Analysis, investment and innovation programme in imaging equipment to improve healthcare diagnosis

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Abstract

The presented project was developed at a company which is one of the top players providing healthcare diagnosis services. This dissertation focuses on the imaging equipment department and its renovation. The leading position was achieved by a series of mergers and acquisitions along the years. Also, companies in this industry are recognizing the importance of the imaging diagnosis as a non-invasive method and are starting to empower their quality of service and market share.

Although this growth strategy allows for a rapid increase in the market share, it can sometimes compromises the organization and operations of some departments. In fact, for the imaging department, it is extremely difficult to have an up-to-date equipment database whilst simultaneously preparing all maintenance and state of the art of the fleet of equipment. Besides, most of the times, when companies know that are going to be acquired, they slow down their investment in imaging equipment and by that, they get outdated equipment. This highlights the importance of having up to date equipment as it not only endangers the quality of the service provided but also rises maintenance costs.

In order to provide a better service level to patients, the present thesis is divided into three stages. The first was aimed at evaluating the current imaging equipment of the company according to specific criteria (AS IS). Then, based on this evaluation, an investment programme to renew equipment was developed in order to improve healthcare diagnosis. This investment was planned together with the financial and imaging departments of the company, started two years ago and, due to its dimension, is expected for the next ten year span. The third stage was launching a tender where suppliers offered their proposals taking into consideration the equipment desired to be replaced.

After the appraisal of suppliers' options, one have been financially assessed and chosen. Until now, although one proposal was accepted there was not enough time to precisely plan the replacement of the first set of equipment.

Resumo

Este projeto foi realizado numa das empresas líder do mercado de diagnóstico clínico, sendo o seu principal enfoque no equipamento de radiologia e a sua renovação. Esta posição foi conseguida através das acentuadas fusões e aquisições com outros players do mercado. Ao longo dos anos, devido à crescente importância deste tipo de diagnóstico, as empresas têm vindo a trabalhar de forma a melhorar a sua qualidade de serviço e, consequentemente, a quota de mercado.

Apesar desta estratégia de crescimento permitir o rápido aumento do número de serviços prestados, por outro lado compromete a organização e as operações de vários departamentos. De facto, torna-se bastante complexo para o departamento de radiologia conseguir, simultaneamente, preparar todas as manutenções de equipamentos enquanto integra todos os sistemas de informação relativamente aos equipamentos adquiridos e o estudo das mais recentes tecnologias. Para além disso, maior parte das empresas, quando preveem que vão ser adquiridas reduzem o investimento em novos equipamentos e, deste modo, estes ficam desatualizados. Este desinvestimento não só coloca em risco a qualidade do serviço prestado, bem como provoca um grande aumento nos custos de manutenção dos equipamentos.

De forma a melhorar a qualidade dos serviços prestados aos utentes, a presente Dissertação divide-se em três fases. Inicialmente, foi realizada uma avaliação do equipamento existente na empresa de acordo com critérios específicos de avaliação de ativos no ramo da radiologia. Seguidamente, tendo em conta a avaliação, foi desenvolvido um projeto de investimento de forma a expectar os principais custos do investimento na renovação dos equipamentos. Este investimento iniciou-se há dois anos, tendo sido planeado com o departamento financeiro e o departamento de imagem. Tendo em conta a sua dimensão, é expectável que o seu plano de renovação perdure ao longo dos próximos dez anos. A terceira parte retrata a avaliação intensiva das propostas de equipamentos feitas pelos fornecedores.

Finalmente, um dos fornecedores foi avaliado financeiramente e escolhido. Apesar da proposta ter sido aceite, não houve tempo suficiente para preparar de forma precisa a renovação do primeiro conjunto de equipamentos a ser renovado.

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Acronyms and Symbols

M&A	Mergers and Acquisitions
MLCT	*Medicina Laboratorial Doutor Carlos Torres*
BU	Business Units
CAPEX	Capital Expenditures
OPEX	Operational Expenditures
SLA	Service Level Agreement
AI	Artificial Intelligence
CT	Computed Tomography
ORTO	Orthopantomography
MR	Magnetic Resonance
US	Ultrasound
CF	Cash Flow
NPV	Net Present Value
IRR	Internal Rate of Return
KPI	Key Performance Indicator
ESR	European Society of Radiology
APA	*Agência Portuguesa do Ambiente*
DGS	*Direção Geral de Saúde*
TAT	Turn around time
AHP	Analytic Hierarchy Process
CAPM	Capital Asset Pricing Model
Rf	Risk free rate
WACC	Weighted Average Cost of Capital

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Chapter 1

Introduction

The project developed in this Dissertation was performed at Unilabs Portugal under the Integrated Master in Industrial Engineering and Management at *Faculdade de Engenharia da Universidade do Porto*.

One of the most important issues in any business sector is providing high quality service to customers. Unilabs is the domestic market leader in Clinical Diagnostics, losing ground to three major private hospital groups operating in the country when it comes to private health-related companies. This was accomplished through an aggressive merger and acquisition (M&A) strategy over the years. Within the healthcare sector, the competition is increasing, and due to that delivering the quickest and highest quality services are the company's priority. To assure and maintain these characteristics, Unilabs requires a powerful structure to invest in high quality equipment in order to deliver rigorous diagnosis and ideal conditions for evaluating reports. Unilabs' operations department is subdivided by diagnostics specialty: clinical analysis, imaging, genetics, pathology, gastroenterology and veterinary. All of these departments are responsible for managing daily operations and performance of equipment. This thesis was performed in the imaging operational department, where all imaging equipment are managed.

As previously mentioned, Unilabs' M&A strategy brings some difficulties regarding asset management. When Unilabs acquires or merges with another company, they inherit all the equipment, databases and prices the company previously practiced in their products. Then, it is extremely important to evaluate accurately everything the other company has and its conditions. By that, and taking into consideration the importance of equipment in helping doctors to provide the best healthcare diagnosis, Unilabs is constantly evaluating the performance of its equipment and seeking new releases in order to invest in new technology.

This chapter provides an overview of the industry as well as the history of the business. With this in mind, it will make the issues and proposed solutions discussed in the following chapters more understandable.

1.1 Company Overview

Unilabs Group was founded in 1987 in Switzerland through the merger of three clinical diagnostic laboratories. The company's business model is based on merger and acquisitions of other diagnostic companies with strong organic growth, allowing it to grow substantially over the years. During the early years, Unilabs acquired laboratories in various countries such as France, Italy and Portugal, whilst developing their own brand image. In 2007, Unilabs expanded its operations to Sweden, Norway, Finland, Denmark and the UK through the merger with another major imaging diagnostics company named Capio. This merger positioned Unilabs as the European market leader in diagnostic, providing different types of services such as laboratory medicine, medical imaging, cellular pathology, genetics, veterinary and gastroenterology. Regarding all services showed in Figure 1, the clinical analysis and medical imaging are the two most meaningful areas for the company.

Figure 1: Unilabs' Business Units (Silva, 2020)

In 2007, Unilabs was acquired by APAX, a venture capital, headquartered in London. The new management entity implemented strict measurement and control of all cost and performance of Unilabs. Later, in 2017, APAX reinvested again in order to help further develop the company and growth culture in the healthcare market.

Nowadays, Unilabs is operating in seventeen countries around three different continents (South America, Europe and Asia) and is composed by more than 250 laboratories and 12 700 employees. This growth represents more than one billion euros in annual sales and 213 million laboratory tests.

The radiology department plays an important role within Unilabs as imaging exams are vital to provide accurate diagnosis for patients. In fact, nearly 2 000 Unilabs colleagues in 180 units across Europe perform and interpret close to four million exams per year to help patients and healthcare professionals reach the right diagnosis and treatment decisions (Unilabs Group, 2021). Unilabs' mission is "To be at the heart and start of all effective treatment decisions", whereas its motto is "We give you answers that help give care".

1.2 Unilabs Portugal

Unilabs Portugal is providing services in Portugal since 2006, being now the market leader in clinical diagnosis (Unilabs Portugal, 2021). Unilabs entered the portuguese market through the acquisition of *Medicina Laboratorial Dr. Carlos Torres* (MLCT) that was one of the biggest market players in medical diagnostic in the North of Portugal. Since then, it continued to merge and acquire other companies enabling an increase in market share of the group and accelerating the organic growth inside the company.

In 2017, Unilabs Portugal acquired *Grupo Base Holding*, the domestic leader performing different healthcare diagnosis in sectors such as cardiology, nuclear medicine and gastroenterology. This acquisition helped Unilabs develop even more market share.

Nowadays, Unilabs' Portugal structure is comprised of more than 3500 workers distributed along almost entirely all the country's districts, more than 1000 care units and 11 laboratories where all clinical diagnoses are carried out for the different Business Units (BU). These numbers reflect on the revenue of the company, and renders Unilabs as the fourth largest group in the private health sector, just after three Private Hospital groups: *Luz Saúde*, *Lusíadas* and *José de Mello Saúde* (CUF) (Silva, 2020).

In the Clinical Diagnostic market, Unilabs Portugal takes the first place in revenue, followed by *Germano de Sousa* and then Synlab (Silva, 2020).

However, even though Unilabs is the market leader in clinical diagnostic, the competition with other players within the different Business Units is very strong and medical imaging is no exception. In fact, this Business Unit, together with clinical analysis, are the two most significant areas of the company and require constant adaptation according to the evolution of current technology.

1.3 Project Context

This project will focus in the medical imaging department (also known as radiology department) with a targeted approach in the equipment used for that purpose. Within the radiology department, Unilabs Portugal counts with 58 centers of human medical imaging across Portugal. It is important to emphasize that these centers are concentrated in the north of the country.

Although Unilabs' core business is to grow through M&A, there has been a recent approach to invest in their own imaging equipment aiming to provide the best quality of services for customers. This project started to drive internal growth two years ago, and due to its dimension it is expected to have a ten year span. Actually, this renovation needs a particularly attention, as it involves a huge transformation plan. It also requires a massive Capital Expenditures (CAPEX) investment, as these equipment are very expensive, and finally it will lead to a decrease in revenue, as during this transformation the services the equipment provides will not be operating. Based on this, the main objectives of this project are:

- Evaluation of the actual equipment at Unilabs and costs associated in various aspects such as Operational Expenditures (OPEX) and CAPEX;
- Definition of the investment in terms of quantity and characteristics of equipment to be chosen for the radiology department;
- Increase the service level agreement (SLA) with better quality equipment;

- Improve user experience while using new equipment with a faster and more accurate diagnostic;
- Financial evaluation of the proposal.

Even though the project is based onthe imaging department's ownership, the investment business plan will be developed in collaboration with the financial and infrastructure departments.

1.4 Methodology

The presented project was planed in five principal stages as described in the Gantt chart in Figure 2.

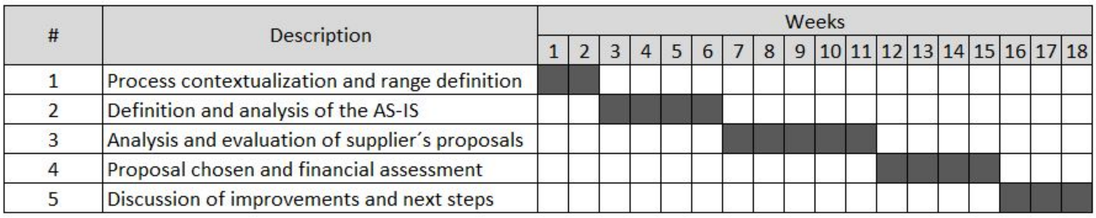

Figure 2: Project's Plan

The first step was analysing the way how the imaging department fitted in the overall Unilabs operations. Then, the evolution and technologies associated with the radiology market were explored, not only in Portugal, but also across similar European Markets. The comprehension of the equipment's technical characteristics allowed for a more effective assessment of the existent equipment at Unilabs Portugal. Subsequently, an investment business plan was developed, and different options of equipment renewal were evaluated, taking into account different criteria such as the quantity of radiation emitted, the price and quality of the image. The investment plan was then analysed and approved by the executive officers. Finally, the accepted proposal was further evaluated and the next steps were discussed.

1.5 Dissertation Structure

This project is divided into six chapters with the following structure:

Chapter 1: Introduction(actual)- project presentation;

Chapter 2: Literature Review of the most relevant topics to be in-depth analysed in the thesis;

Chapter 3: Description of the AS IS state of the imaging market and the actual situation of Unilabs' equipment;

Chapter 4: Analysis and evaluation of different plans for renewing equipment based on the budget allowed by the company;

Chapter 5: A financial analysis was made to evaluate the investment project. The proposal chosen was further evaluated.

In the last chapter, are drawn some conclusions about the project, the methodology applied and future improvements to the work developed.

Chapter 2

Literature review

This chapter addresses the theoretical background of the project, including crucial topics related to investment projects and themes essential for the AS IS analysis in Chapter 3, decision-making in Chapter 4 and a deeper analysis of results in Chapter 5. The chapter is organized in a top-down structure, beginning with an overview of the importance of imaging diagnosis, followed by the evolution of this type of equipment. Then, also other topics like SWOT analysis, methodologies for evaluating investment projects and asset management were studied, as they are of special relevance for this project.

2.1 Importance of Imagiology

During the last years, imaging healthcare diagnostics has been one of the most important ways to help doctors finding and evaluating patients' health. This type of services can be vital when providing an accurate and precise diagnosis (Unilabs Group, 2021). In fact, this medical specialty has numerous advantages:

- An early and precise diagnostic can be crucial when treating a patient;
- The exam is not highly expensive neither intrusive;
- Most of the exams performed do not require special preparation;
- The doctor is allowed to see the internal parts of the body, improve diagnostics and treatment specificity.

As showed in Figure 3 that refers to the USA diagnostic imaging market, it is expected to grow in the next years. According to Levin and Janiga (2020), this industry is getting much larger in terms of revenue and number of diagnostics performed. In fact, the imaging market in the United States is estimated to generate more than $100 billion annually with radiology practices and imaging centers accounting for approximately $19 billion.

Over the last years, huge investments are being made as this sector is getting remarkable and by that, new equipment has been developed to help doctors getting the best quality images in order to take the right decisions for human health.

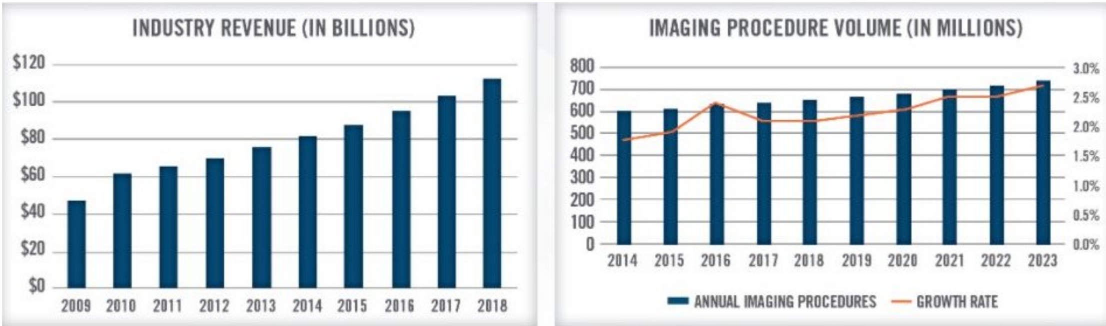

Figure 3: USA diagnostic imaging market size and growth (Levin and Janiga, 2020)

2.1.1 The image in radiology

In radiology, the type of radiation emitted by the equipment differs according to the equipment we are analysing. Actually, in radiology there are two main groups of radiation:

- ionizing: according with Olivier (2017) is any type of radiation with enough energy to eject one or more electrons from the furthest orbital of an atom or molecule; In radiology, modalities that use ionizing radiation are: X-ray, Computed Tomography (CT) scan, Bone Densitometry, Orthopantomography (ORTO) and Mammography;

- non-ionizing: refers to the radiations that are not strong enough to eject one or more electrons from the furthest orbital of an atom or molecule; In imaging healthcare sector, just the Magnetic Resonance (MR) and the Ultrasound (US) emit non-ionizing radiation.

Figure 4 shows different types of radiations according to its frequency and level of energy. The ionizing radiation is harmful for humans as it breaks the connection between molecules or cells and eliminates their core function. Contrarily, the non-ionizing radiation is not dangerous, since it does not have enough energy to remove electrons.

According to Lança et al. (2008), the amount of radiation the equipment emits to the patient depends on different factors. In fact, the technology of the equipment has a huge influence in the quantity of radiation received by the patient. This is related to the fact that state of art equipment has methods to auto adjust parameters in order to reduce the total of ionizing radiation obtained. Manually, the set of parameters can be changed, however it is very difficult to mix them and find the best set to capture the best image with the less quantity of radiation admitted. These parameters are:

- tube potential (kV);

- tube intensity (mA);

- exposure time (s) which represents the total time the patient is receiving radiation;
- focus to detector distance (cm) which refers to the distance from the tube to the patient.

Sometimes the exposure time and the tube intensity are treated has one unique variable and its unit is mAs.

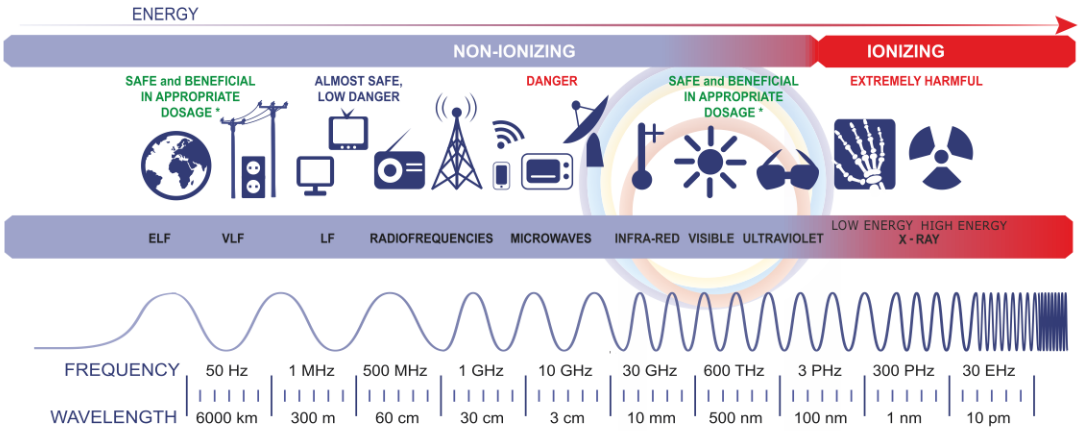

Figure 4: Types of radiation (Polimaster, 2018)

Regarding the ionizing radiation, the way the image is formed is basically the same and independent of the equipment that is performing the diagnostic. In fact, following Allisy-Roberts and Williams (2008), in the X-ray, CT scan, Mammography, Bone Densitometry and Orthopantomogram the image is formed by the relation between the quantity and distribution of radiation that a light bulb emits and the quantity of radiation received by the detector. This happens because the radiation transferred to the detector depends on the density of the material and by that, the behavior of the radiation is completely different while going through a bone or a muscle. According to the spacial distribution of the radiation received by the detector, the image is created.

In the Magnetic Resonance, the equipment creates a magnetic field that reacts with the hydrogen atoms. The atoms absorb and emit the radio frequency energy. Afterwards, the MR creates different shades of grey in each corresponding image pixel, taking into consideration the way the hydrogen reacts with the magnetic field. Finally, the Ultrasound equipment works through waves, which are created by converting an electrical signal to an Ultrasound beam. This conversion is made by a transducer and the image is created due to different reflections and echoes resultant from various tissues.

2.1.2 Evolution of equipment

Based on Lança et al. (2008), for diagnostic purposes, there are three critical aspects for the diagnostic quality of the radiographic image. These aspects are:

- type of technique used;
- radiation dose to the patient;

- type of protocol chosen.

The choice of the most adequate radiographic technique to each clinical situation involves the selection of the correct exposure parameters. All these parameters are related to the equipment installed. According to Pavlek et al. (2016) it is recommended that at least 60% of the installed equipment in radiology departments be up to five years old. Up to 30% should be 6–10 years old, whereas no more than 10% of the equipment should be older than ten years. In fact, as the equipment develops, the amount of ionizing radiation administered to patients reduces, and image quality improves, resulting in better diagnosis and treatments. Also, maintenance costs increase along the years. These considerations are confirmed by the European Society of Radiology (2014) that explain different issues and recommendations related to old equipment such as:

- Radiological equipment has a short life cycle span, resulting in unavoidable breakdown and decrease or loss of image quality, which renders equipment useless after a certain time period;

- Equipment older than ten years are no longer state-of-the art equipment and replacement is essential. Operating costs of older equipment will be high when compared with new equipment, and sometimes maintenance will be impossible if no spare parts are available;

- Older equipment has a high risk of failure and breakdown, causing delays in diagnosis and treatment of the patient and safety problems both for the patient and the medical staff;

- Every healthcare institution or authority should have a plan for medical imaging equipment upgrade or replacement. This plan should look forward a minimum of five years, with annual updating.

Due to improvements in technology, equipment are getting better throughout the years. In fact, according to the European Society of Radiology (2014), recent equipment offers considerable improvements in terms of quality and security, both for diagnostic and therapeutic imaging. Also, an increase in spatial and temporal resolution, combined with a better lesion characterisation, leads to identification and diagnosis of smaller lesions, with considerable impact on patient care, e.g. in cancer diagnosis. The new technology offers 10-30 % of the radiation exposure levels from five years ago. This reduction of ionising radiation dose delivered to patients provides better image quality, thus improving diagnoses and treatments (Pavlek et al., 2016). Figure 5 summarizes the life expectancy of different equipment from different modalities according to the number of exams performed by year.

Finally, the design of the equipment have been changing during years with more pleasant characteristics for patients. Actually, nowadays there is an open MR scanner and it was developed partly because, according to Björkman-burtscher (2021), between 3% and 5% of people suffer from claustrophobia which is a strong contraindication for MR. In some cases, those patients need anaesthesia and result in a significantly increase in the risk of the exam.

Device type (analogue or digital)	Device life expectancy based on utilisation: HIGH-MID-LOW	Utilisation based on exams/year		
		HIGH	MID	LOW
Radiography, general	10-12-14	>20,000	10,000-20,000	<10,000
Radiography, mobile	10-12-14	>6,000	3,000-6,000	<3,000
R/F fluoroscopy (conventional/remote)	8-10-12	>4,000	2,000-4,000	<2,000
R/F interventional integrated c-arm	8-10-12	>4,000	2,000-4,000	<2,000
R/F urology	8-10-12	>1,500	750-1,500	<750
Mobile C-arm (all types including O-Arms)	8-10-12	>2,000	1,000-2,000	<1,000
Angiography (1/2 plane)/interventional	8-10-12	>4,000	2,000-4,000	<2,000
Cardiac suite (single/biplane)	8-10-12	>3,000	1,500-3,000	<1,500
CT scanner	8-10-12	>15,000	7,500-15,000	<7,500
MRI scanner	8-10-12	>8,000	4,000-8,000	<4,000
Ultrasound	7-8-9	>4,000	2,000-4,000	<2,000
SPECT/gamma	8-10-12	>6,000	3,000-6,000	<3,000
SPECT/CT	8-10-12	>4,000	2,000-4,000	<2,000
PET (likely replace with a different technology such as PET/CT)	8-10-12	>6,000	3,000-6,000	<3,000
PET/CT	8-10-12	>4,000	2,000-4,000	<2,000
Bone densitometry	8-10-12	>10,000	5,000-10,000	<5,000
Mammography	8-9-10	>7,000	3,500-7,000	<3,500
Lithotripter	8-10-12	>3,000	2,000-3,000	<2,000

Figure 5: Equipment's lifetime (European Society of Radiology, 2014)

2.1.3 Artificial intelligence in radiology

The evolution of artificial intelligence (AI) systems in other sectors also encouraged the development of these systems also in the imaging healthcare market. In other sectors, artificial intelligence systems are already used as part of daily routine, helping data analysis and taking decisions. However, according to van Leeuwen et al. (2021), engineers that are implementing the concept of artificial intelligence in imaging healthcare equipment, are still at an early stage. In fact, over the years, companies have invested a lot in AI. Since 2018 investments have more than doubled to $ 1,17 billion (Alexander et al., 2020). Actually, based on the Radiological Society of North America, the number of AI Exhibitors almost tripled from 2017 to 2019. However, Park (2019) showed that only 6% of the conclusions made by deep learning algorithms were valid on independent external data.

It is also crucial to emphasize that imaging diagnosis also generates ethical issues. Actually, taking into consideration Cuocolo and Imbriaco (2021), in some countries there are ethical and regulatory rules that do not accept the clinical use of any machine learning package. The European

Union regulation is very strict in terms of people's privacy which creates some difficulty to identify patients willing to try this new method of performing the imaging healthcare diagnosis.

This new technology allows for several benefits for both the service level and the quality of the diagnosis. According to Loria (2021), the number of doctors to draw conclusions from images would reduce, the quality of reports and the efficiency would increase and finally, additional information can be perceived, that humans would not normally detect.

However, there are also disadvantages to this innovation. The equipment and the development of intelligence platforms are extremely expensive. It is expected that prices in these equipment would be very high since they are related with state of art technology and high developed information systems that are capable of working with AI technology. Also, as AI technology in radiology is not so common, only financially healthy companies could invest in this new equipment. In accordance with Rouger (2019), the development of a new platform made by a group of dutch radiologists that enabled an easier deployment of AI tools, and helped improving the clinical workflow at the hospital, needed an investment of almost one million euros and it was not yet finished. Also, applying the AI equipment in the workflow would be a big challenge and it will take time until this new technology is effective because developers of AI do not have a strong background of this sector.

To sum up, it is very important to note that even though this new technology still has many factors to improve, this is the future in the imaging healthcare sector. In fact, as Coiera (2019) states, if used carefully, AI is already capable of transforming much of what we do. It would help giving faster and more accurate diagnosis for patients. The business model would also change, turning radiologists into people that earn their salary according to the value they create and not related to the volume of exams they analyse. This means they can be more focused on what they do and not in the quantity they assess. Moreover, over the years, the increasing in the number of equipment getting advantage of AI would turn this new technology cheaper and more accessible for companies in this sector.

2.1.4 Criteria for replacement of equipment

According to the World Health Organization (2014) and Medicines and Healthcare Products Regulatory Agency (2006), local decisions related to equipment rely on combination of multiple criteria:

- Age;
- Breakdowns: along years the available rate of the equipment gets lower as the number of breakdowns increase;
- Operational costs;
- Repair possibilities: throughout the years, some parts of the equipment become unavailable and due to that, repairing costs get much higher;

- Image quality: with the development of technology, equipment's characteristics get better and consequently, provide better quality image;
- Safety: new equipment is designed with technology to reduce radiation dose exposure to the patient. By that, older equipment emit higher level of radiation than state of art one;
- Regulatory obligations: in some countries governments have very strict policies in terms of radiation exposure and over the years equipment transcendent the maximum radiation doses imposed by the government;
- Equipment efficiency: state of art equipment is much more ergonomic and has a greater throughput rate which is reflected in a possible increase of revenue.

As reported by the Australian Government Department of Health (2013) , in order to have a better control of the criteria mentioned above, some countries developed measures such as:

- Regulatory obligation to report the type and age of the equipment used;
- Regulatory obligations to measure and optimise the radiation dose;
- Quality control of the equipment (security, image, radiation);
- Reimbursement models on fees for exams, taking into account the level of performance of the equipment, its age and possible upgrade.

All of these criteria combined results in an investment by imaging healthcare companies. On one hand, to answer all these obligations and reduce costs in terms of repairs and loss of revenue. On the other hand, to provide the best quality of service to the patient and get differentiated from other competitors. However, investments should not be done without preparing the strategical role of the company within its sector. By that, in order to provide a deeper evaluation, some strategical and investment concepts were further analysed.

2.2 SWOT Analysis

Nowadays, with the development of the healthcare sector and the increasing number of companies operating, the importance of a well strategical positioning can be crucial for company's sustainability. In fact, all companies have a close relation to the supplier which allows having a deep knowledge about state of art equipment and their features. However, markets do not rely only on the operational part of the business, but also the strategical positioning of the company is equally important. Taking into consideration Sarbah and Otu-Nyarko (2014), having a well established strategy allows the company to have a more proactive behavior instead of a reactive one. However, choosing the positioning of a company within its market is very difficult. By that, in order to increase the probability of choosing the most accurate strategy, it is necessary to perform a series of studies and decisions. According to Oliveira (2017), the strategical position of a company should take into account its vision and mission. Whereas the vision emphasises the way the company wants to be positioned in the future, the mission not only focus on the future "picture" of the company, but also concentrates in the things that should be avoidable in the current moment. The final step of a strategy is to achieve an objective: the company wants to reach a goal to create competitive advantage.

The SWOT analysis is an elementary but effective tool which helps in the assessment of the company and finding out possible positioning for the future. In fact, it is a strategical technique to evaluate the Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T) of the company in comparison to the sector that it is inserted into. Normally, all these four parameters are presented as a 2X2 matrix where in the top are the internal factors and in the bottom there are the external ones. The S and W refer to the internal factors of the company and how they have advantage and in what they should make more effort in order to be more valued than the other competitors. The O and T are external factors regarding chances and risks the sector has. The company should try to focus their attention on the O's and measure the risk of the T's. In Sammut-Bonnici and Galea (2017), as external factors, the author makes reference to competitors' activity, suppliers, government laws, economical changes, societal and technological development. Strengths and opportunities help companies to achieve their goals, whereas weaknesses and threats need more awareness because they can be worrying while trying to reach objectives.

This tool helps companies to get an overview of themselves within the sector and in what they should invest their time and assets in order to get a better positioning in the market and increase the service level of satisfaction. Basically, it is a planning tool to help companies taking better decisions and preparing their future actions within the sector they are inserted into.

2.3 Investment Project

The recognition of a good investment project has an important role in developing a sustainable organization as it could involve a large amount of capital. An investment in financial assets or real assets consists in investing funds with the objective of fully recovering them and obtaining a financial surplus. Thus, an investment project refers to an investment in real assets (or fixed capital), tangible or intangible (Silva, 2015).

The economic viability of a project is determined by the application of different methodologies. Most of these assessments are based on all financial flows related to the project.

As Silva (2015) explained, the evaluation of a project has to be analyzed from a double point of view: cash flow (CF) management and incremental cash flow. In the perspective of cash flow management, only cash inflows and outflows are assessed. In the incremental perspective, only cash flows that result from the project's implementation are evaluated.

There are two types of projects: the ones that start from scratch (creation of a new company or business) and others that begin in a company already operating. The latter, as it is the case of the present project, according to Silva (2015) can be classified according to the following objectives:

- Expansion, which is related to an increase in productive capacity;

- Replacement or maintenance that supposes changes in the productive capacity;
- Innovation that involves the creation of new business areas.

Regarding the investment project, it is necessary to distinguish three phases.

1. The pre-investment, is about searching for ideas and information about different markets. In this section of the project, opportunity and feasibility studies should be taken in order to make the decision of going a step further or not;
2. The investment part which corresponds to the acquisition or development of assets;
3. Finally, the exploration part which can eventually be divided into sub-phases according to the strategy of the company (Silva, 2015).

Within the scope of the investment project concept, it is relevant to mention the importance of the identification and evaluation of cash flows. In fact, it results from the comparison between the inflows (cash inflow) and the outflows (cash outflow). This concept comprises several components: investment in fixed capital (CAPEX), operating cash flow, working capital and residual value. In order to take the decision of investing or not in a project, it is mandatory evaluating the project.

2.4 Methods for evaluating Projects

A business is considered viable when it is profitable, meaning that it has more revenue than expenditure. However, the approval of a project is not only dependable on the economic viability, but also on the profitability alternatives of the investment itself. This means that there are profitable projects that are not approved due to the fact that there is a better way for investing the money. In order to get the best evaluation of a project, there are several criteria for measuring the sustainability of it, each one depends on the evaluation of different financial indicators (Lopes, 2018).

2.4.1 Net present value

The net present value (NPV) is one of the most common criteria for evaluating a project. In fact, the net present value corresponds to the value of the surplus generated by an investment, expressed in the current currency, in relation to the value of the initial expenditure and the minimum remuneration claimed by the investor. In other words, it compares the current value of the cash flows generated by the project with the investment made. Equation 2.1 refers to the NPV calculation, which is the sum of the CF from year zero until the last year of the project. From year one until the last year of the project, all cash flows take into consideration the discounted rate (r_c), that is, the return that could be earned in alternative investments. The "t" refers to the number of time periods (years).

$$NPV = CF_0 + \sum_{t=1}^{n} \frac{CF_t}{(1+r_c)^t} \tag{2.1}$$

Related with this evaluation, its weaknesses are when evaluating projects with different lifetime and projects in situation of capital rationing, that is, projects with a limit that a company decides to undertake.

2.4.2 Internal Rate of Return

The internal rate of return (IRR) indicates the intrinsic return on invested capital. In terms of calculation, its objective is to find the discounted rate which equals the current value of project's net operating flows to the current value of investment costs, that is, the discounted rate that forces the NPV to zero. IRR is thus a special case of the NPV. The equation of the IRR is as follows:

$$\sum_{t=1}^{n} \frac{CF_t}{(1+IRR)^t} - CF_0 = 0 \tag{2.2}$$

To calculate the IRR it is not necessary to determine the cost of capital of the project to identify its profitability, which becomes an advantage of this method. Also, in order to be used as a decision criteria, it is necessary to compare the IRR value obtained, the internal profitability of the project, with its financing cost (or the required return rate for investments of equal risk). If the project has an IRR higher than the cost of capital, it creates value and will be accepted, otherwise the project should not be implemented. The IRR can also be analyzed as the maximum rate at which the investor could finance the project without losing money, that is, if the project had to be entirely financed by a loan that had to be paid with the project's flows (Mota, 2015).

2.4.3 Payback Analysis

The payback corresponds to the number of periods required to recover the initial investment, in other words, the number of periods required for the NPV to equal zero. According to this criteria, an investment is accepted when the recovery period is less than the number of periods foreseen for its lifetime span. Also, the payback time is closely related to the NPV, when the NPV is positive, the payback time is less than the expected lifetime of the project. Equation 2.3 is considered when calculating the payback time for a investment project.

$$PaybackTime(years) = \frac{Initialinvestment}{Cashflowperyear} \tag{2.3}$$

The difference between NPV and payback time rely on the fact that the net present value estimates the financial return of the project over a specified time period, whereas the payback period focuses on calculating the amount of time until the investment is totally paid. Hence, this last analysis, does not take into account the time value of the money and does not consider cash flows after the break even.

In addition to the investment evaluation, another very important issue that companies need to face is the analysis and management of their assets.

2.5 Asset Management

Asset management refers to the way an entity or an individual administrate the assets they are in charge of over the course of their entire life cycles. This management has a long term span rather than a short, or day to day, analysis. During the assets' lifetime, it is necessary to take some decisions. In fact, according with the United States Environmental Protection Agency (2005) and Spüntrup and Imsland (2018), this type of management is initiated through the acquisition of the asset. During its lifetime, there are maintenance operations and associated costs that require monitoring and analysis. Finally, when the asset becomes obsolete, the asset manager has to decide whether to renew the equipment/object or to discard it. This decision should be supported by the analysis of a possible acquisition of a new equipment.

This management is aimed at reducing the costs, while continue to provide a good quality of service for customers. In other words, the objective is to find a balance between all costs and the quality of service customers are expecting from the company (Institute of Public Works Engineering Australasia, 2017).

Asset management is closely related to the term risk. This word refers to situations where people or organisations are exposed to danger. There are different types of risk, in this case, the vulnerability is related with the asset risk. In fact, while taking decisions, measuring risk is one of the most important things. This analysis should be taken evaluating the probability and the consequences of an event. Equation 2.4 refers to the risk measurement. This means, it is totally different if a decision has a very high probability of happening and disastrous consequences or not. Due to that, and more related to equipment, there are some actions that can be done in order to minimise risk. The choice between a preventive or corrective maintenance are examples of behaviors that asset managers need to take.

$$Risk = Probability \times Consequence \tag{2.4}$$

Following Adams et al. (2016), a proper evaluation of the optimum maintenance plan can result in a huge reduction of costs for the company/user. Due to the impact of these costs in companies' financial health, nowadays people are more conscious about that and trying to find methods to reduce them. Particularly in the healthcare sector, as equipment and maintenance are very expensive, managers have to be careful while taking decisions regarding those assets. Also, radiologists' salaries are high as they have a crucial role while performing the diagnosis. In fact, according to Camponovo (2004), in the imaging healthcare sector, companies need to reassign their assets frequently and one of the biggest issues is allocating those assets in places where they could reach the maximum revenue.

Another significant factor while evaluating and distributing assets to their local of work, is their life span. In fact, reallocating an asset in their last moments of life could be just a waste of resources. In order to perform an accurate appraisal of the asset is necessary to distinguish the different phases of its life cycle. Based on Davis (2013), there are four consecutive steps:

1. Acquire- This stage starts with the planning, designing and obtaining the desired asset. There are other authors that consider the "planning" as another stage;

2. Commission- Refers to the installation or production of the asset as well as the verification of its functionality;

3. Operate- The part of assets' life cycle while it is performing the purpose for which was developed. The duration of this interval depends on the type of asset. During this time, the asset should be monitored, maintained, refurbished, and upgraded as needed to meet any changes in condition or operational requirements;

4. Dispose- This is the phase that is usually forgotten. However, assets life cycle can go through million of years and the consequences of devaluing this stage can be catastrophic. For example in the nuclear industry this is a critical period due to material's radioactivity. During this time, the asset should be effectively removed from service. Also, its components should be disposed of or recycled. The operational requirements should be added to the planning for the replacement asset to determine the working requirements based on the effectiveness of the action and the failure modes encountered.

According with Marquez et al. (2020), companies are developing asset management platforms that take advantage of solutions based on artificial intelligence algorithms to take decisions. All of this because asset managers, from different hierarchical positions, know that a rigorous and continuous analysis of assets can have a huge impact in the performance of the company while delivering the best quality of service level to customers. Even though not all companies have financial resources to acquire AI solutions, there are many other options and innovation systems that help managers taking better decisions while choosing the assets and their maintenance plan.

Chapter 3

Problem Context

As modern healthcare market is turning very competitive, patients and healthcare authorities are getting increasingly strict in terms of requesting the best quality services for patients. This can be achieved through the use of state of the art imaging technologies (The Royal College of Radiologists, 2012). Besides, technicians and all people engaged since the moment the patient is scheduling the type of diagnosis, until the moment the patient receives the exam report, everyone involved should be totally focused in providing the best quality of service. Also, it is very relevant having ergonomic facilities in order to increase the productivity while reducing the fatigue of employees. Following Raziq and Maulabakhsh (2015), employees motivated are crucial for businesses' success as their performance gets much better. Due to that, providing a pleasant working environment is essential. According to Silva and Rodrigues (2011), private and public healthcare imaging healthcare centers that do not focus their business model in quality would not survive since patients would look for other better alternatives.

Regarding technological development, the medical imaging is always innovating and continuously improving. This sector depends completely on the use of special equipment, according to the type of exam the doctor asks the patient to do.

The main objective of these equipment is to offer best quality images whilst emitting limited amounts of radiation. This allows for a very accurate evaluation of the patient's health. Also, the evolution of radiology equipment follows the technological development of day to day equipment and improvements in information systems. This means the development of the imaging healthcare sector follows the progress of other markets. In fact, during past years, the development of image quality and the digitization of all imaging processes made a huge impact on medical imaging diagnostics and costs. Digital imaging provides rapid and improved flow of diagnostic information. Besides, these images can potentially be viewed immediately after acquisition on a screen, rather than waiting for a film to be processed. This benefits the technician's evaluation of the image quality and the doctor's diagnosis response (as the work-flow is much faster). Moreover, nowadays the increasing demand and requirement of effective healthcare services have compelled hospitals and other imaging diagnosis healthcare centers to integrate advanced technologies (Blazona and Koncar, 2007). These integrated systems allow for a better management of workforce and increase in patient's service level. These changes that happen all over the world also happen in Portugal as nowadays, due to globalization, suppliers remain the same even though the country changes. However, companies find difficult to follow this extremely fast development in technologies that we are currently going through. One of the reasons for that is the fact that these developments are related with high investments. These investments rely not only on the equipment itself, but also in the maintenance contracts and infrastructures required.

3.1 Imaging diagnosis in Portugal

In Portugal, the evolution in radiology equipment is notorious and with the increased number of exams performed, the competition within the imaging healthcare sector enhanced and companies are starting to invest in this area of diagnosis. In fact, to react to the fact that this market is increasing, players tend to invest in state of art equipment in order to get differentiated from the others. However, the quality of image does not depend only in the quality of the equipment. Technicians need knowledge to choose the best parameters to then capture a very good quality image taking into consideration the amount of radiation emitted. For this part, it is company's responsibility explaining technicians how to work with the existent equipment in the imaging units. Also, when equipment are renovated, software can suffer changes and technicians need to update the way of managing them. As explained before, according to Lança et al. (2008), the radiation emitted depends on three main factors: the type of radiology technique used, the quality of the diagnostic equipment and selection of the protocol. This means, for example, in the case of the CT scan, it is different to perform a perfusion scan or a sequential one in terms of radiation dose. Also, if the equipment is more recent, due to technological development would emit less amount of radiation than an older one. Finally, even though the choice of radiation is normally adjusted by the protocol chosen, technicians can do small adjusts if they think it would help extracting better conclusions in the image quality and reduce the dose of radiation emitted to the patient.

In the imaging healthcare sector, having state of the art equipment is very important to help providing a complete diagnosis. However, companies should not concentrate all their effort only in acquiring state of art equipment. Actually, a well developed strategy with state of art equipment could be the perfect combo for company's success. A SWOT analysis was developed in order to further analyse the Portuguese imaging diagnosis sector.

As it is possible to see in Figure 6, this market is suffering from a technological revolution and since Unilabs is one of the biggest players in this sector, should develop their service level agreement to get differentiated from the other competitors. Also, it is a business that is expected to grow along years and as Unilabs is already in this market should take advantage of its specialized and high-skilled technicians. Actually, imaging diagnosis is getting more common in evaluating human diseases as it is a non-invasive way of analysis and allows doctors to see internal parts of the body. Moreover, Unilabs should also invest in improving facilities and infrastructures to provide better working conditions as the imaging sector has developed different technologies to increase patient's comfort. Giving better conditions for doctors and technicians would motivate them to continue working in Unilabs and if clients have a better experience, for sure they would repeat. However, should be conscious of to the resistance to change within this sector, the dependence to Portuguese laws and the moves of other players in the market. In fact, specifically in this sector, according to Mareš (2018), there are many resistances to change. This concept is related to the opposition in changing the status quo and, in this sector, specially in companies that work for a long time, turns even more difficult to cope with this challenge. Actually, it is very difficult to ask technicians and doctors to change, for example, their local of work as their routine is already embedded. Also, they feel their job as a vocation and it is difficult to make them trust in a more strategic administrative business point of view.

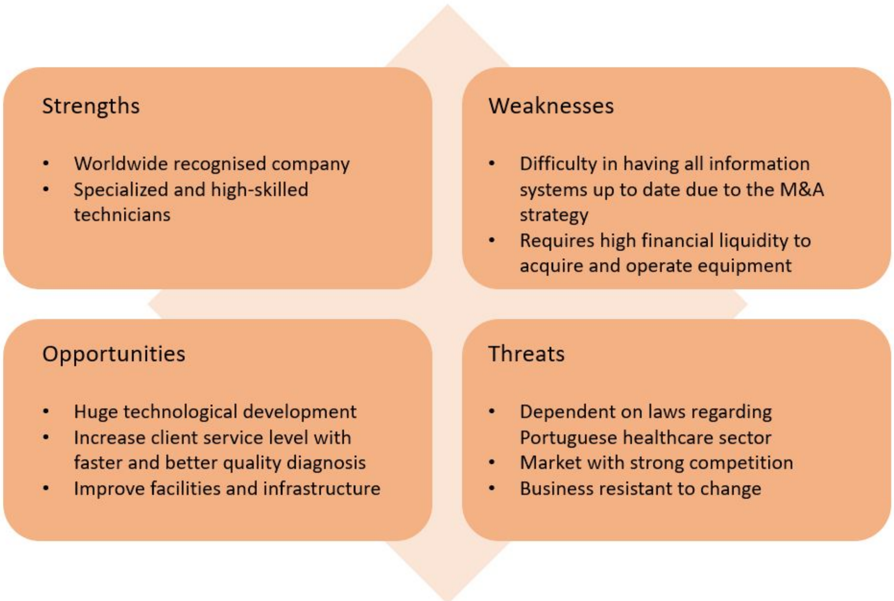

Figure 6: SWOT analysis of the imaging healthcare sector

Even though this sector is in rapid growth, it has very strong barriers to entry such as the number of players and the high financial liquidity of the company required to acquire imaging equipment, which is one of Unilabs' weaknesses. In fact, the price of the equipment can change substantially depending on its characteristics and technical specifications. This happens because each modality offers different types of techniques and each equipment provides a different range of image. In addition to the acquisition cost of the equipment, maintenance costs are also very high. Regarding suppliers, all equipment available in Portugal are the same as in the other parts of the world as the suppliers are worldwide companies and offer the same range of products in all different countries they operate. By that, Unilabs can take advantage of its international recognition and benefit with worldwide contracts. Furthermore, the licensing of equipment is also a very complex procedure. In fact, as explained before, depending on the type of equipment, the patient is exposed to different types of radiation. Regarding the equipment that emits ionizing radiation, and due to its increasing number of diagnosis throughout years, in 2019, the Portuguese Government launched and approved a law where the equipment licensing got even more strict. Even though the law is composed of multiple requirements, it is important to highlight the need for regular inspections in healthcare units. These inspections happen whenever an imaging unit suffers a re-structure or a company wants to build one from scratch. It was necessary to impose stricter limits of radiation emitted by the equipment that is performing the diagnostic and a definition of an entity to regulate and control imaging activities that use ionizing radiation- the one that it is harmful for humans. Before this restructuring, the entity responsible for these activities was *Direção Geral de Saúde* (DGS), whereas nowadays it is *Agência Portuguesa do Ambiente* (APA). This choice was based on the fact that APA was already specialized in issues and inspections regarding the environmental safety and therefore was the more appropriate organization to be in charge about those questions.

With this new law, the owner of each imaging diagnostics is responsible for the level of radiation workers are exposed to in every imaging room. The level of radiation that workers are exposed to, is 70% less than it was before than 2019. These limits are directly related to the thickness of the armored wall, the amount of time that technicians are exposed to radiation and the quantity of radiation emitted by the equipment. However, it is important to refer that APA does not restrict the dose of radiation the equipment emits. There is no reference value for the quantity of radiation emitted. The value for this parameter that is taken into account is related to foreign laws, particularly, laws in the United Kingdom. The result of combining this law and the goal of reducing the radiation dose emitted to the patient is the necessity of acquiring an equipment that ejects lower quantities of radiation.

Finally, the know-how needed to work with these equipment is very specific. There are multiple parameters that technicians need to know in order to capture an image with enough quality that doctors can perceive all details and make an accurate assessment. The technician is responsible for choosing the most adequate protocol to the type of imaging diagnostic to be performed. Also, nowadays, technicians have become increasingly specialized and can have a positive influence in the diagnostic turn around time (TAT). For example, a professional technician is the one that knows how to evaluate the images and when encountered with a serious pathology, notifies the doctor.

3.2 Imaging department in Unilabs

In Unilabs Portugal, the radiology department has a very important role as it represents approximately 37% of the company revenue. In fact, this department tends to work every day on technological innovation in order to improve the quality of the service provided to the patients. Also, it is a department that has a great impact in people's healthcare. Actually, nowadays people are more concerned about their health and with the developing of imaging healthcare equipment, this sector is increasing its market value. People requesting this modalities are becoming more usual and it is pleasant to know that everyday Unilabs is helping their customers to have their best health diagnosis.

The imaging department, which is part of the operations department, has the hierarchical structure shown in Figure 7:

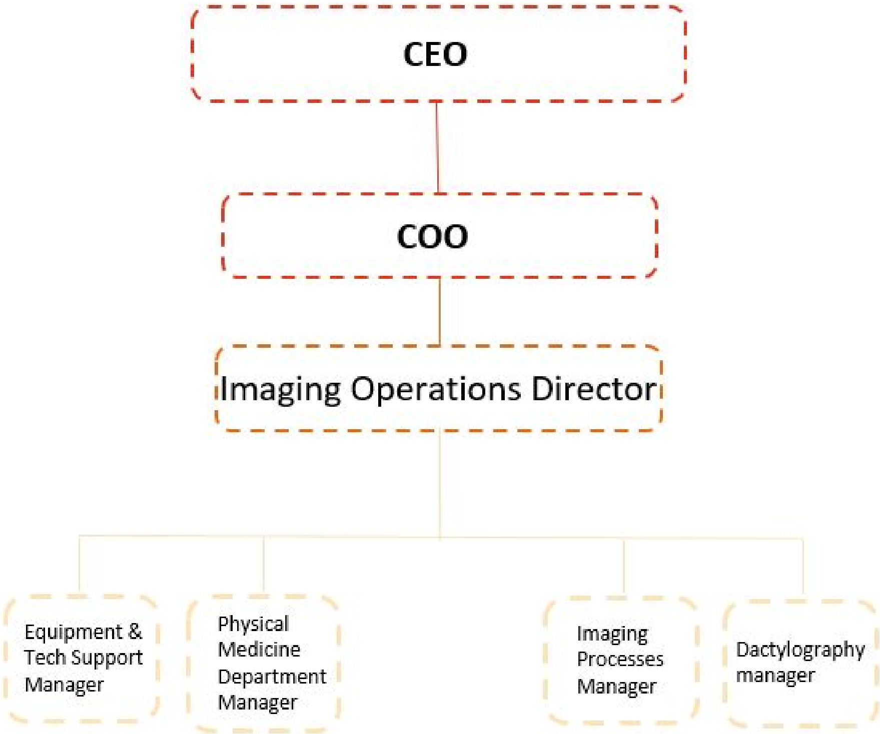

Figure 7: Hierarchical structure of Unilabs' imaging department

In fact, the imaging department is inside the Operations department. Regarding the Operations Department, this is immediately below the Chief Executive Officer (CEO), which means that every issue is directly reported to him. In the same hierarchical level of the Imaging Operations director there are other departments that are also under the Operations' Chief Officer (COO) responsibility. The imaging operations director is in charge of four different managers:

- The equipment and technological support: responsible for all equipment issues, performance and maintenance;
- Physical medicine department: responsible for licensing the nuclear medicine equipment such as PET CT and Gamma-Camera. Besides, problems related to those equipment are also in its responsibility;
- Imaging process manager: in charge of all concerns related to the quality of the image;
- Dactylography manager: responsible for coordinating all dactylography technicians.

The imaging operational department at Unilabs encompasses the asset management, including maintenance and equipment substitution, as well as the technological innovation of the imaging diagnostic catalogue available to clients.

The first parameter of asset management and the day to day management of equipment has already a very structural model, including Key Performance Indicator (KPI) reporting and preventive maintenance schemes. Every imaging unit has its own Excel where all events related to every equipment are monitored. This means that, when equipment is undergoing maintenance operations, operating or stopped working due to an unexpected reason, everything is being controlled by a responsible in each unit. Depending on the modality and downtime, it is possible to estimate the value of revenue loss. This value differs according to the modality because the price of the exam is different depending on the diagnosis pretended.

Regarding the technological innovation, all existing equipment are registered in an excel where different parameters are specified. This part of the department is responsible for evaluating the condition of the equipment taking into account its age, number of exams performed, maintenance costs. Considering that Unilabs is a company that grows through M&A and is constantly acquiring other companies, the number of equipment is always changing. Equipment suppliers are continuously upgrading models for every modality, making it difficult to maintain up to date information.

The department manages 58 care units throughout Portugal, which provide different types of imaging diagnostics. In fact, according to Unilabs Portugal (2021), these units perform per day 2724 Ultrasound exams, 1968 X-Ray, 723 Computerized Tomography, 435 Magnetic Resonance Imaging and 1240 Mammography. Each service has different types of equipment provided for use which can differ according to the type of radiology technique the doctor pretends to perform. For instance, while referring to the CT scan, the price of a perfusion technique is not the same as the price of a sequential one. As can been apprehended, these units are distributed throughout Portugal with special emphasis in the northern region. However, in the last years, Unilabs has focused on migrating its imaging care units to the center and south of the country. In the north Unilabs is represented by 36 imaging units, in the center four and in the south by the remaining ones.

3.3 Unilabs equipment

After fully comprehending the imaging department's functions and structure, one can now describe the equipment which are managed by this department. In the radiology department, the equipment can be divided into four main groups:

- Equipment that use high-energy electromagnetic radiation to get the image: X-ray, CT scan and Mammogram. There are also two other equipment: the Bone Densitometry and the Orthopantomogram but they are not under the scope of this project;

- PET CT and Gamma Camera equipment that need the injection of small amounts of radioactive materials called radiotracers or radiopharmaceuticals to the patient and use a special camera and a computer to evaluate organ and tissue functions;
- MR that need strong magnetic fields, magnetic field gradients and radio waves to generate images of different parts of the body;
- Ultrasounds, the ones that use high-frequency sound waves to produce images of structures within the body. The image can provide valuable information for diagnosing and treating a variety of diseases and conditions. Most Ultrasound examinations are done using an Ultrasound device outside the body, though some involve placing a device inside the body. Contrarily to the other imaging diagnosis that are performed by technicians and then reported by doctors, this modality is performed by a doctor who also makes the report.

Table 1 shows important information regarding the equipment. This information is the common one and sometimes depend on the model and the brand of the equipment. In this table only the radiology equipment has been analysed because the nuclear equipment would not be evaluated under this thesis.

Table 1: Summary of imaging healthcare modalities

Equipment Type	Average Price of the equipment (€)	Type of Room	Average price of the diagnosis (€)	Warranty	Preventive Maintenance (€/Year)	Exam Duration (minutes)
CT	306 000	Blinded Walls	75	1 year of full warranty	30 000	15
Mammogram	120 000	Blinded Walls	21	1 year of full warranty	12 000	10
Ultrasound	31 500	Normal Walls	20	1 year of full warranty	3 000	7
X-Ray	150 000	Blinded Walls	7	1 year of full warranty	9 000	10
MR	750 000	Faraday Cage	95	1 year of full warranty	45 000	20
Ortho	37 500	Blinded Walls	15	1 year of full warranty	6 000	6
Bone densitometry	52 500	Blinded Walls	27	1 year of full warranty	990	9

As it is possible to see in the Table 1, characteristics and prices depend on the modality. The Magnetic Resonance is the most expensive equipment. This happens because this equipment generates scans based on little magnetic properties of the body tissues and due to that, every component needs to be created with even more precision. The price of this equipment depends on the strength of the magnetic field created which is related with the quantity of liquid Helium inside the gantry. Also, the preventive maintenance of these equipment is about €45 000 per year which represents a considerable annual OPEX. As this type of diagnosis is the one that requires more time per exam, the consequence to deal with all these parameters is a more expensive cost per exam. This modality has also a particular characteristic that is related to the fact that the entire room is inside a Faraday cage, that means, a protection shield from radiofrequency waves in order to reduce the interference between the pulses that the MR emits and external ones. This cage is very expensive and costs nearly €35 000. Moreover, as a result of creating a very strong magnetic field, all patients and technicians can not enter the room with magnetic elements since they are attracted to the center of the magnetic field. Regarding the other equipment, the ones that emit ionizing radiation need shielded walls with lead to prevent external people from receiving radiation emitted by the equipment. The other characteristics are different according to the type of modality and the average price of the diagnosis is proportional to all costs related to its service and exam duration.

Finally, it is important to mention that these maintenance costs do not remain constant along years, they tend to increase and it is very difficult to predict them because each component has its own cost. In the graphical analysis shown in Figure 8 it is illustrated how the failure of one component can influence the price of the maintenance for that year. In this picture is only showed for the CT scan and the X-ray but it happens with other equipment. Sometimes becomes financially healthier acquiring a new equipment than changing just a component of an older one. Besides over the years, the probability of a component failing increases and that is why maintenance costs rise very quickly.

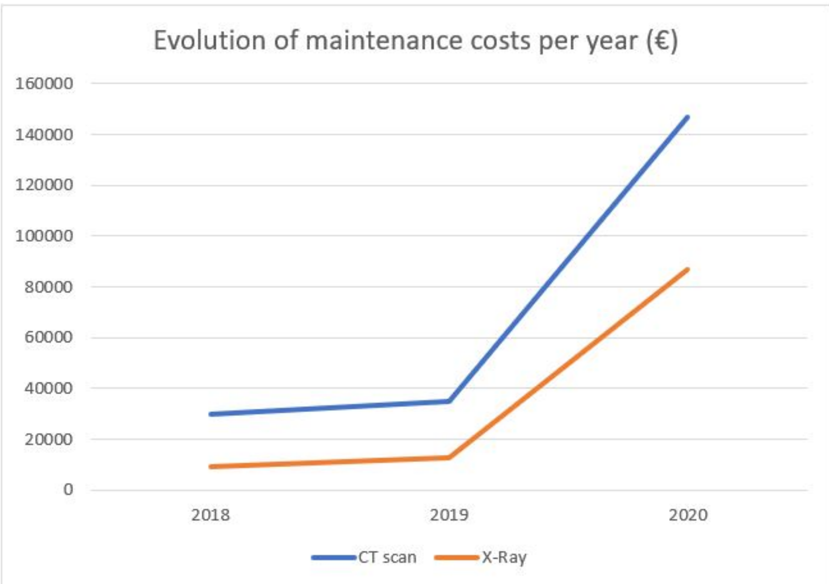

Figure 8: Evolution of maintenance cost

Nowadays, in Unilabs Portugal, the total number of equipment, average age per modality and, according to European Society of Radiology (2014), the recommended age for each modality is distributed as shown in Table 2:

As demonstrated in Table 2, the average age of the Mammogram is much greater than the recommended average age. Another problem refers to the percentage of the equipment that is above the average age. In fact, 72% means that more than half of the equipment that Unilabs uses for performing Mammographies are out of date. The second modality with higher relative number of equipment above the average age is the X-ray. Related to this modality, the issue is not only related with the average age, but also the number of exams performed as it is one of the modalities that performs a great number of exams. The number of exams that were taken into account for this analysis were the ones from 2019. Actually, 2020 was a specific year and due to Covid-19 reasons, many centres were not open but are expected to reopen again as soon as this situation gets better. Another relevant conclusion is that more than half of the Ultrasounds are above the recommended age. Even though the difference between the recommended age and the actual average is not large, both the number of existing Ultrasounds and the number of exams performed are very large.

Table 2: Equipment's average age according to its modality

Equipment Type	Actual Average Age (Years)	Recommended Average Age (Years)	Equipment Above Average Age	#TotalEquipment
CT	10,3	10	42 %	45
Mammogram	15,2	9	72 %	47
Ultrasound	9,4	8	53 %	145
X-Ray	16,1	12	64 %	56
MR	13,3	10	48 %	25
Ortopanthomogram	19	10	85%	38
Bone Densitometry	20	10	93%	41

This fact has multiple consequences in the equipment's performance. Actually, maintenance costs have a notable increase with age since equipment require more frequent preventive maintenance and the number of breakdowns increases. In addition, breakdowns normally involve substitution of parts which are not always available, translating in increased equipment downtime. It is important to emphasize that even though age is the most important characteristic, it is not the only parameter that should be evaluated in a X analysis, but also the number of exams performed per equipment. This is due to the fact that the life expectancy of the equipment depends on the number of exams they perform per year as was shown in Figure 5. Moreover, the increasing age influences the perception of customer's view about the equipment. Clients are constantly looking for up to date technology equipment and when they go to an imaging healthcare unit and feel themselves being evaluated by an outdated equipment, they will not feel comfortable about that and start looking for other alternatives. For customers the perception of quality is closely related to the physical aspect of the equipment. The age of the equipment is also related to the image quality as components get out of date and due to the number of exams performed, the equipment loses accuracy.

Related to the radiation emitted by equipment, it differs depending on the type of diagnostic performed. This radiation can be harmful for humans or not. Due to that, the impact of a ionizing equipment that is not well calibrated is not the same as if it is a non-ionizing equipment. Nowadays, as technologies are being developed in an extremely fast pace, there are equipment with a radiation reduction mode in order to diminish the quantity of energy in the form of waves to the patient. This type of equipment has internal auto adjust procedures to minimize the dose of radiation received by the patient. As Unilabs is constantly investing in new equipment, it already has many CT scans with this new technology. However, as Unilabs grows organically and through M&A, when acquiring another company, Unilabs gets their equipment. Also, even though this growth strategy has the advantage of increasing the market share very fast, it is very difficult for the acquiring company to follow this rapid expansion. In fact, many companies do not renew their equipment so often and by that Unilabs has also other equipment without this mode. Actually, regarding the AI technology, Unilabs does not have any type of this equipment. That is also because of the fact that this requires a very high investment and as explained before, it still does not have a completely trustworthy performance when evaluating human diseases.

Unilabs Portugal imaging units are not equally distributed along Portugal. In Table 3 it is shown equipment allocation along the country. In the north of Portugal the market share is higher than in the center and south. Associated to that is the fact that there are more imaging diagnostic centers in the north than in the other parts of Portugal. Consequently, the number of equipment is also much greater in the upper region of the country. Table 3 shows the geographical distribution of diagnostic centers across Portugal.

Table 3: Unilabs' equipment distribution

Region	#Equipment	#Imaging Units
North	276	36
Center	27	4
South	94	18

The total number of equipment distributed along Portugal is 397 and in the north there are 276 equipment representing the following modalities: CT scan, X-ray, Mammography, Bone Densitometry, Orthopantomography, MR and Ultrasounds. This number corresponds 69,52% of the total number of equipment existing along the country. Secondly, the south represents 23,68% of the total number of equipment. This percentage portrays the 94 equipment existing in this region. In the center, Unilabs Portugal has 27 equipment. The Table 4 shows the number of equipment according to its modality and the region where it is.

Table 4: Unilabs' modality equipment distribution

Region	CT scan	Mammography	Ultrasound	X-Ray	MRI	Orto	Bone Densitometry
North	32	34	102	34	18	25	31
Center	4	4	9	4	2	2	2
South	9	9	34	18	5	11	8

The modalities that have a higher number of equipment are the Ultrasound and the X-ray with a total of 145 and 56, respectively. This number is related to the fact that these modalities are the ones that perform more exams than the others since they carry out faster diagnosis and are the most common ones. It is not that usual a doctor asking a patient to perform a MR as it is to perform an Ultrasound or a X-ray. Actually, CT scans and MR are normally performed after a first evaluation with an X-ray and/ or an Ultrasound. Also, even though not in the same proportion between modalities, the number of equipment per region for each modality follows the path of having always more equipment in the north, then in the south and finally the center.

3.4 Acquisitions rationale and consequences

As explained before, Unilabs expansion is mostly through mergers and acquisitions of other companies in the healthcare sector. Although it helps a lot in terms of increasing very fast the market share, it turns difficult to organize all information when those companies use obsolete technology.

One of the most common methods for evaluating a company is taking account the discounted cash flows. This analysis is used to estimate the value of an investment based on its expected future cash flows. Basically, it represents the amount of the investment that should be made according to the future predictions of generating revenue. When companies knows that probably would be acquired, they tend to reduce their investment in acquiring, upgrading and maintaining their tangible assets - reduction in CAPEX. Actually, reducing CAPEX expenditures results in a increasing of cash flows and consequently, the company gets more valuable.

For that reason, sometimes companies that are acquired by Unilabs suffered from a lack of investment in their last years. Necessarily, that brings an issue for the company that is acquiring. In fact, this can lead to the acquisition of obsolete and out of date technology which is often represented not only in terms of old equipment, but also in information systems that are not linked with each other and significantly increase the workflow.

All of these factors have influence in the equipment's performance in different aspects: operating time and image quality, difficulty in licensing and time expended throughout the workflow. Also, doctors and technicians need to adapt their way of working with other information systems and equipment's software.

3.5 Critical Analysis

As described above, in Unilabs Portugal, there are many modalities in which equipment do not respect the average lifetime age recommended. As equipment are updated through years, the availability of parts to be substituted in equipment out of age is decreasing. Due to that, the price of those materials and the time to receive them increase and consequently, maintenance costs rise. During maintenance interventions, the equipment has to interrupt operations, therefore decreasing its productivity and thus reducing the revenue. Depending on the price practiced in each modality, this has different impacts. For instance, one hour of maintenance in a MR has an impact of 285 € whereas one hour of maintenance in an Ultrasound equipment has an impact of 170€. These values just took into consideration the average price of exam and the number of exams that are possible to be performed in one working hour. Furthermore, still related with the loss of revenue, is the cost of having a technician or a doctor that can not perform those modalities as they are not available. Also the cost of asking the maintenance to help solving the problem, possible components that need to be acquired and most of times the equipment is not working much more than one hour.

Moreover, the age and number of exams influence the quality of image. Equipment lose their quality during years, as their parts start getting worn out and less rigorous while creating the image. This leads to a more difficult evaluation from doctors since it gets increasingly difficult to find details and an accurate analysis in a picture with much less quality. Also, recently graduated doctors and technicians intend to work with state of the art equipment and not older ones.

All of these factors add up to a much more critical consequence which is the decreased level of confidence these equipment have. Doctors no longer feel comfortable in using these equipment to indicate a healthcare diagnosis. Ultimately, customers start to perform their imaging diagnosis in other centers that offer higher quality equipment. The equipment out of age does not have a positive impact in extending the average life expectancy of people and the assets technicians and doctors are using while performing those diagnosis are representing the company's image. By that, in last case, associating old equipment to a bad quality of image resulting in high maintenance costs and bad diagnosis can result in a reduction of the demand, increase in costs and financially compromise the company.

Chapter 4

Methodology

4.1 Equipment Evaluation

All of the aforementioned issues resulted in the necessity to replace the imaging equipment, but not from all modalities. In fact, all of the PetCT and Gamma Cameras were not considered in this analysis since these equipment belong to nuclear medicine and are not in the scope of radiology equipment. Furthermore, since the Bone Densitometry and Orthopantomogram are already being replaced, they were also excluded from this analysis. Therefore, the equipment under this dissertation are: the CT scan, Ultrasound, X-ray, Magnetic Resonance and Mammogram.

For a more accurate evaluation of the actual equipment in Unilabs, there were defined indicators. Subsection 2.1.2 of Chapter 2 clearly describes all probable consequences that could arise from high average equipment age. Also, the number of exams performed by equipment have a great influence in its performance. Both factors combined result in increasing maintenance costs since the wear of components is higher.

In order to overcome these issues and diminish the impact of maintenance and downtime costs, these equipment need to be replaced. Multiple metrics were developed in order to determine which equipment should be replaced and helping to decide in which order. The main elements to be evaluated for decision making were based on their impact on equipment performance and technicians' health. These elements are:

- Age;
- Number of exams performed;
- Revenue for Unilabs;
- The value of this equipment for Unilabs;
- Comply the RP 162 criteria: just in case of ionizing radiation emission equipment;
- Doctor model preference;
- Number of services provided by the imaging unit.

Regarding maintenance costs, they were not considered a single criteria as they are closely related with the age and the number of exams performed. In fact, the current age of all existent equipment in Unilabs Portugal imaging healthcare units was calculated. After that, with the information of Unilabs information systems, the number of exams performed by each modality in each imaging healthcare center was then perceived. Additionally, the revenue per equipment was also observed in the information systems. Also, each equipment was evaluated according to its value in the market if it was sold at that moment. The compliance with RP 162 is related to the total amount of radiation that is emitted by the ionizing equipment and absorbed by the technician. As such, it is also related to all shielding because this is associated to the amount of radiation that goes through walls and continues being diffused to the environment. Then, in this assessment, doctor's opinion was taken into account on the model and brand preference. Due to this, there are equipment desired to be replaced in order to increase doctor's working conditions and satisfaction level as they are the ones who would spend more time working with them. In accordance with Australian Government Department of Health (2013), the importance of having motivated workers while performing their jobs is considered one of the most important factors to give their best and keep them. The evaluation of all equipment according to these factors, helped to get a clear view of which equipment should be replaced and the reason for that. However, it was not possible to find a metric to evaluate all equipment as the number of equipment was very large, not all criteria could be applied in the same way for different modalities and there was not enough time. The Analytic Hierarchy Process (AHP) was considered but since the number of possible combinations was very large, it was not possible to perform it. In fact, not all criteria had the same importance while taking the decision to replace equipment because each one has different consequences. When choosing the set of equipment that should be replaced, factors were weighted. For example, modalities that do not respect RP 162 law could not be licentiated by APA and due to that, the priority of substituting this equipment is higher than other ones. However, it is important to note that this law was only applied in Portugal in 2019 and that is why Unilabs still has imaging units that do not comply with RP 162. Also, it is completely different replacing two equipment with the same age but one performs a much high number of exams and the other a low. Furthermore, the result of these factors together with the number of services provided by the imaging healthcare unit, helped in evaluating the priority of replacing the equipment. In fact, units that provided MR, CT scan, X-ray, Ultrasound and Mammography diagnosis were considered tier one, the ones that performed all types of exams excepting MR were considered tier two and the others tier three. The number of the tier is normally related with the revenue of the imaging unit as units that perform more modalities are the ones with higher value of revenue, too. Table 5 shows equipment evaluation for one imaging healthcare unit taking into consideration the criteria explained above.

Table 5: Equipment's evaluation for one unit

ID	Site/Location	Tier	Priority	Modality	System Identification	Install Date	Model	System Age 2021	Exams/year	Actual System value (Unilabs)	Annual Turnover	Comply RP-162	MAX Usefull Lifetime Recommended (ESR)
1	A	1	5	Mammography	A	1996	ND	25	557	0 €	13 150 €	NO	8
2	A	1	5	X-Ray	B	2009	ND	12	7 907	0 €	60 405 €	NO	12
3	A	1	5	MR	C	2008	1,5	13	5 218	13 686 €	535 683 €		10
4	A	1	5	CT	D	2009	64	12	8 122	15 397 €	641 638 €	YES	10
5	A	1	5	Ultrasound	E	2017	ND	4	12 315	3 422 €	238 485 €		7

In Table 5, as this imaging unit provides all types of services, it is tier one. The Mammogram and Magnetic Resonance are older than the maximum useful lifetime recommended. Also, the X-ray does not comply with the RP 162 and therefore APA would not licentiate this unit. Furthermore, both the Ultrasound and CT scan, under doctors' opinion, are not from the brand they prefer the most. Actually, due to these considerations, Unilabs proposed that for this set of equipment, all of them should be replaced. Even though Unilabs desires to replace all of these equipment, this substitution can be performed over a long term span. From these, just the CT scan, the X-Ray and Mammography emit ionizing radiation and, due to that, were the only ones that were evaluated according to RP 162. The Magnetic Resonance and the Ultrasound as they are non-ionizing equipment, do not have to comply with any regulation regarding radiation emission. By that, they were evaluated according to the other criteria proposed. All of this evaluation was made together with the Unilabs imaging department, as they have a deeper knowledge about equipment and more experience in this sector. Besides, since they have a close relationship with doctors and technicians, they also know the type of software they prefer to work with. After the evaluation regarding the parameters mentioned above, from the total of 318 equipment existent in the presented modalities, 255 were proposed to be substituted. Table 6 presents the number of equipment per modality that are requested to be substituted.

Table 6: Number of Equipment proposed to be replaced

Modality	#Equipment
Mammography	33
X-Ray	28
MR	18
CT	32
Ultrasound	144

As expected, the modality with more equipment intended to be replaced is the Ultrasound. This is related to the large number of exams they perform, its shorter lifetime in comparison with other modalities and doctor's preferences while performing this type of exams. Mammography is the second modality with more number of equipment planned to be substituted. This happens due to the high percentage of equipment above the average age recommended by the European Society of Radiology (ESR) which is confirmed by Table 2. The MR is the modality with less number of equipment intended to be replaced because of the proportion with the actual amount of existing equipment in Unilabs and more than half of those equipment are under the average

age recommended by ESR. Finally, the number of CT scan and X-ray wished to be replaced are similar. In fact, even though the number of X-ray is higher than the number of CT-scan, according to the criteria mentioned above, there are more CT-scan intended to be replaced than X-ray.

The large number of equipment pretended to be replaced according to its modality and its technical specifications, resulted in an expected quotation of 65 million euros. This estimation was done together with the imaging department and took into consideration the actual price of same level of quality equipment and those maintenance costs.

4.2 Tender Plan

Since the beginning of its operations, Unilabs works with the best suppliers of imaging healthcare equipment and due to the large number of equipment, established a close relation with them. Nowadays, Unilabs has equipment from different suppliers and this leads to different contracts with them. This is also related to the fact that as Unilabs grows through M&A, acquires the equipment of the other company, which is not necessarily from the same brand. However, since the amount of equipment to be substituted is very large, Unilabs contacted three different suppliers and requested them to propose the best set of equipment and maintenance plan, with a budget of 65 million euros. This value was only considered for equipment and maintenance costs. However, as other restructures would be necessary, Unilabs had a total budget of 85 million euros and there are also included some modifications in radiology rooms that are not included in suppliers' quotations. Moreover, suppliers were also advised to take into consideration Unilabs' opinion regarding the equipment proposed to be replaced according to the criteria explained above. Taking into consideration the number of restrictions imposed by Unilabs, in terms of equipment, suppliers offered the proposals shown in Table 7:

Table 7: Equipment supplier's proposals

	A	B	C
CT	32	38	37
Mammography	33	37	40
MR	18	15	20
Ultrasound	144	121	120
X-Ray	28	38	35
Total	255	249	252

All suppliers received the information regarding the assessment of all equipment and taking into consideration their know-how made their own evaluation and presented their options, too. Also the budget of 65 million euros was considered in these possibilities. This budget was not only considered for the equipment itself but also for OPEX expenditures. In fact, all preventive maintenance and installations are included in the ten year span budget. In fact, in supplier's A proposal, the number of equipment per modality suggested to be replaced respected Unilabs Portugal considerations. Actually, the number of CT scans, Mammographies, MR, US and X-ray are exactly the same as the number of these equipment advised by the company. This particular supplier decided to make an approach where completely trusted Unilabs' opinion in terms of which equipment should be replaced and just chose the model of equipment desired. In relation to supplier B and C suggestions, both considered Unilabs' point of view but made some changes. Supplier B preferred replacing more CT scans, Mammographies and X-rays than supplier A, 38, 37, 38 respectively. With the increased number in these equipment, supplier B decided then to reduce the number of the other modalities, also because of the budget restriction. As CT scan, Mammography and X-ray are more expensive than Ultrasounds, this supplier had to diminish the number of Magnetic Resonance and Ultrasound in order to maintain a very good quality in the set of equipment proposed. Finally, supplier C focused on offering an alternative with more MR, Mammographies, CT scans and X-rays than Unilabs initial proposal. The number of Ultrasounds is less than supplier A and B. This happens because the investment in the other modalities is more expensive and to maintain high quality levels, this supplier decided to make this choice.

4.2.1 Equipment technical evaluation

Even though the total number of equipment do not have a great difference between suppliers, in each modality the number of equipment differs. Also, the set of equipment proposed is different and exclusive to supplier's brand, by that, equipment's characteristics are distinct from supplier A to B and C. Despite the fact that all suppliers are totally trusted by Unilabs and the company is used to work with them, Unilabs decided to make an evaluation for each equipment in each modality. In fact, this evaluation was made in order to help taking the decision of choosing which supplier would be preferred. This evaluation was made with help of the imaging department and took into consideration important criteria related to the type of exam performed. Actually, for each modality, important criteria was established and then, considering its relevance, each equipment has been evaluated. The criteria took into account different characteristics of the equipment, not only technical features but also characteristics related with the patient such as the amount of radiation emitted. Table 8 shows an example of this evaluation for an equipment from one of the modalities suggested by supplier C.

The criteria evaluated was the same for each modality in order to maintain a controlled evaluation. According to the importance of the characteristic to the equipment, each feature was evaluated. Then for each appraisal the value considered for the equipment was directly proportional to the maximum and minimum. For example, for criteria "Power of the generator (kW)" in the group "Generator", the importance considered for this parameter was 6. Afterwards, with the information about each equipment that suppliers sent to Unilabs, the equipment with the highest power was considered 6 and the one with the lowest one was considered 0. The other equipment were measured by calculating its proportion according to the maximum and the minimum value.

According to Unilabs' extensive study of all equipment, for each modality, all suppliers were evaluated and was possible to know which had better equipment. In fact, for each modality, each supplier had an evaluation of all equipment suggested. This evaluation also helped in the decision-making process because, even though in the same modality equipment can perform different types of exams and Unilabs needs to evaluate the equipment also taking into account those information.

Table 8: Equipment's specifications evaluation

Technical features	25	Equipment	23.7
Tube - detector distance, variable from 110 to 180cm	5	Vertical movement for suspension 180 cm.	5,0
Vertical and horizontal Potter	4	Wallstand with vertical and tilting motorized movement.	4,0
Vertical and horizontal movement of the table	2	Range of vertical movement from 50 to 85 cm	2,0
Mention the table size and area of examination	4	Tabletop size: 93 cm x 240 cm - Longitudinal 188 cm	2,7
Maximum weight that supports table (kg)	4	320	4,0
Floor or ceiling column equipment	2	Robotized overhead tube suspension with 5 axis servo motion	2,0
Automatic positioning	4	Yes Auto-positioning, Auto-tracking to align with Wallstand detector.	4,0
Generator	**16**		**16,0**
Power generator (kw)	6	80	6,0
Maximum Voltage (kV)	5	150	5,0
Automatic exposimetria, with a minimum of three independent areas (cells)	5	Yes	5,0
Dose calculation system	**6**		**6,0**
Registration system of dose file and send it to the PACS	6	Yes	6,0
Tube	**9**		**9,0**
Rotary anode of double focus, with nominal dimensions of 0.6 to 1.2mm	4	Yes. 0.6 mm y 1.25 mm	4,0
Heat dissipation value of the anode (Storage - KHU / min)	5	350	5,0
Digital detector	**20**		**17,7**
Detector dimensions	6	Two detectors: 43 x 43 cm and 35 x 43 cm	6,0
Detector Resolution (μ)	7	Cesium Iodide 100 μm 100	7,0
Time interval between the shooting and the fully processed image display (s)	7	Final conditioned image including Auto-shuttering:	4,7
Acquisition workstation	**24**		**24,0**
Monitors to be installed near the equipment console	4	24" LCD color monitors. Resolution: 2 MP	4,0
DICOM protocols - With standard DICOM 3.0 and ability to SEND, STORAGE, PRINT	5	DICOM Storage	5,0
Other options	4	Anti-virus (AV) and intrusion detection (AIDE)	4,0
EXTRA-LONG SYSTEM (automatic / sync detector-Tube)	7	Automatic Image Pasting on the table and on the wallstand with Artificial Inteligent AutoSpine algorithm.	7,0
ADDITIONAL SOFTWARE	4	Quick Charge: detectors charge when they are in the table or wall stand housing.	4,0
TOTAL	**100**		**96,4**

4.2.2 Equipment age evaluation

Another very important parameter to be evaluated is the age of the equipment, as it is the factor that is related with most of the equipment implications such as equipment's performance in terms of operating time, maintenance costs, quantity of radiation emitted. Since this tender is relative to a ten year period, and due to the large number of equipment to be replaced, suppliers developed a replacement plan in order to diminish the effects of equipment age in Unilabs' daily operations. This means that, in addition to selecting the equipment, each supplier recommended a substitution plan, taking into account their priorities. The number and the model of equipment planned to be replaced each year differs from supplier to supplier and due to that, the average age of the entire set of equipment is different. By that, Figure 9 shows the average age of equipment of the entire set of equipment existent in Unilabs during the substitution plan. This combine the equipment that is planned to be replaced and the other equipment that is still performing exams in Unilabs.

In the graph of Figure 9 all proposals are represented taking into consideration the average age evolution. Partnership 1 represents the average age of the set of existent equipment. As this plan is supposed to start in the present year, the second partnership year represents the average age of equipment at the end of 2021, following suppliers' replacement plans. From the third to last year of partnership, the average age of all equipment was portrayed taking into account the equipment that are pretended to be replaced. All suppliers' proposals have different average age since the replacement plan is different and therefore, the number of equipment intended to be substituted per year is not the same. Besides, the influence of replacing an equipment of 2012 or a equipment from 2004 has different impacts in the average age of the total set. Unilabs considers annual average equipment age to be at 8 years. This means that, the average age of equipment, after substitution in a given year, should be under the eight year line, according to the European Society of Radiology (2014).

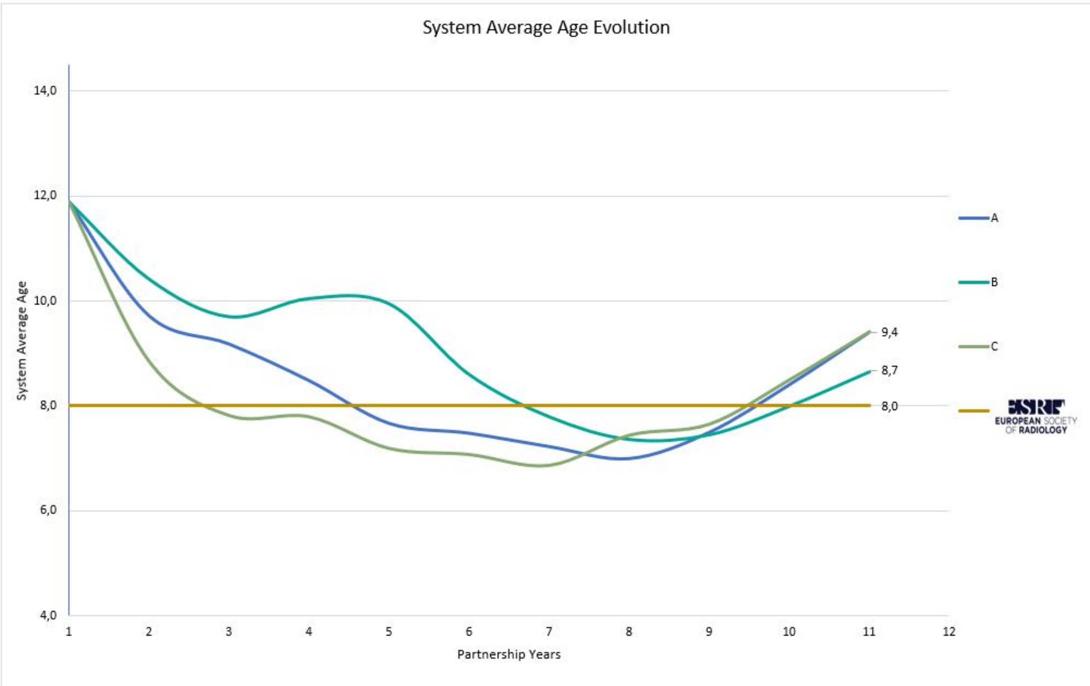

Figure 9: Equipment's age

The supplier that has more years under the recommendation from the ESR is supplier C, followed by supplier A and then B, the first one for seven years, then five years and three years, respectively. In the tenth year of the project, supplier B is the one that reveals the lower value for the average age of the equipment set. By examining the graph, supplier B is able to maintain the lowest average age of equipment at the end of the period. At the end, both suppliers A and C have the same average age of equipment. After the tenth year, if there are not any other equipment replaced, the average age of equipment would increase. After this ten year span, Unilabs will develop or consider new strategies in order to approach equipment which are above the eight year limit.

All features evaluated until now are mainly related with the technical part of the equipment, which refers to the quality of the equipment and its performance. However, another very important point is if it respects the total of the 85 million euros budget, where 65 million euros correspond to the equipment and its operational costs and the other 20 million euros for infrastructures. In fact, all quotations need to be below or equal to that amount. Thereby not only the sum of the value of each partnership equipment was calculated, but also all operational costs for each proposal and all costs related to infrastructure modifications.

Regarding the equipment partnership total price shown in Table 9, each proposal was evaluated per modality according to the value of each equipment proposed. Table 9 shows the price per modality for each proposal. Supplier C presents the lowest partnership price. Actually, this supplier presents a lower price for all modalities, except the X-ray. This supplier is followed by supplier B and finally supplier A. Even though supplier C has proposed more MR than supplier A, the partnership value for the modality is cheaper. This could be achieved through discounts made by the supplier and also because of particular characteristics of the equipment that have a huge impact in its price. This happens not only for the Magnetic Resonance, but also for the other modalities and that is why a supplier could have a more expensive value in one modality and lower numbers of equipment proposed.

Table 9: Total partnership price per modality

	A	B	C
CT	9 401 383 €	8 733 810 €	6 662 349 €
Mammography	5 001 029 €	5 282 496 €	4 567 074 €
MR	15 332 700 €	10 844 760 €	9 910 149 €
Ultrasound	5 820 285 €	7 300 487 €	5 977 674 €
X-Ray	4 540 299 €	4 934 775 €	5 059 004 €
Total	**40 095 696 €**	**37 096 328 €**	**32 176 250 €**

4.2.3 Suppliers service evaluation

Even though technical specifications are related with operational ones, not all of them have been evaluated. Regarding the operational costs, in the equipment partnership price there were already included the installation cost. However, another relevant costs are the maintenance costs. In fact, nowadays spare part and labour expenditures represent a high amount in Unilabs' annual financial statement. Since given proposals are exclusive for each supplier, all of them presented a full maintenance price for the ten year span. Actually, more than one year of guarantee, these programs included all preventive maintenance required by the equipment in order to prevent unexpected component breakdown. Also, for sudden equipment failures, even though there is a loss of revenue related to the equipment's stoppage, Unilabs does not have to worry about the maintenance cost since it is already included in the maintenance price. Spare parts, if needed are covered, too. In respect to this part of the agreement, Unilabs could decide between accepting just the equipment or the equipment and maintenance. In Table 10 there is a comparison of the maintenance costs proposed by the three suppliers. Note that despite the fact that Magnetic Resonance is the equipment with higher maintenance costs, supplier C is the one in which the price for full maintenance is cheaper and it is who has more Magnetic Resonance in his replacement plan. Due to that, suppliers were also evaluated in terms of their operational services. For example, the time an equipment is stopped per year is related with different types of costs. It is reflected in the number of working hours the technician cannot provide services for patients, the loss of revenue linked to the fact that the equipment could be operating and is stopped, and the service level agreement. Also, patients are expecting a high quality of service from Unilabs and the company is not corresponding with their needs. Moreover, the price of a breakdown component is another cost incurred in these situations. Due to that, the assistance provided by each supplier and its availability during the ten year span was evaluated. In order to diminish the maintenance time required, some equipment can be assisted remotely. In fact, suppliers provide a secure access to essential operational controls to help companies solving their issues. Regarding the maintenance, each modality has different types: the preventive and corrective maintenance. As expected, these types of maintenance have different values as they are related to the probable consequences that result from that. In the preventive maintenance, the equipment is carefully analysed regularly to avoid sudden stoppages, whereas in the corrective maintenance, the issue occurs and then the company asks the supplier to evaluate the situation and solve it. On one hand, the first alternative requires frequent interruptions of the equipment but can prevent a broken component. On the other hand, in the second alternative, the equipment just stops working if needed however, the problem can be very serious and consequently, very expensive. Regarding this replacement plan, in all proposals, from the moment the equipment is replaced, since suppliers only sell equipment with its own brand, they assure full maintenance until the ten year span is reached. This means that the equipment that is replaced in the last year of the project would only have one year of maintenance included.

Moreover, with the evolution of information systems, the workflow since the acquisition of the image and its processing got much faster. However, this is dependent on the type of system offered by the supplier and differs from supplier to supplier. In respect to the emission of radiation, there are already equipment that have dose monitor, which means they save the dose of radiation the patient received during the exam performed. In order to evaluate these characteristics, an assessment was made to compare each supplier. This assessment aimed at evaluating each supplier according to the services they provide during the partnership. All parameters evaluated had different scales. The ones that were already numerical and understandable remained the same and could be compared directly, whereas the others have been adjusted to a scale in order to better evaluate them. Actually, other ones are represented by a binary scale where zero means that the equipment does not have that characteristic and one means it has. Also, there was another types of criteria that according to its characteristics were evaluated in a scale from zero to the number of possible conditions. For example the software to automate the workflow and system pre characterisation which is the diagnostic workflow tool system was evaluated from 0 to 3. Zero represents an equipment that does not have automation tools and 3 means full Diagnostic workflow tool system. All criteria measured for each equipment for each supplier is in Appendix A, also the explanation and the score for each parameter. This assessment was made together with the imaging department, as they have further knowledge in this area, defining the criteria that should be used to get an overall view of each proposal. Table 10 is the result of this evaluation following suppliers' data about their proposals.

Table 10: Overall evaluation per supplier

Comparative Evaluation Items Rating	A	B	C
Replacement System	255	249	252
Partnership System Price (M€)	40,1	37,1	32,2
Full Maintenance price_10 Years (M€)	28,6	22,3	18,8
Replacement Year (Average)	2024	2025	2024
Maximum System Age (Years)	15,1	15,9	15,1
Final System Age_2030 (Years)	9,4	8,7	9,4
New/Upgraded System (0 to 1)	255	217	236
Production year > 2020 (0 to 1)	228	239	245
AVG System Technical Specifications (0 to 100)	60	75	77
System OK to Site (0 to 1)	241	245	252
System Maintenance Downtime (hours/year)	16065	1114	1584
Average System Replacement Downtime (MAX =2)	4	5	4
Out of Hours Preventive Maintenance (0 to 3)	0	183	72
Remote Assistance 365_24/7 (0 to 1)	222	244	252
Positive Pacient Experience (MAX =3)	3	0	10
Imagiologist Experience (MAX =3)	300	360	363
Postprocessing System (Server) (MAX =3)	132	201	191
Diagnostic workflow Tool System (CAD) (MAX =3)	210	222	154
Dose Monitor Management (MAX =1)	93	117	112
Monitor Integrated System Management (MAX =3)	150	170	182
Remote Scanning Assistant & Control (MAX =2)	80	61	57
Number of obsolete equipment (>10 years) (%)	22%	26%	23%

In Table 10, there are represented the three partnership suppliers and their evaluations for the parameters considered crucial to help decision making. Each criteria has been rated according to the information given by the supplier for the particular equipment. In order to have an evident recognition of which supplier has a better classification in each criteria, each cell was coloured. The reason behind is the fact that in some criteria the best supplier is the one that has the lowest value and in others is the one that has the greatest value. By that, cells in green represent the supplier that has the best classification for that category, the one intermediate is represented by the yellow colour and the worst is represented by light orange. Since criteria is different from each other and not all of them are regarding the same topic it was not possible to create an uniform evaluation system for all of them. In fact, by analysing Table 10, supplier C appears to have a better score since it attained the best classification in more categories. Alternatively, supplier A has more orange coloured items, meaning that it is the supplier with worst evaluation. Also, not all criteria have the same level of importance and sometimes they are related with each other. For instance, the partnership system price cannot be only evaluated alone as the total budget is not only for the equipment. Related to this criteria is also the full maintenance price for the ten year span which represents the amount of money the supplier is investing in order to be responsible for the full maintenance of equipment during this time. However, evaluating those values in a separate way is also significant to get a clear view of the supplier who has the most expensive equipment and maintenance services.

4.2.4 Infrastructure costs

The presented investment would have several significant implications in Unilabs' daily operations. In fact, due to the huge number of equipment being replaced, Unilabs would take benefit of that moment to make some changes in their imaging units. Actually, in order to deliver a great experience for patients there are different ways of designing imaging rooms. Nowadays, there are many ways of humanizing radiology rooms and while taking the exam, patients feel much more comfortable. Particularly while performing a Magnetic Resonance or a CT scan, most of times people are inside the gantry and feel claustrophobic. In those cases, having a more convenient room would help patients feeling more comfortable. For technicians, Unilabs also pretends to create more pleasant conditions. Regarding equipment, the logistic to transfer them needs to be considered. The old equipment is removed and the new one enters the room. This seems simple, however there are imaging rooms where the equipment entered before the construction of the walls and now, due to the dimension of them, walls must be demolished. For that reason, these costs were also took into consideration while making the quotation.

Besides, some modalities require special heating, ventilation and air conditioning. By that, Unilabs decided this would be the moment to make those modifications, too. In addition, in the tender plan, the equipment and maintenance costs were included. However there are some equipment that requires special cooling systems, as is the case of Magnetic Resonance which needs a chiller to answer this requirement.

All these modifications are already included in the budget and by that need to be predicted. All costs considered were based on previous situations were Unilabs have been through this same type of circumstances. For all constructions, 25% of the total area of the imaging centers was considered because there are very heavy equipment that requires propping up the floor. Table 11 shows the quotation for the expenditures predicted.

Table 11: Total infrastructure costs

	m^2	Cost	Number of clinics	Impact	Total Cost
Room Humanization CT and US		5000	62		310 000,00 €
Room Humanization MR		20000	18		360 000,00 €
AVAC		150000	15,5		2 325 000,00 €
System transfer between sites		15000	31		465 000,00 €
Quench piping		4000	19		76 000,00 €
Chillers		20000	62		1 240 000,00 €
All US probes included		2100	62		130 200,00 €
Contructions	125	900 per sqm	9	25%	253 125,00 €
	350	900 per sqm	39	25%	3 071 250,00 €
	600	900 per sqm	10	25%	1 350 000,00 €
Total (NO VAT)					9 580 575,00 €

Chapter 5

Results

The ultimate goal of this investment was to provide Unilabs' clients the best quality of service. Also, with state of art equipment, Unilabs Portugal would differentiate its service from the other competitors. Although all proposals were very interesting for Unilabs, the group had to make the decision of selecting one. Actually, all of them included very good quality equipment and assistant services. It was a difficult decision to make, but after a detailed evaluation according to the criteria mentioned before, the decision had to be taken.

Supplier A did not respect the restriction of the 65 million euros available for this investment and due to that it was rejected. Even though the total number of equipment in the proposal was greater than in other proposals, Unilabs Group was limited to the budget and therefore rejected supplier's A proposal. Also, since nowadays equipment are being developed at a very fast pace, Unilabs preferred to restrict the amount of money invested in this project and, if needed, establish a new tender for the following ten years. Regarding supplier B, the total budget, which included both operational and capital expenditures, was respected. The total number of equipment was less than supplier's C proposal. However, the decision of choosing between supplier B or C did not rely only on the number of equipment, other important criteria was taken into consideration. Together with Unilabs' imaging department, the technical features of the equipment were reviewed and compared with supplier's C option. Also, the services provided by both suppliers were assessed. After a deeper evaluation, the team was inclined to select supplier C since it gathered better technical specifications and quality of service. However, before taking the final decision to validate supplier's C proposal, a financial analysis was performed. Indeed, the executive directors can only accept the project when accurately financially appraised.

Effectively, supplier C was the one that followed the money constraint and offered a balanced proposal with very good equipment in terms of technical features and post-sales services. Besides, the equipment from this brand is the preferred by technicians. It is the one with more intuitive software which is easier for technicians to use. This allows for reduced training time and, consequently, cost reduction. Moreover, the setup time is reduced and technicians can perform more exams in the same working time, resulting in a increase of productivity. Table 12 shows a global summary of all proposals in terms of CAPEX, OPEX and infrastructure expenditures. Since the replaced equipment is intended to be sold afterwards, the actual value of those equipment is subtracted in the total of the proposal. There is also the average age of the system including and excluding the Ultrasounds. In fact, since Ultrasounds are the type of equipment with more replacing systems, it has a huge impact in the average age of all equipment. Due to that, in the global overview of each proposal, it is a significant metric.

Table 12: Proposal's overview

	A	B	C
Proposed Systems	255	249	252
System Age (2030)	9,4	8,7	9,4
System Age (2030) - Excluding Ultrasounds	11,9	9,5	9,8
Infrastructure costs	9 580 575 €	9 580 575 €	9 580 575 €
Equipment sold	-832 833 €	-818 361 €	-886 964 €
10 years – CAPEX	40 095 696 €	37 096 328 €	32 176 250 €
10 years – OPEX	28 630 482 €	22 280 779 €	18 827 127 €
10 years Partnership	68 726 178 €	59 377 107 €	51 003 378 €
Total Expenditures (Including VAT)	**95 292 921 €**	**83 811 364 €**	**73 427 296 €**

5.1 Financial Analysis

All investment programs should be accurately evaluated in order to maintain the company's financial health and avoid unexpected outcomes. This particular project is related to the renovation of Unilabs' equipment to increase the SLA and, consequently, the net income. However, net income is not the same as cash flows and, as explained in Chapter 2, the diverse methods to evaluate a project are related to cash flows and not to net income. Whereas cash flows refer to the net amount of cash that is transferred into and out of the business, the net income is the difference between sales and cost of goods sold and expenses. For instance, there are companies that have a great net income but as they need to wait a long time to receive the cash, their cash inflows are low. In order to provide a more complete and precise analysis, the IAPMEI sheet for evaluating a business was used and some assumptions were made which will be explained in the following sections. This tool was designed by a public institution that supports companies when developing a investment project. Regarding the assumptions made, they are crucial for the project's expectations as they differ across the time and sector.

5.1.1 Investment description

The investment for this project is only related to tangible assets. In fact, according to this proposal, 63 million euros will be required for the purchase of the equipment and 12 million euros for all the infrastructure. The annual value of the investment in equipment considered was calculated through the sum of the maintenance and the cost of the equipment replaced per year. The investment in constructions was equally divided into the first three years of the project to prepare the imaging units to receive the new equipment.

Regarding the working capital, since Unilabs works with many insurance companies and the Government, the average time for receivables is greater than the payables. By that, the working capital considered was 2 925 506 euros and enough to pay all external services, supplies and salaries. This decision was made to ensure the daily operation of the company.

5.1.2 Financial assumptions

Time span

For this programme, due to the dimension of the investment, 10 years were considered to take into account all the renovation plan developed by the supplier. The investment project is planned to start in 2021 and finish in 2030.

Corporate tax

According to the imaging healthcare services taxation, for the services provided, the tax was 0%. However, regarding the corporate income tax, 21% was considered as it is the normal tax for companies that provide commercial activities. For all consumables and equipment acquired the tax was 23%.

Cost of equity

The Capital Asset Pricing Model (CAPM) was used to determine the project's theoretical rate of return under review, comparing with a perfectly diversified market portfolio.

Risk Free Rate

The risk free rate (Rf) is the theoretical expected rate of return of investments with zero risk. To estimate this, it is common to use the issued bonds emitted by Governments with rating "AAA".

Taking into consideration the fact that the chosen country's currency should be the euro to avoid exchange rate variations, Germany was the one chosen. Based on the time horizon considered in the elaboration of this business plan, the rate of -0,18% was used as it corresponds to the rate applied to the ten years German treasury bonds (rating "AAA") (Investing, 2021).

Average Market return

In order to estimate the expected market return, it was used as a proxy the value associated with the number of shares representing the Portuguese market. In this sense, a value of 6,85% was obtained for the average market return (Aswath, 2021). Then the premium risk rate was calculated through the difference between the average market rate of return and the risk free rate, obtaining the value of 7,03%.

Estimation of project's Beta

The Beta of a potential investment is the measure of how much the investment can have in terms of risk in a portfolio that resembles the market. In this sense, to estimate the Beta value of the Project it is necessary to find the Beta of the sector. After research and considering the company is operating in the sector of health, the value of β_U is 1.17 (Finbox, 2021). To calculate the beta value of the project, it was used the Hamada Formula as shown in Equation 5.1. The "t" refers to the corporate tax, the "D" is the debt and the "E" is the equity. Since the value of the equity and the debt vary along the years, the beta of the project also changes as shown in Appendix B. In the beginning, due to the value of the loan, the debt is higher and consequently, the risk of the project is higher. Throughout years, the debt is being paid and as the equity increases, the beta for the project diminishes which means the risk decreases.

$$\beta_p = \beta_U(1+(1-t)\times(\frac{D}{E})) \tag{5.1}$$

Cost of Capital

Based on the aforementioned estimates and through the use of the CAPM, the cost of capital for each year of the time horizon under analysis is in Appendix C. This value is calculated according to Equation 5.2. However, it is possible to evaluate the cost of capital as the average of the yearly costs of capital, obtaining an average value of 10,2 %.

$$CostofCapital = Rf + \beta_p \times (Rm - Rf) \tag{5.2}$$

5.1.3 Financing plan

To pay all equipment and constructions, Unilabs will take out yearly loans corresponding to the value of them. As explained before, regarding equipment, the value of the loan is equivalent to the sum of equipment's and maintenance costs for the year the equipment would be replaced. For constructions, the annual value is four million euros. For all loans, zero years of grace were considered, and the total time to pay each loan was until the last year of contract. Finally, the interest rate considered was 1,7% based on Pordata (2021).

5.1.4 Feasibility indicators

After preparing investments financial statement forecast, the step further involves calculating the cash flows generated by the investment and analyzing the feasibility of the project. Regarding the balance sheet and the income statements, the values considered were the ones of the actual imaging healthcare units of the company just from the modalities that are going to be replaced.

However, some changes were made because, as a consequence of this investment, the company expects some modifications. In fact, these assumptions are:

- a growth rate of 5% in the total revenue for the first four years as a consequence of the investment made in state of art equipment and the growth in market value. This value was a proxy based on the historical revenue growth rate when in past periods an equipment was replaced;

- marketing costs increase in a rate of 5% in the first four years to advertise this new equipment. This value was based on the previous average costs incurred by the marketing department with other equipment renovation;

- the maintenance costs contemplated are from the equipment that are not going to be substituted, since the others are already included in the tender plan.

The different solutions to assess the feasibility of the investment are usually complementary in terms of providing information to the analyst, as well as helping him to make the decision of whether or not the investment should be implemented.

Post Financing Perspective

In the post-financing analysis, the effects of debt capital are reflected in the rate of update. The discount rate is called Weighted Average Cost of Capital (WACC), in other words, the average cost of capital weighted by the proportions that each type of capital has in project financing (equity and debt). Since the calculated project cash flows are free cash flows, the discount rate also includes the tax savings obtained in the period. Also the cost of equity is calculated encompassing the risk associated with the investment itself, arising from the capital structure. By that, instead of using the β of the sector, it is used the β for the project.

The net present value is 171 345 347 euros which means the project should be accepted since it has a positive financial return to the company.

Since the weighted average cost of capital changes along the years as a result of changes in the equity value, the internal rate of return should be annually compared with the WACC. The IRR 291,97% is which is greather than the 10,2% required rate of return, thus validating the NPV obtained.

Finally, the payback time provides the number of periods required to, through the cash-flows generated, recover the invested capital. It is a model that does not takes into account the time value of money. The payback time for this project is less than a year which means that after that time, the break even has already been surpassed.

After the analysis of those financial parameters, the decision of choosing supplier C was enhanced and the company concluded to move forward with the contract.

5.2 CAPEX and OPEX evaluation

The investment in the equipment itself and all operational costs related are equally important. In fact, choosing cheaper and lower quality equipment would have a negative impact in maintenance costs and as explained before, these costs could rise and replacing the equipment could be a smarter decision.

Regarding the equipment, taking into consideration the actual price per modality and the ten year contract proposed by the supplier, differences were significant. In fact, in the presented proposal, the supplier made an average discount of 30%. In addition, the use of state of art equipment would allow to attract the prescribing doctors to recommend this new technology. Actually, Unilabs would differentiate from its competitors since it would have high quality system specifications and digital tools. However, in relation to RP 162 compliance, which is related to the protection levels of radiation, Unilabs has ionizing equipment that still do not respect these levels. There are five CT scans, 27 Mammographies and 56 X-rays that do not respect this criteria. As this is an imperative criteria to license imaging units, at the end all CT scans and Mammographies would respect this report. At the end of the 10 years, only 21 x-ray equipment would be out of the RP 162 directive.

In respect to the operational costs, even though all new equipment have one year of guarantee, after that there are maintenance costs that will be paid. The preventive maintenance category can be divided into two sections, one that includes all possible components to replace, and one that does not include these components. The proposal from this supplier included full maintenance costs. Actually, all preventive and corrective maintenance were included in the total value of the proposal. This means that if a component breaks down and requires replacement, all of the parts and services for that replacement are included. In fact, spare parts for the those modalities are very expensive and, together with the imaging department, predictions of the expected amount that would be spent in components was designed. The value achieved was exceedingly expensive and due to that, the maintenance contract was also accepted. The predicted spare part costs are shown in Appendix D. Effectively, before this tender spare parts cost and the full maintenance costs were high. Also, the labor cost for technical issues was really expensive as it is a very particular type of work. This difference could only be accomplished since the number of equipment is very large and this allows the supplier to provide quantity discounts.

Chapter 6

Conclusion

Even though the imaging department has continuously proven to be an essential part of Unilabs operations and Unilabs business as a whole, its monitoring and investment in the equipment renovation could not follow company's growth. In fact, company's recent expansion plan, which was mostly a result of several mergers and acquisitions, has resulted in substantial challenges, notably in terms of merging all information and an accurate evaluation of the equipment acquired. Also, most of the equipment acquired from the other competitors were not up to date. Consequently, focusing efforts and investing in a plan to renew most of the out of date equipment became a priority. As one of the market leaders providing imaging diagnosis, it was time to install state of art equipment and provide patients a better quality service.

The scope of the program was clearly defined. Taking into consideration the budget Unilabs had to invest in equipment, maintenance, and all infrastructure, replace the existing equipment from X-ray, CT scan, Mammography, Magnetic Resonance and Ultrasounds in order to provide a better diagnosis while emitting lower amounts of radiation. The financial evaluation of the supplier was crucial to help Unilabs taking the final decision as it could explain in a more theoretical and concrete sense the advantage this investment would bring to the company. Also, improving the working conditions for doctors and technicians would help in future contracts. In fact, as a result of the increasing competitiveness between companies, Unilabs needs to differentiate its service. Furthermore, the imaging diagnosis market value is expected to grow and the company intends to follow this trend.

With the development of this programme, Unilabs could get a great discounted price not only in the equipment, but also in maintenance costs. In fact, the actual maintenance costs would be reduced by 28% after the replacement plan. After the two years of negotiation, the project could only be accepted thanks to all the analysis made in this Dissertation as it could demonstrate the viability of the investment project based on applied theories and concepts.

To sum up, according to *Expresso's* article from the twenty first of June of 2021, the waiting list for the MR is more than an year, which reflects the increasing post Covid demand. This is the proof that the imaging market in Portugal is increasing significantly its value and this project would allow Unilabs Portugal in providing the best quality services and maintain their organic and

M&A growth sustainable.

Future works

On the short term, there are some actions that should be taken. Due to the huge number of equipment that are going to be replaced, Unilabs needs to prepare each substitution in a very accurate way in order to reduce the downtime of the modalities. In modalities such as the X-ray, Ultrasound and Mammography the installation and the removal of the old equipment is a simple procedure. In fact, these equipment do not require differentiated conditions in terms of weight that the floor needs to support as they are not so heavy. Contrarily, Magnetic Resonance and CT scans have very heavy components. Actually, those gantries have most of their weight concentrated in a small area and due to that need a floor with special characteristics to support them. To prepare this and reduce the substitution time, Unilabs should get all the information regarding the actual equipment and compare with the new one. If the new equipment is heavier than the old one, the company should verify if the floor has conditions to support the more recent one or needs a reinforcement. Also, to transport the gantry through the imaging unit, all floor need to have a special support to avoid its damage. For this reason, Unilabs should start planning all infrastructures taking into consideration the replacement plan proposed by supplier C, so that it would be possible to reduce significantly equipment´s downtime. Table 13 shows the number of equipment intended to be replaced in each year of the plan. In the early years, the number of equipment replaced is much higher than in the last ones. In fact, for Unilabs this has the great advantage of reducing the average age of all equipment drastically and the chance for taking the full maintenance of those equipment for a larger number of years. Furthermore, this requires an even more precise way of programming its replacement as it would be necessary to substitute, in average, more than three equipment per month.

Table 13: Number of equipment replaced per year

Year	#Equipment
2021	55
2022	32
2023	32
2024	36
2025	29
2026	34
2027	12
2028	16
2029	4
2030	2

On the medium to long term, which corresponds to the seventh and eighth years of the investment project, Unilabs should start planing another replacement plan as the average age per modality start to increase.

Furthermore, Unilabs should be aware of the development of artificial intelligence equipment. Over the years, as a result of the investment in those type of systems, more accurate equipment using AI are expected to be launched and Unilabs should be up to date to be one of the first companies acquiring equipment with this new technology. Also, during this ten year project Unilabs is allowed to acquire further equipment from other suppliers which is beneficial if another supplier launches an innovative equipment.

Finally, in order to have a more accurate evaluation of the equipment, during the next years, Unilabs should also develop or adapt a metric to evaluate their equipment. This was not possible to create due to the limited time of the project but it is one of the future works that Unilabs should prepare.

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Appendix A

Overall Criteria evaluated

Comparative Evaluation Items Rating	Description	Level 0	Level 1	Level 2	Level 3
Replacement System	Number of systems to be replaced in the Site	—	—	—	—
Partnership System Price (M€)	Special system price for Unilabs only during the Partnetship	—	—	—	—
Full Maintenance price_10 Years (M€)	Special maintenance price for Unilabs only during the Partnetship	—	—	—	—
Replacement Year (Average)	The Year that the system will be replaced	—	—	—	—
Maximum System Age (Years)	Maximum system age during Partnership	—	—	—	—
Final System Age_2031 (Years)	The system age in 2031	—	—	—	—
New/Upgraded System (0 to 1)	New or Refurbished system	Refurbished system	New System		
Production year > 2020 (0 to 1)	The system continues to be manufactured in 2021	Descontinued	Continues to be manufactured		
System Technical Specifications (0 to 100)	The technical specifications of the system are in accordance with several system characteristics as mentioned in the modalities sheets.				Maximum rating 100
System OK to Site (0 to 1)	Minimum requirements for the site	The system has no minimum technical characteristics	The system has minimum technical characteristics		
System Maintenance Downtime (hours/year) ((MAX =1)	Hours required for annual preventive maintenance	System need many maintenance hours/year	System need some maintenance hours/year		
Average System Replacement Downtime (MAX =2)	Days required for system replacement	Many days to be replaced		Less days needed to be replaced	
Out of Hours Preventive Maintenance (0 to 3)	Preventive maintenance carried out after hours	Preventive maintenance in working hours	Out of Hours Preventive Maintenance		
Remote Assistance 365_24/7 (0 to 1)	Remote assistance carried out 365_24/7	Remote Assistance 365_24/7	Out of Hours Remote Assistance 365_24/7		
Positive Paciente Experience (MAX =3)	Positive experience for the patient	Nothing new for the client		The equipment denotes a increased comfort for the patient	Small Dose Radiation
Imagiologist Experience (MAX =3)	Positive experience for the Imagiologist	Nothing new for the doctor			Doctors do prefer these equipements with theses characteristics which improves producitvity and satisfaction
Postprocessing System (Server) (MAX =3)	System that helps the imagiologist in the pacient diagnosis	No Postprocessing System	Some features Postprocessing System	Partial automated postprocessing System	Full automated postprocessing System
Diagnostic workflow Tool System (CAD) (MAX =3)	Software to automate the workflow and system pre-parameterization	No automation tools	Few Diagnostic workflow Tool System	Partial Diagnostic workflow Tool System	Full Diagnostic workflow Tool System
Dose Monitor Management (MAX =1)	Radiation dose management software	No Dose Monitor Managment	Dose Monitor Managment		
Monitor Integrated System Management (MAX =3)	Software to monitor systems and patient examination time	No Monitor Managment	Monitor Brand system	Some competitors monitor system	All competitors monitor system
Remote Scanning Assistant & Control (MAX =2)	Possibility of assistance and remote control of the system	No Remote assistant & Control	Brand Remote Assistant & Control system	All competitors Remote Assistant & Control system	
Number of obsolete equipment (>10 years) (%)					

Appendix B

Beta for the project

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Beta of the Project	1,80	1,73	1,72	1,60	1,49	1,41	1,33	1,28	1,23	1,20

Appendix C

Cost of Capital

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Cost of Capital	12,5%	12,0%	11,9%	11,1%	10,3%	9,7%	9,2%	8,8%	8,5%	8,2%

Appendix D

Expected Spare Parts Costs

Spare parts for the 10 Year Low Risk Maintenance expectations	
Tubes	9 620 000 €
US probes	6 667 500 €
X-ray and Mammogram detectors	33 750 000 €
X-ray and Mammogram tubes	6 000 000 €
Helium	180 000 €
Coils	1 200 000 €
Total	57 417 500 €