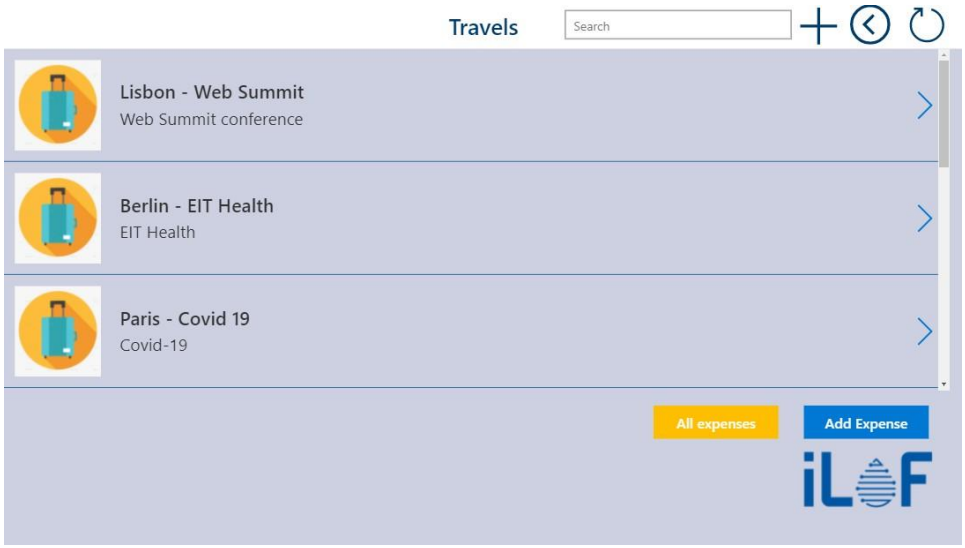


Figure 36 – Travels Screen

The user can search for the wanted travel and, by clicking on it, the respective information will show up (see **Figure 37**). This data can be edited or deleted. This screen also shows the expenses associated with the chosen travel.

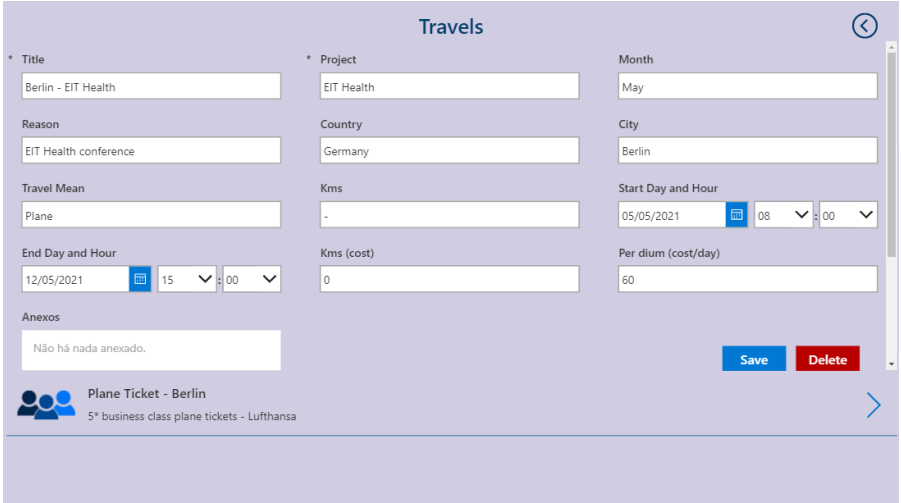


Figure 37 – Travel's Information Screen

The user is also able to register a new travel by filling its respective form.

On the travels list (see **Figure 36**), by pressing the "**All Expenses**" button, the user will access to the list of all the expenses registered on the system. By clicking on any of them, the user will access its information, and may edit or delete it. If the user wants to add a new expense, he must fill the expense's form.

10. On the main menu (see **Figure 23**), by clicking on "Search by date" button, the user will open up the search by date screen (see **Figure 38**). A set of different options will appear: if the user clicks "**Supplier**", he will be able to search for the suppliers that were registered on a certain period of time; if he clicks "**Quotes**" he will be able to search for the quotes that were registered on a certain period of time; if he clicks "**Items Requests**" he will be able to search for the items requests that were placed in a certain period of time; if he presses "**Purchasing Orders**" (see **Figure 60**) he will be able to search for the purchasing orders that were placed on a certain period of time, also to search for purchasing orders that are due to be delivered on a certain period of

time; and lastly, if he clicks "**Invoices**" he will be able to search for the invoices received in a certain period of time.

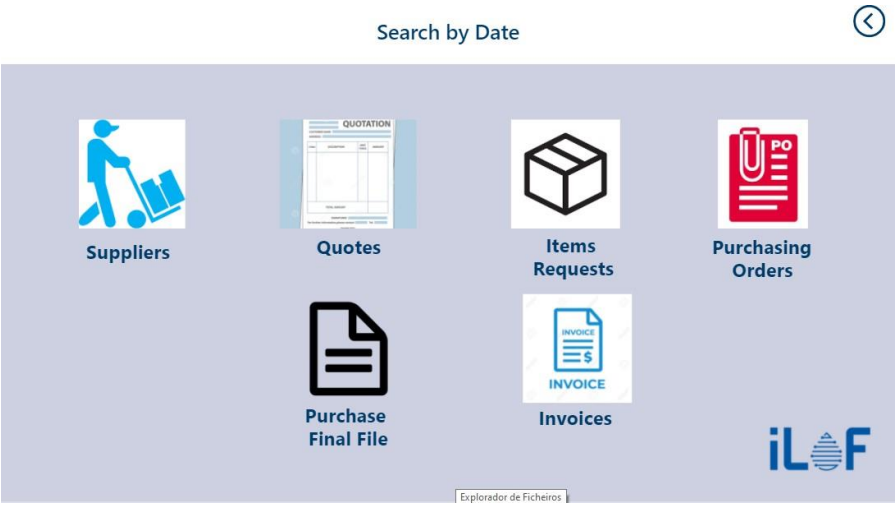


Figure 38 – Search by date screen

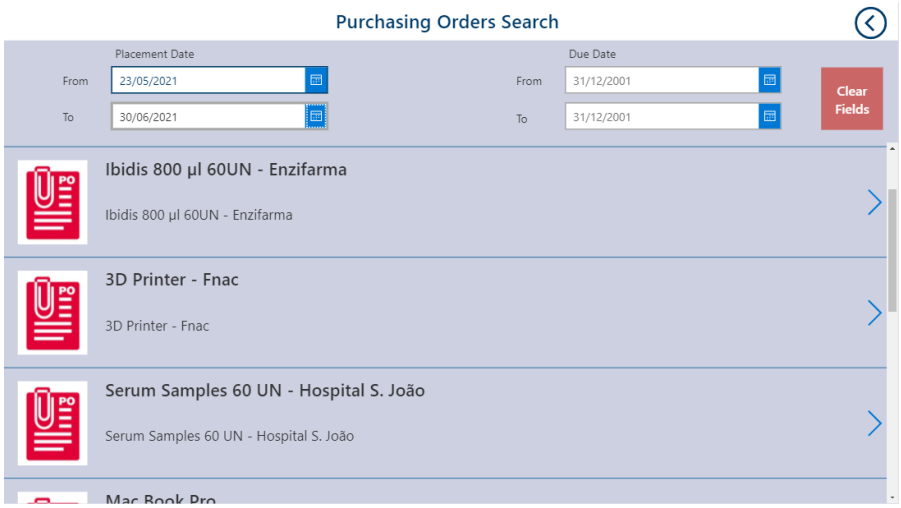


Figure 39 – Purchasing Orders – Search by date screen

11. On the main menu (see **Figure 23**), by pressing the "**TOPSIS**" button, the user will access to the TOPSIS screen (see **Figure 40**). The TOPSIS algorithm was implemented in the app. The user can compare between 2 to 5 different suppliers using the pre-defined criteria and weights. The app will display the **Ca** (closeness coefficient) of each alternative supplier. This number is always between 0 and 1,

where 1 is the preferred action. If an action is closer to the ideal than the anti-ideal, then Ca approaches 1. **Therefore, the supplier with the highest Ca is the best alternative.**

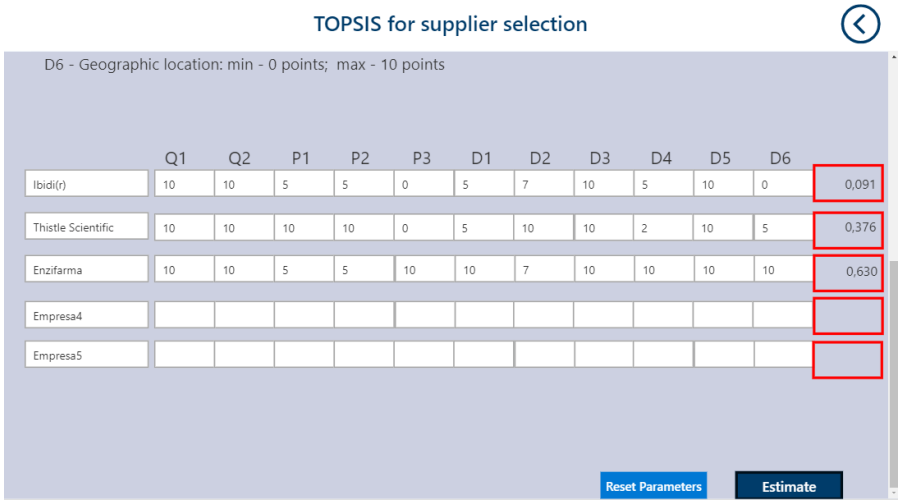


Figure 40 – TOPSIS implementation on Power Apps Screen

12. A **flow of approval** of the requested items was created using Power Automate (see **Figure 42**). Every time an item is sent for approval, the process owners will receive an e-mail with the relevant information about the request, and will either approve or decline the request, being able to attach a comment that will be sent to the creator of the request (see **Figure 41**). The creator of the request will receive an e-mail with the process owner's decision, and the status of approval of the item will be automatically updated.

    The approval can be done on the application too.

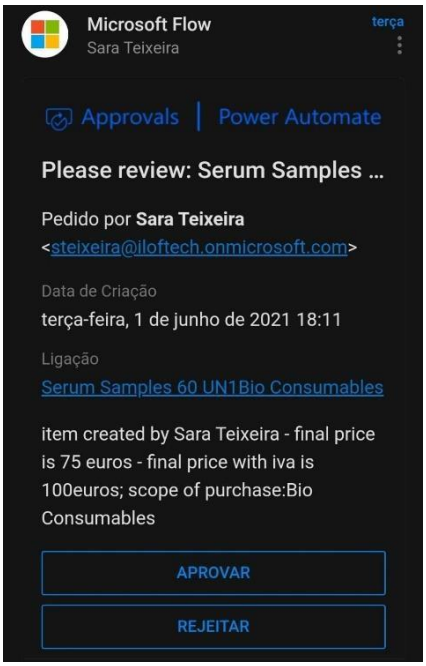


Figure 41 – Approval E-mail – Item's Request

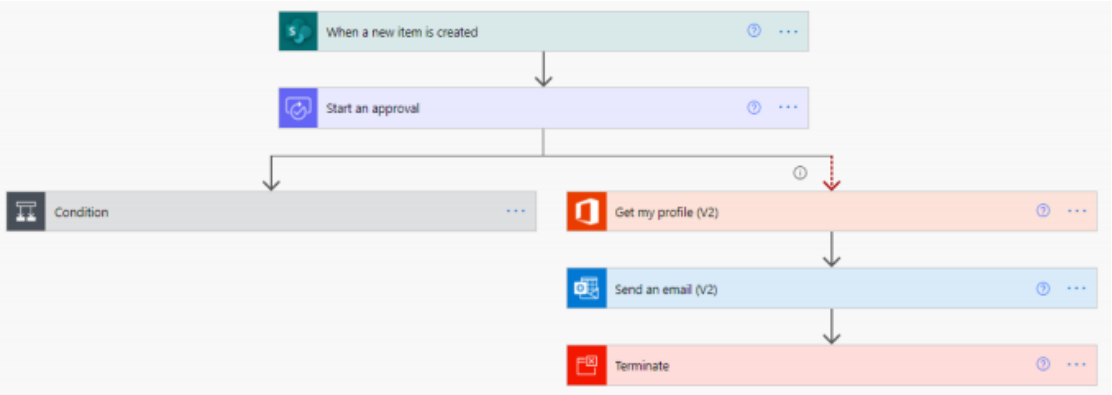


Figure 42 – Flow of approval on Power Automate – Item's Request

4.3.3 Procurement Software Testing

The main goal of the procurement-support software above presented is to improve processe's efficiency, while facilitating employee's daily purchasing tasks. For that reason, all the stakeholders envolved in the procurement activities – since the Management Team (CEO and CTO), to several members of the BioPhotonics Team - were consulted during all the

development stages of the software, to ensure that user's needs were guaranteed. Thus, the following steps were followed:

1. The procurement process was re-designed and later validated by the management team.
2. A focus group with all the different stakeholder was held, in which it was discussed the different modules and features that the software should present.
3. One of the software's modules was developped, which worked as the first protoytpe of the system. This prototype was exhaustively tested by the different stakeholders. All the mistakes were corrected and all the improvement opportunities identified were implemented.
4. The rest of the development worked as an iterative process, similarly to what was described on the third point: as new modules were developped, they were tested by the different stakeholders and consequently improved.

5. Conclusion

In this chapter, the key target is the outlining of conclusions. The project will be summed up, its main contributions for the company will be summarized, as well as its limitations. Future improvements will also be stated.

5.1 Final Considerations

Organizations can benefit from the application of new technologies on Procurement Processes. E-procurement is already widely used but the fourth industrial revolution arises the concept of **Procurement 4.0**, which has potential to boost the state-of-the-art practices, allowing companies to collaborate with all the partners along chain, and consequently gaining competitive advantage over possible competitors. However, new smart technologies will produce increasing amounts of valuable information, which must be efficiently managed so that it is possible to take advantage of it. **Information Management** must not be neglected during this transitional phase and Lean Information Management is a useful approach to reduce wastes that may compromise the value of the information that is being stored.

Company X is still at a very preliminary phase of its life cycle but is growing rapidly. Anyhow, since it operates in the medical industry, the company must certificate its processes before starting to commercialize its product and service. Therefore, the company is currently walking towards an ISO 13485 certification, which implies a redesign of its current procurement process. The work performed at Company X, during approximately 8 months, was exhaustively portrayed throughout this document and aims to analyze and improve the procurement at company X, in the light of ISO 13485's requirements.

To support this project, several different fields were researched and integrated. The main focus was on **Procurement, Industry 4.0, and Lean Information Management**.

Different tools and methodologies were used: **BPMN** was a precious tool in order to clearly describe the as-is procurement process at the company, as well as the to-be proposal. Besides, this tool was essential to clearly visualize all the waste sources that must be eliminated, adopting a **LIM** approach. Since the project encompassed the development of a software, the **RUP** methodology was followed, and **UML notation** was used to model the system to-be developed.

The main goal was achieved: a new process was designed, in which all the proposed improvements were incorporated. A procurement-software was developed, using Power Apps, Power Automate and SharePoint, and allows the company's employees to store all the needed data in a single platform, which is user friendly and effective solving all the information-flow issues. In the middle of the digitalization era, it is extremely important that the flow of data is fluid and flawless. The development of this platform allowed the company to integrate several data sources in one complete and structured information system. This way, the paper documents, as well as the old-fashioned disorganized excel files could be completely eliminated, favoring company's flow of data and information, which enabled a much more efficient and effective decision making. This contributed to a greater consistency of organizational knowledge in the company, since a more streamlined and agile repository of information was created.

A supplier-selection system was also developed and implemented on the software, so that the users can easily apply it.

Company X is now one step closer to the ISO 13485 certification due to the work developed and portrayed on this thesis, which is a great advancement in the go-to-market strategy.

5.2 Future Research

The developed solutions were exhaustively tested and validated by the management team of the company, as well as by other employees. Nevertheless, they have not been implemented as standard by the end of the project due to the unexpected condition in which the project was developed: the whole internship happened in a remote regime, which delayed several activities and made the whole development process occur slower than expected. Therefore, the to-be procurement process must be implemented on the company.

Key Performances Indicators for procurement that are aligned with the company's strategy must be defined, so that the processes' performance can be monitored. Since the procurement data is currently stored on Sharepoint, it would be advantageous to create a dashboard on Power BI, that would be connected to Sharepoint, and would constantly update the KPIs as new data is registered. A structured supplier-rating system must be developed, including yearly assessments of the performance of each approved supplier.

The procurement-support software developed has potential to be improved and expanded: new modules can be created, and information regarding other business areas may also be incorporated.

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Annex I - Procurement Software User's Guide

The software architected was developed using **Power Platform** integrated with **SharePoint**. **Powers Apps** provided the environment in which the software was developed and **Power Automate** was used to automate tasks, and to create flows of approval, which will be described further. The information was stored in **SharePoint'**s lists. The final procurement-support software prototype will now be presented:

13. There are two types of users interacting with the software – employees and process owners, and each user-type has different permissions on the software. For that reason, the first step when entering the application is **logging in** using a valid personal username and password (see **Figure 1**). The entered username has an associated type, which defines the permissions that the user will have access to.

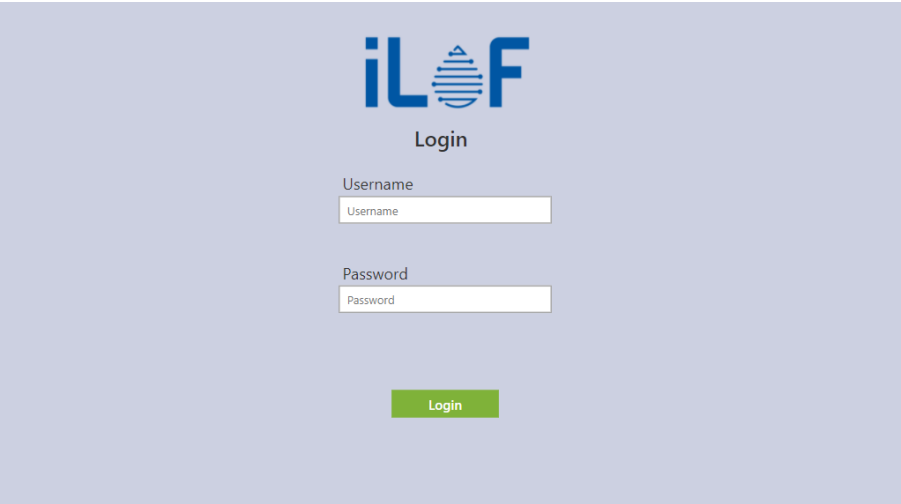


Figure 1 – Login screen

14. If the log in information is validated by the system, the user will get into the **main menu** (see **Figure 2**). Through this menu, it is possible to access all the use-cases of the application. Each use case will be further explained.

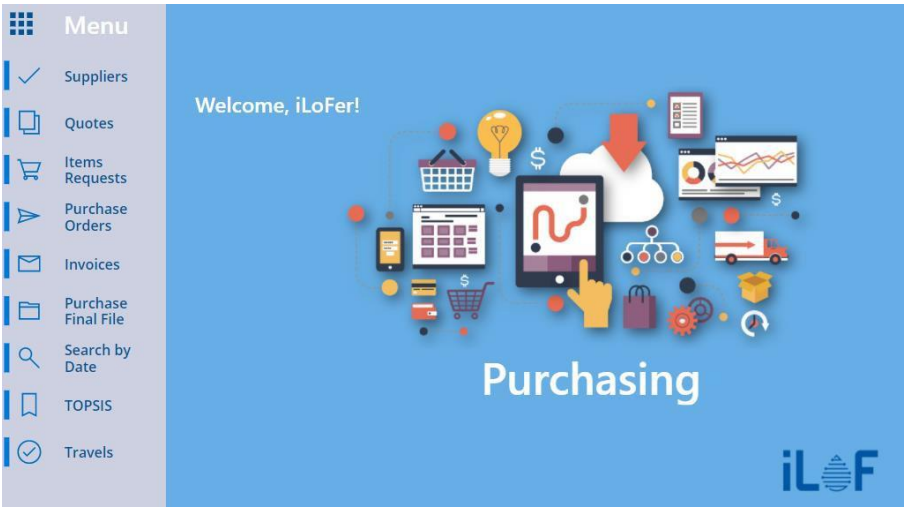


Figure 2 – Main Menu

15. When a need is identified, the user may register it on the system. By clicking on **"Items Request",** the third button of the main menu (see **Figure 2**), the user will get into the Item Request's screen (see **Figure 3)**.

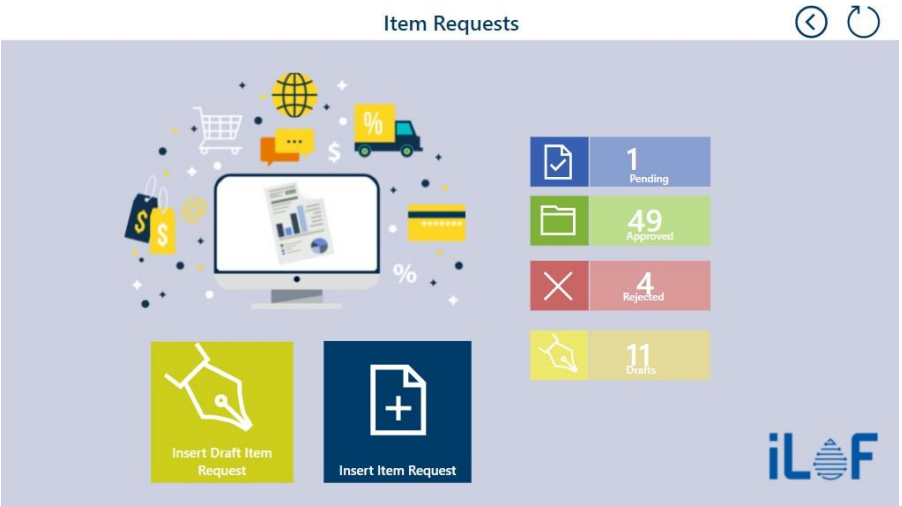


Figure 3 – Items Requests

Figure 3 shows the screen through which the user can access to all item requests: either the approved, declined, pending and draft items. This is automatically updated every time a flow of approval is completed (see **point 12**). **Figure 3** also shows that the user can either **register an item request directly for approval (I.)** or **create a draft which can be later updated and sent for approval (II.)** (only when all the needed information is available).

III. **Figure 4** shows the form in which the user must enter all the information regarding the needed item. When all the information is completed, the item must be sent for approval by clicking on the "**Submit**" button. The "**Reset Form**" button deletes all the fields so the user can re-enter the information.

The requested Item will be approved or rejected by the Process Owner, and the Item must only be bought after the approval (explained further on **section 12**).

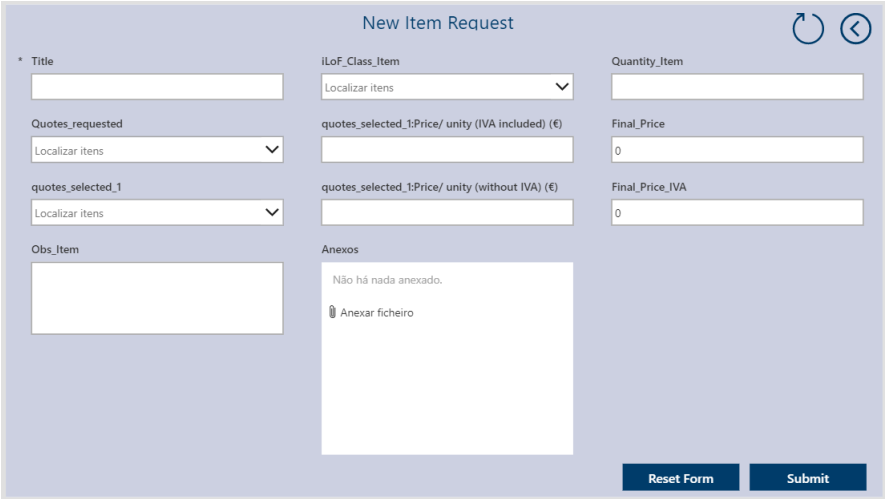


Figure 4 – Item Request Form

IV. On the other hand, if the user does not already have all the information needed to submit the request, he must click "**Insert Draft Item Request**".

The form's fields are identical to the previous one. The item request will be saved as a draft, and the user is able to later complete de information and send the item for approval. To do that, the user must access the items request's screen (see **Figure 3)**, and by clicking on "**Drafts**", a list of all the draft items will reveal (see **Figure 6**). By pressing on any item, a screen with the item's information will show up (see **Figure 7**). The information may be edited, and when all the needed data is gathered and registered, the item can be submitted for approval, by clicking on "**Submit for approval**". The item can also be deleted by clicking on "**Delete draft**".

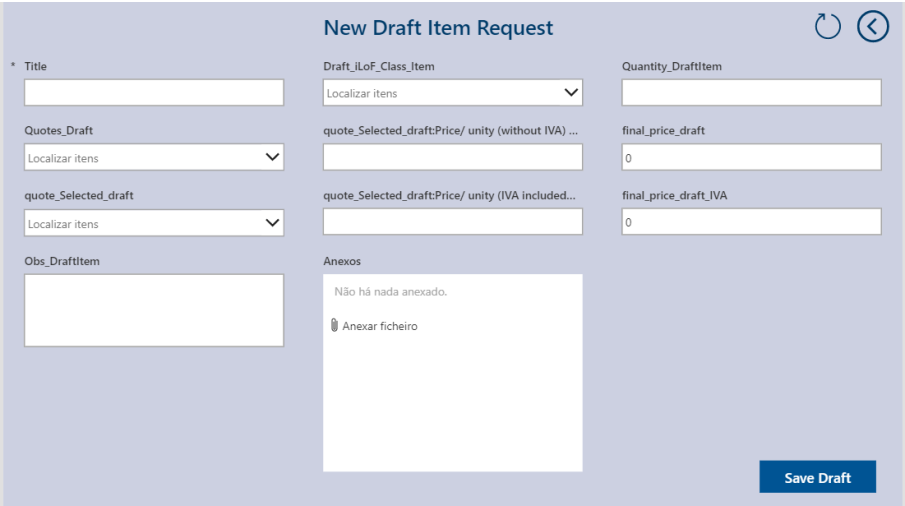


Figure 5- Draft Item form

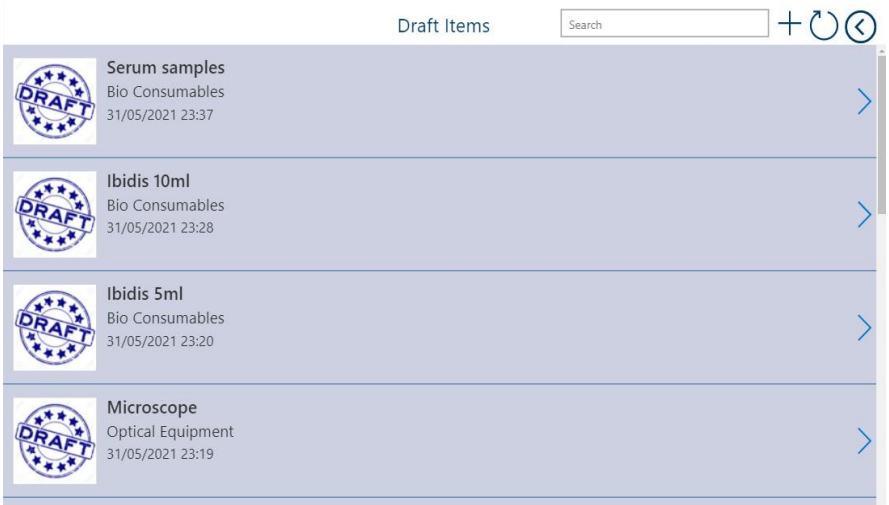


Figure 6- Draft Item Requests

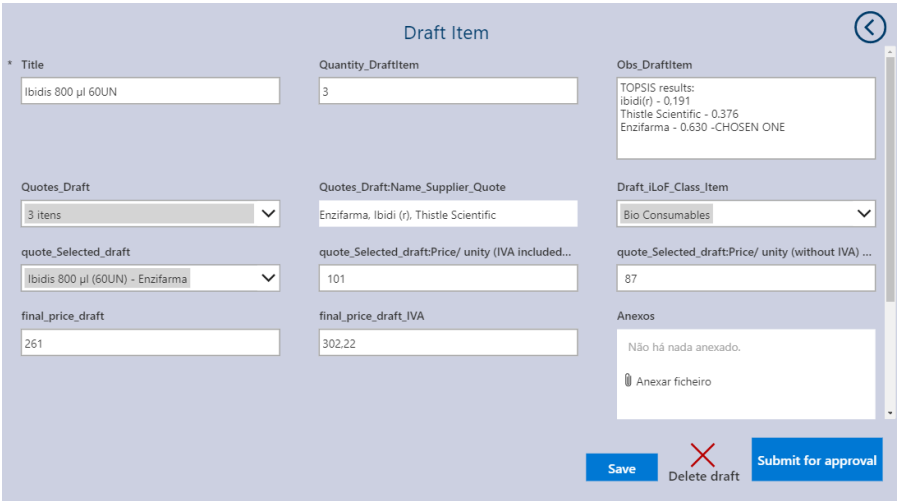


Figure 7– Draft Item View

When the user sends a draft item for approval it will move from the "**Drafts**" list to the **"Pending"** list (see **Figure 8**). The items on this list are waiting for approval from one of the process owners.

Figure 8 – Pending Item Requests

If the user that is logged in the system is defined as "Process Owner", when clicking on a pending item request, he will be able to approve or decline it. On the other hand, if the user is defined as "employee", this option will not be available.

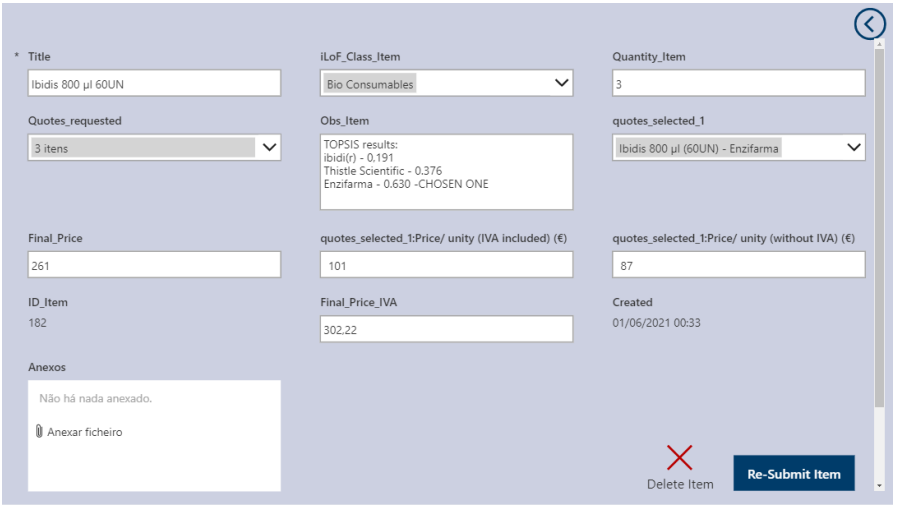


Figure 9– Employee's view of pending Item Requests

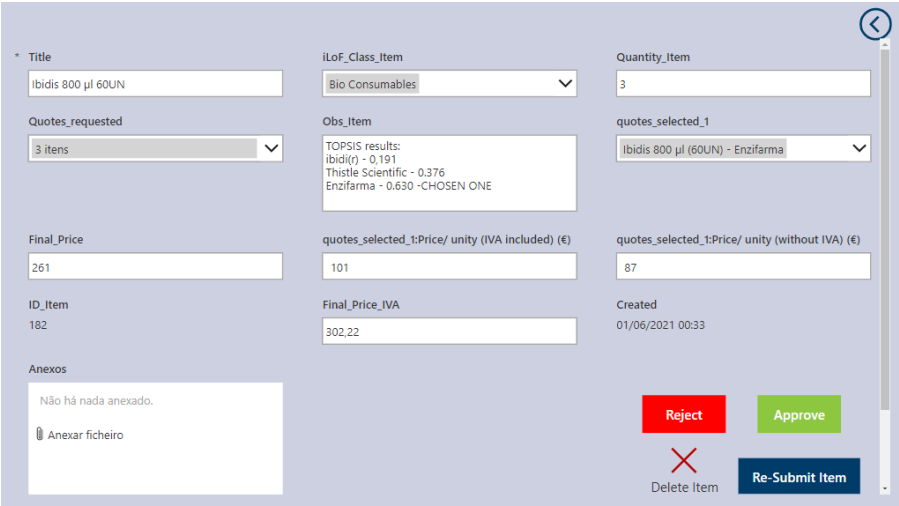


Figure 10 – Process Owner's view of pending Item Requests

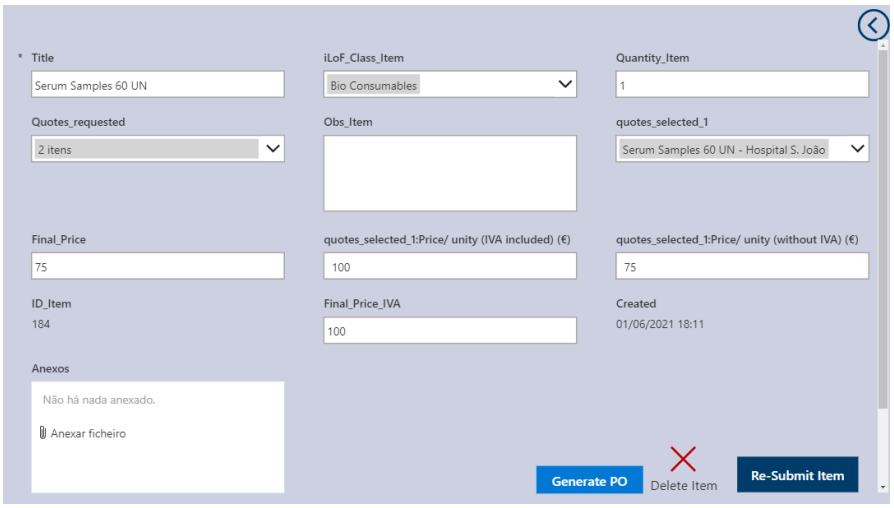


Figure 11 – Approved Item Information Screen

16. After the identification of a need, several quotes must be requested and registered on the software. To access quotes' screen, the user must open the main menu screen (see **Figure 2**) and click on "**Quotes**", which will lead to the screen presented on **Figure 12,** where all the quotes registered on the system show up. Here, the user is able to search for a certain quote, and by clicking on any of them, its information will appear (see **Figure 13**). On that screen, the quote can be edited, or deleted.

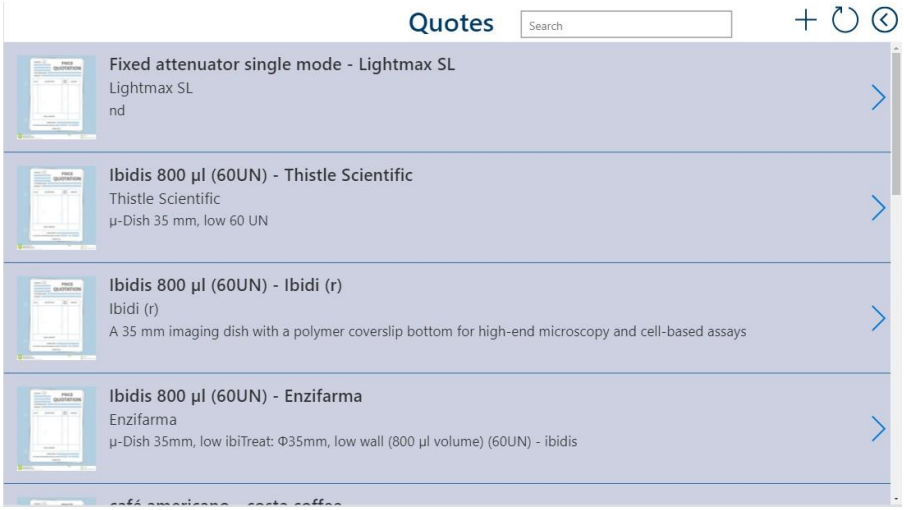


Figure 12– Quotes' screen

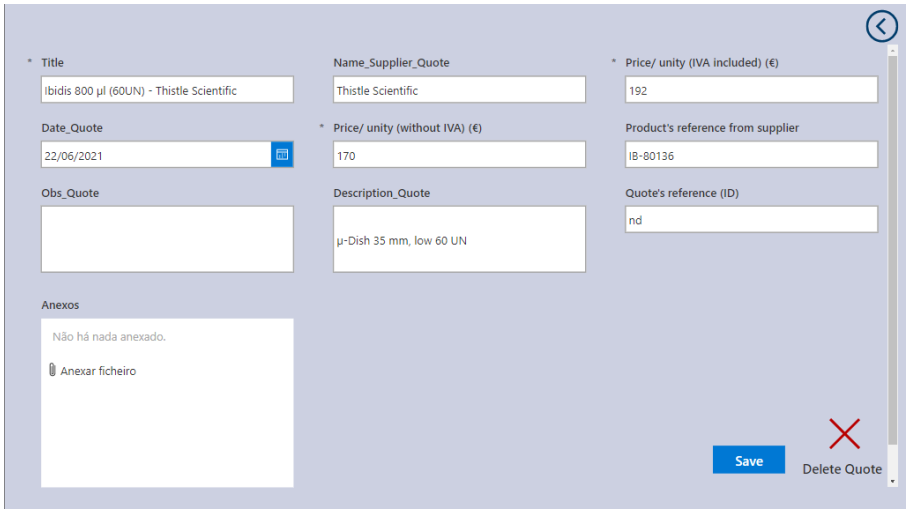


Figure 13 – Quote's information screen

By clicking on "**+**" (see **Figure 12**), the user will open the form in which all the information regarding a quote must be registered (see **Figure 14**).

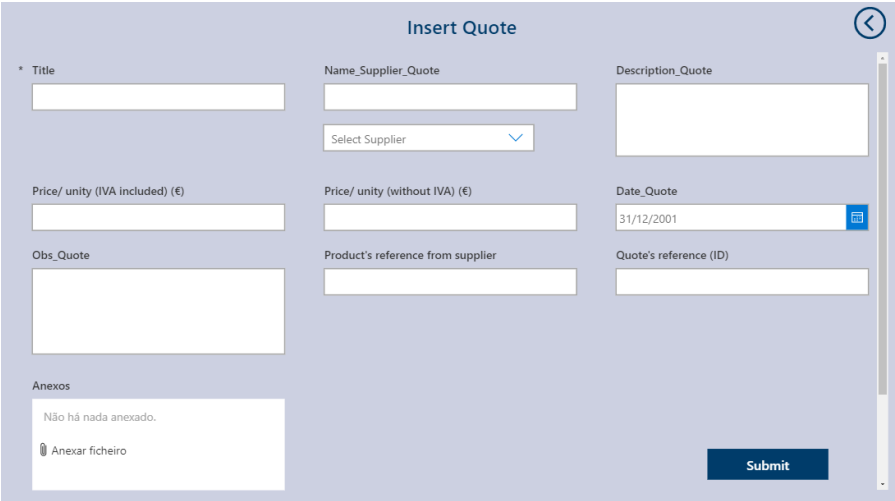


Figure 14 – Insert Quote form

When all the data is inserted, the user must press "**Submit**" to save the entered information.

17. After analyzing the requested quotes, the best supplier will be chosen. The preferred supplier's information must be registered on the system as well. This can be done by accessing the main menu (see **Figure 2**) and pressing the "**Suppliers**" button, which will initiate the supplier's screen (see **Figure 15**).

Figure 15 – Supplier's Screen

By clicking on the "**Approved**" button, the user will access a list of all the approved suppliers (see **Figure 16**). It is possible to search for a certain supplier and, by clicking on any of them, its

information will show up (see **Figure 17**). Supplier's data can be edited or deleted. All the Purchase Final Files associated with that supplier, will show up on that screen, and by clicking on them, the user is able to access its information.

Figure 16 – Approved supplier's list

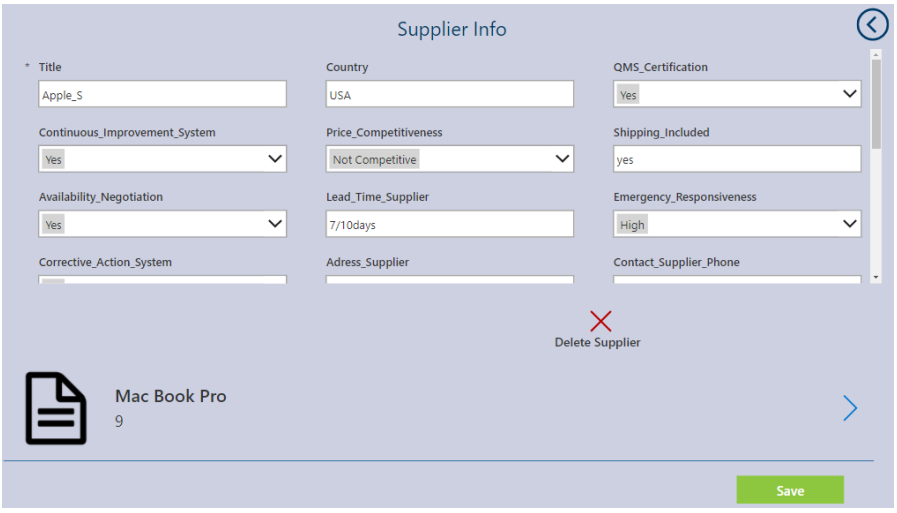


Figure 17 – Supplier's Information

By clicking on "**Insert new supplier**" (see **Figure 15**), a form will appear in which the data about the supplier must be registered (see **Figure 18**).

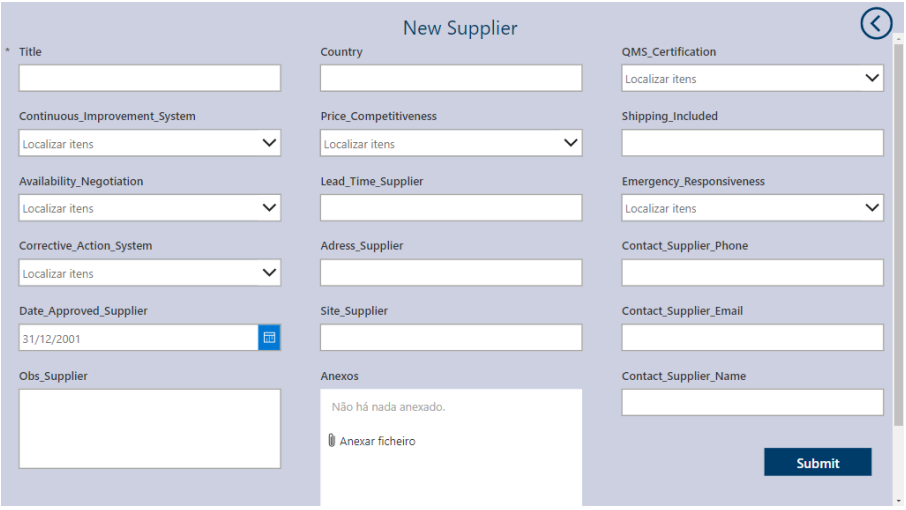


Figure18 – Supplier's Form

18. Once an item's request is approved, the item can be purchased. Purchase Order's information also ought to be registered on the software. This can be done by accessing the main menu (see **Figure 2**) and pressing the "**Purchase Orders**" button, which will lead to the purchase order's screen (see **Figure 19**), where all the PO registered on the system appear.

Figure 19 – Purchase Oder's Screen

On this screen, the user is able to search for a specific PO, and by clicking on any of them, its information will show up (see **Figure 20**). There, the information can be deleted. By pressing "**Add Invoice**", the user is able to add information about invoice(s) referent to the order. The user is also able to generate a PDF, by clicking on "Create PDF", in which all the information regarding the purchasing orders is compiled on a structured PDF file (see **Figure 21**). The document is automatically saved on a proper OneDrive file.

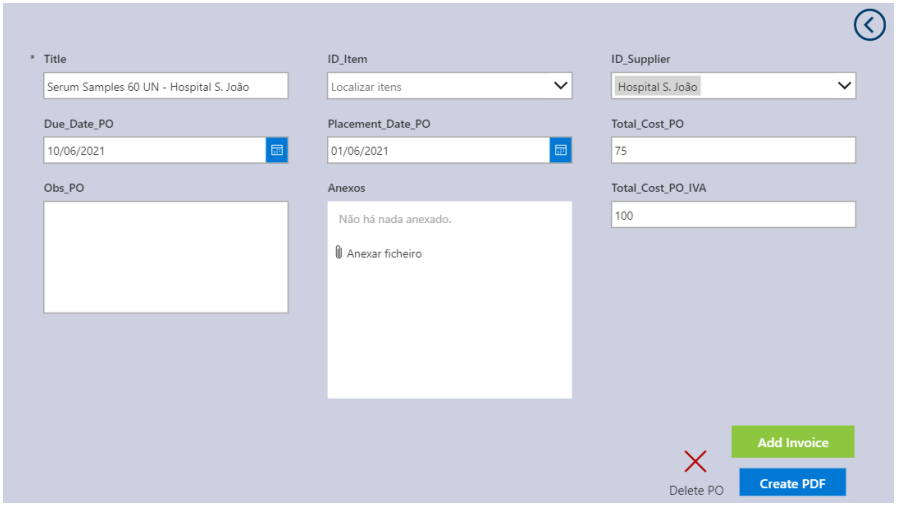
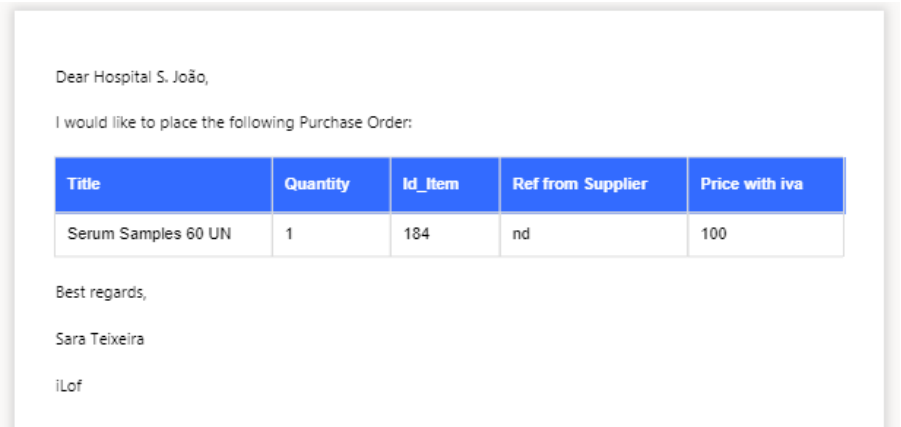


Figure 20 – Purchase Order's Information Screen



Dear Hospital S. João,

I would like to place the following Purchase Order:

Title	Quantity	Id_Item	Ref from Supplier	Price with iva
Serum Samples 60 UN	1	184	nd	100

Best regards,

Sara Teixeira

iLof

Figure 21 – PDF Purchasing Order

To insert a new Purchase Order, the user may either go to an approved item's register or go to the PO's screen and press ("**+**").

A form will open up (see **Figure 22**) and the user must fill it.

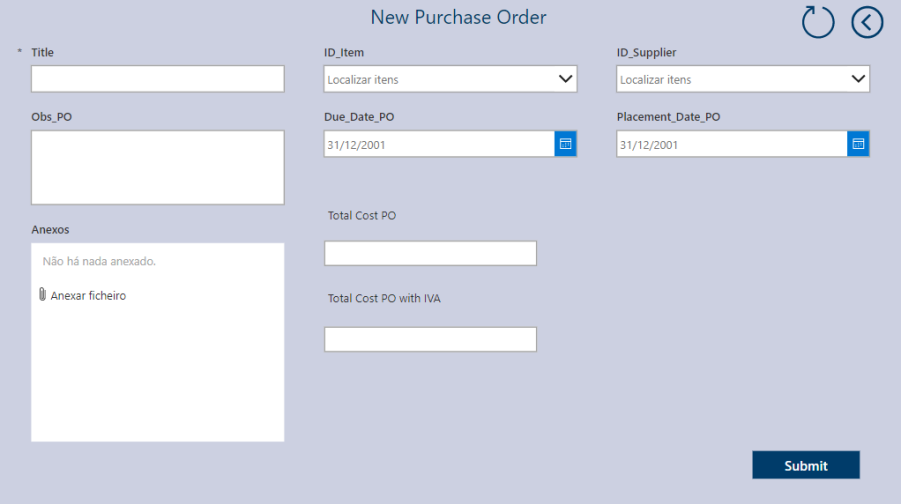


Figure 22 – New Purchasing Order Form

19. After the PO is placed, the supplier will send the invoice(s), which should be registered on the system too. To do that, the user may access the main menu (see **Figure 2**) and press "**Invoices**", which will lead to the invoice's screen (see **Figure 23**).

Figure 23 – Invoice's Screen

Here, the user is able to consult all the invoices registered, search for a specific one, open it information (see **Figure 24**) and delete it.

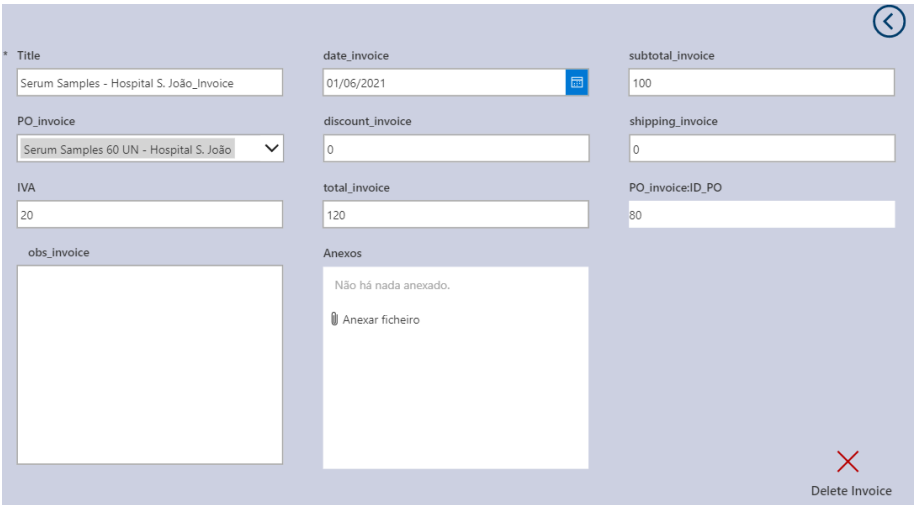


Figure 24 – Invoice's information screen

To register a new invoice, the user may go to invoice's screen and press ("**+**"), which will lead to the new invoice form (see **Figure 25**).

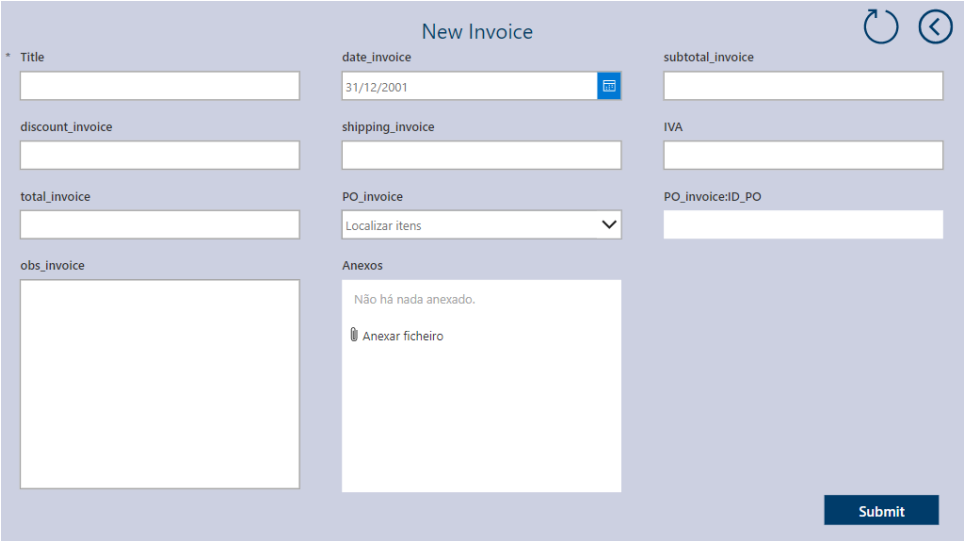


Figure 25 – New Invoice Form

As mentioned before (see Procurement Software - **section 6**), by selecting one specific PO, its Purchasing Order's Information screen will appear, and there is the "**Add Invoice**" button, which will lead to the form presented in **Figure 25.** When the user does it, the "**PO_invoice**" field is automatically filled, and the invoice is immediately associated to the PO that was previously opened.

20. A Purchase Final File (PFF) is a register in which all the information regarding a purchase is compiled. When an order is received, the user must create a new PFF. To access the

PFF's screen, the user must go to the main menu (see **Figure 2**) and click on "Purchase Final File". Afterwards, a list of all the PFFs will show (see **Figure 26**). Here, the user is able to search for a specific PFF, and by clicking on any of them, its information will appear (see **Figure 27**). On that screen, the user is able to edit the information. By clicking on "**+**", a PFF form will open up and a new PFF can be registered. Users my choose a title ("**Title**") for the PFF, state the date of receipt ("**Date_Received_PFF**") and choose the supplier ("**Supplier_PFF**"). Besides, the user must choose the PO (s) that the PFF is referring to ("**PO_PFF**"), which will automatically create a link on the screen to the chosen PO(s)'s information and for the invoices associated with it. Furthermore, the user must choose the items that were received ("**Items_PFF**"), which will automatically create a link to the items' information screen and for all the quotes requested for each item. The user is also able to attach documents to the PFF.

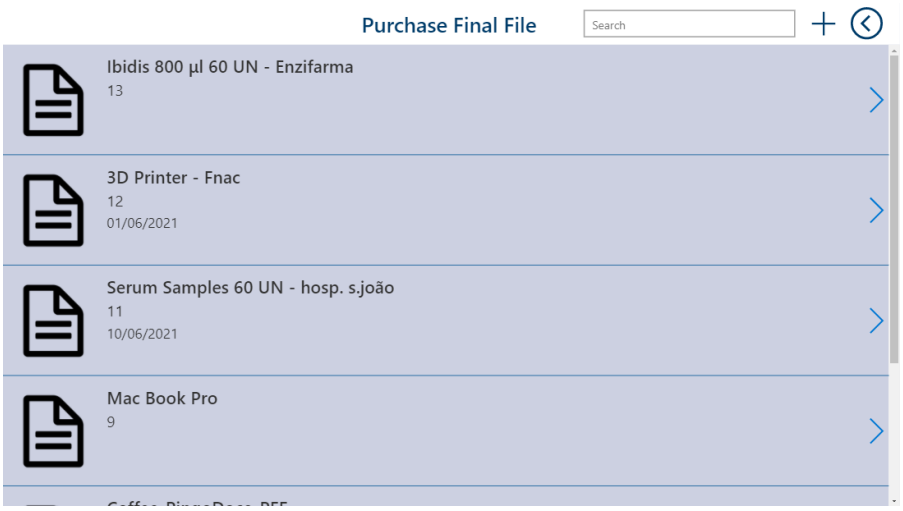


Figure 26 – Purchase Final File's Screen

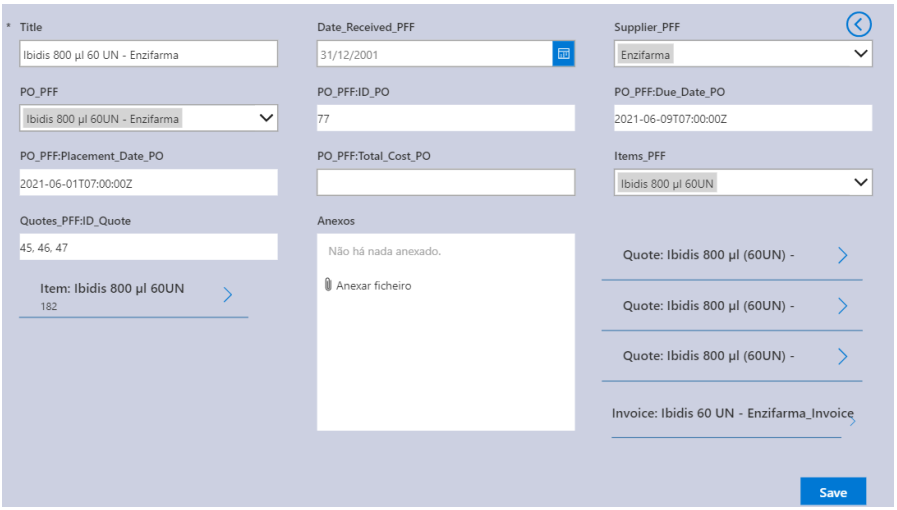


Figure 27 – Purchase Final File's Information Screen

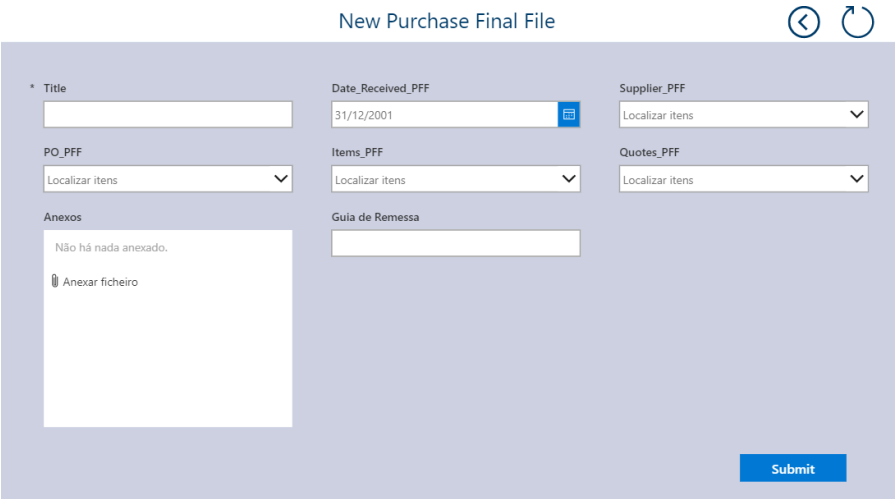


Figure 28 – New Purchase Final File Form

21. The user may also register Travels and its associated expenses on the app, by going on the main menu (see **Figure 2**) and press the "Travels" button, which will open the travel's list screen (see **Figure 29**).

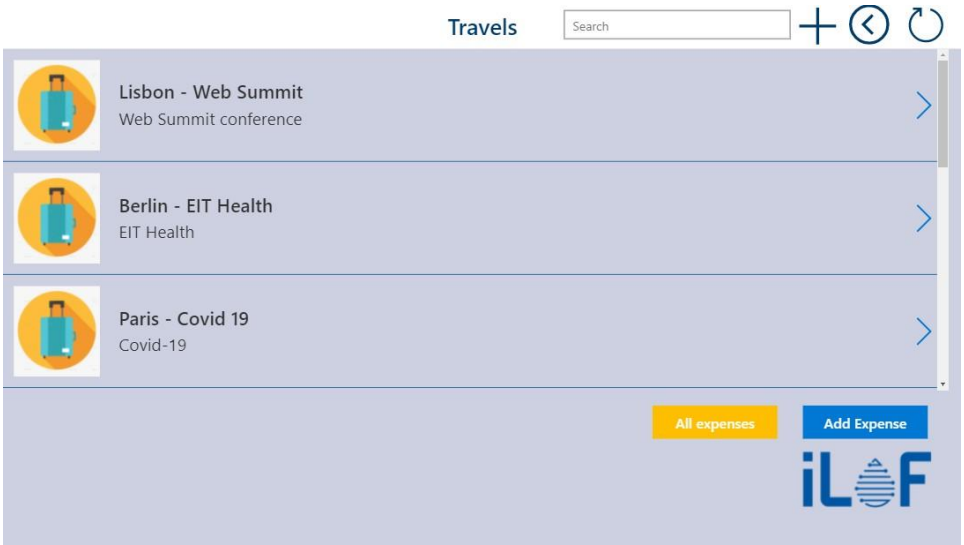


Figure 29 – Travels Screen

The user can search for the wanted travel and, by clicking on it, the respective information will show up (see **Figure 30**). This data can be edited or deleted. This screen also shows the expenses associated with the chosen travel.

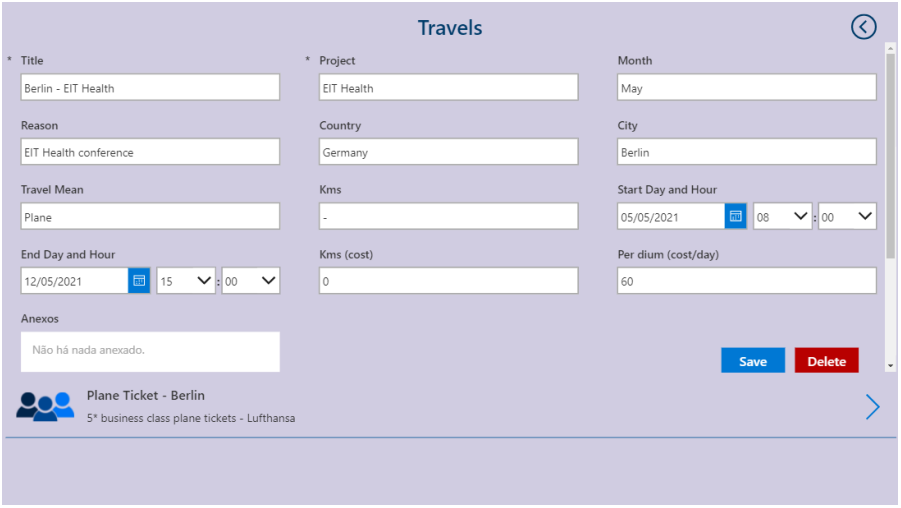


Figure 30 – Travel's Information Screen

To register a new travel, the user must press the button "**+**" (see **Figure 53**) and fill the form that shows up (see **Figure 31**).

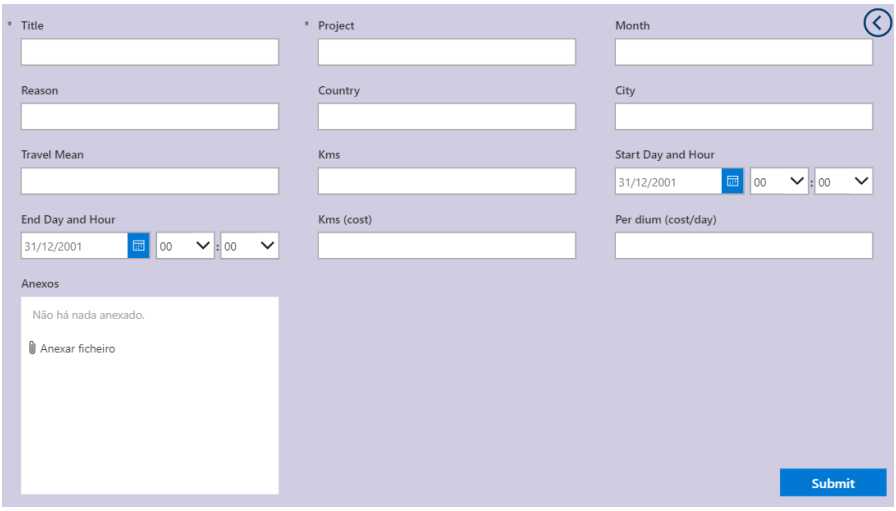


Figure 31 – Travel's Form

On the travels list (see **Figure 29**), by pressing the "**All Expenses**" button, the user will access to the list of all the expenses registered on the system (see **Figure 32**).

By clicking on any of them, the user will access its information, and may edit or delete it (see **Figure 33**). If the user wants to add a new expense, he must press the button ("**+**") and the expense's form will open up (see **Figure 34**).

Figure 32 – Expense's list screen

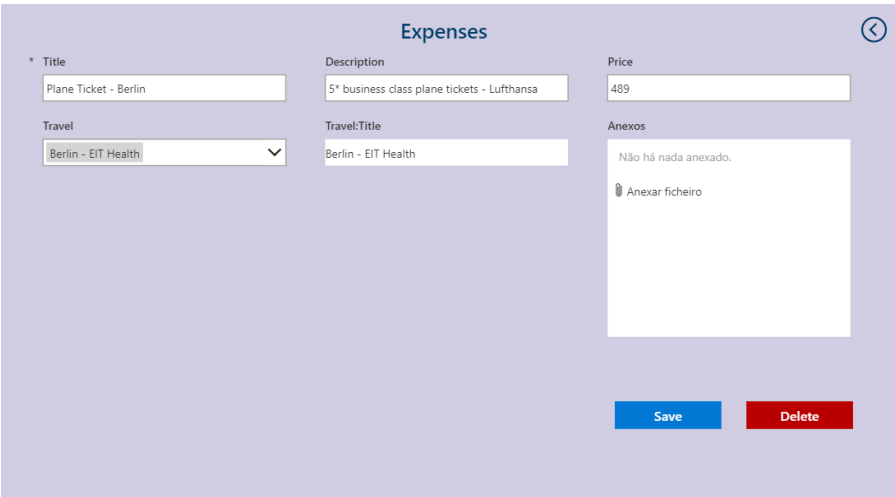


Figure 33 – Expense's information screen

The user must fill the form by choosing a title for the expense ("**Title**"), by writing a description ("**Description**"), stating the price of the expense ("**Price**") and by choosing which travel is the expense associated with ("**Travel**"). The user must also attach the receipt of the expense.

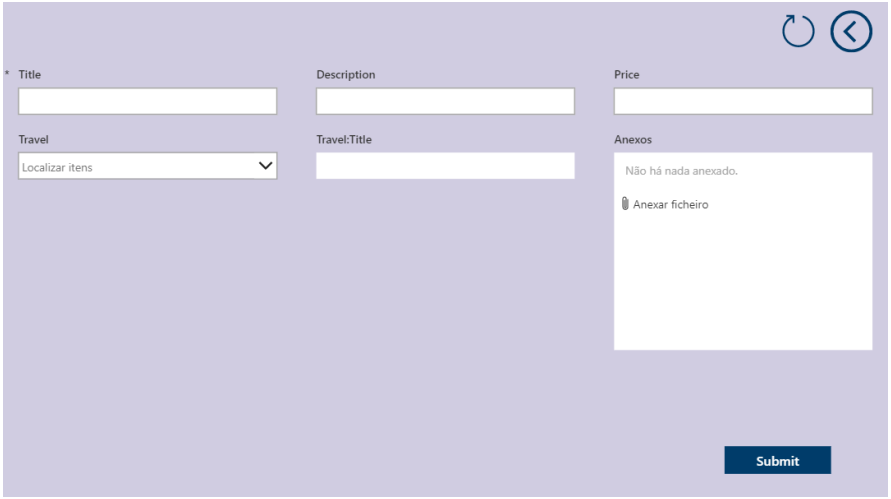


Figure 34 – Expense's form

22. On the main menu (see **Figure 2**), by clicking on "Search by date" button, the user will open up the search by date screen (see **Figure 35**). A set of different options will appear: if the user clicks "**Supplier**", he will be able to search for the suppliers that were registered on a certain period of time; if he clicks "**Quotes**" he will be able to search for the quotes that were registered on a certain period of time; if he clicks "**Items Requests**" he will be able to search for the items requests that were placed in a certain period of time; if he presses "**Purchasing Orders**" (see **Figure 36**) he will be able to search for the purchasing orders that were placed on a certain period of time, also to search for purchasing orders that are due to be delivered on a certain period of time; and lastly, if he clicks "**Invoices**" he will be able to search for the invoices received in a certain period of time.

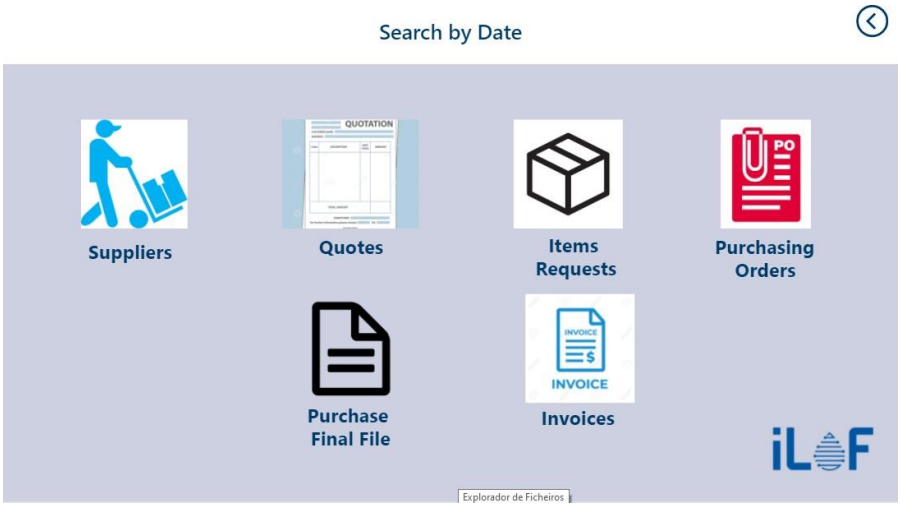


Figure 35 – Search by date screen

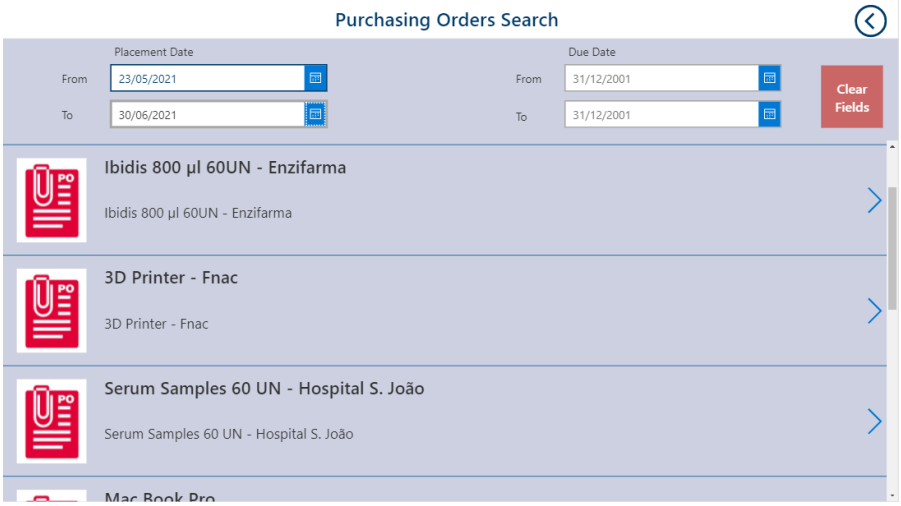


Figure 36 – Purchasing Orders – Search by date screen

23. On the main menu (see **Figure 2**), by pressing the "**TOPSIS**" button, the user will access to the TOPSIS screen (see **Figure 37**). The TOPSIS algorithm was implemented in the app. The user can compare between 2 to 5 different suppliers using the pre-defined criteria and weights. The app will display the **Ca** (closeness coefficient) of each alternative supplier. This number is always between 0 and 1, where 1 is the preferred action. If an action is closer to the ideal than the anti-ideal, then Ca approaches 1. **Therefore, the supplier with the highest Ca is the best alternative.**

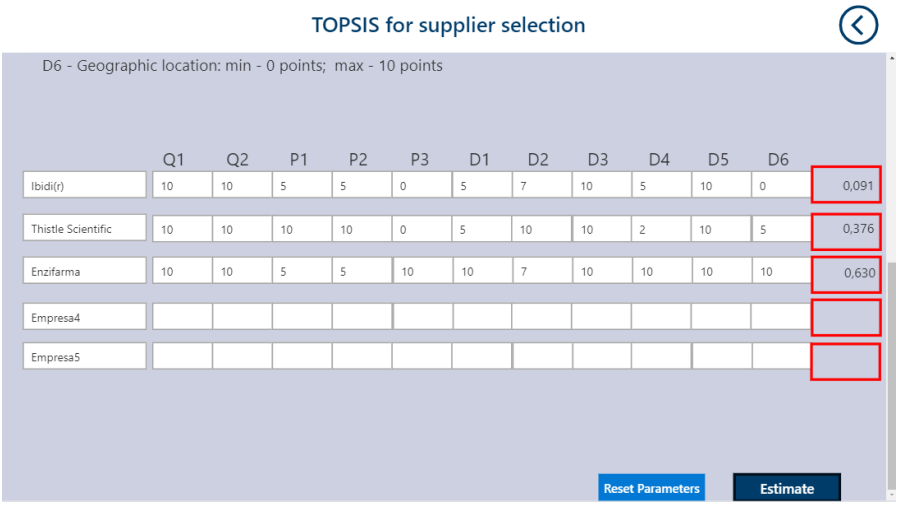


Figure 37 – TOPSIS implementation on Power Apps

24. A **flow of approval** of the requested items was created using Power Automate (see **Figure 39**). Every time an item is sent for approval, the process owners will receive an e-mail with the relevant information about the request, and will either approve or decline the

request, being able to attach a comment that will be sent to the creator of the request (see **Figure 38**). The creator of the request will receive an e-mail with the process owner's decision, and the status of approval of the item will be automatically updated.

The approval can be done on the application too, as mentioned before.

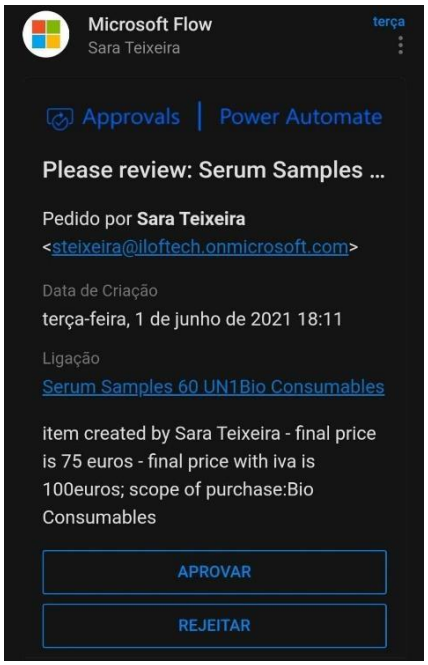


Figure 38 – Approval E-Mail

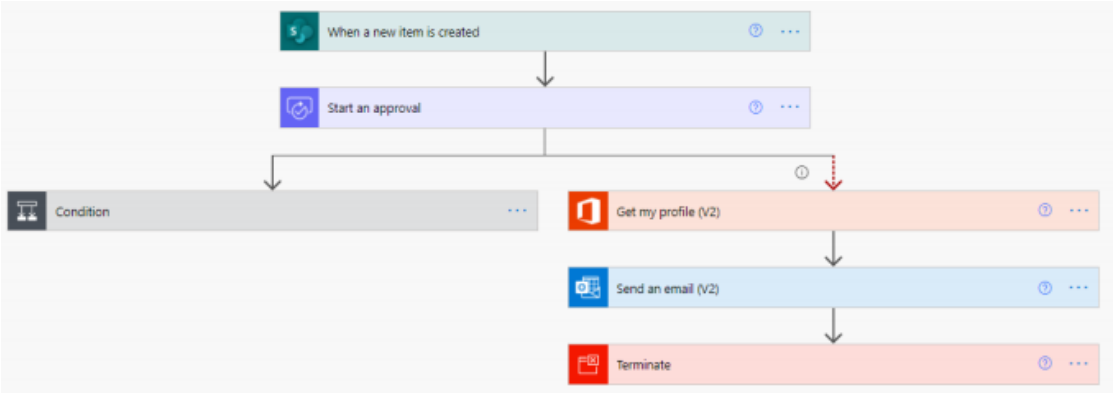


Figure 39 – Flow of approval - Item's Request