Optimization of Patient Centred Processes

The Oesophageal and Stomach Reference Center at Portuguese Institute of Oncology Lisboa Francisco Gentil

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Declaration

I declare that this document is an original work of my own authorship and that it fulfils all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

Declaração

Declaro que o presente documento é um trabalho original da minha autoria e que cumpre todos os requisitos do Código de Conduta e Boas Práticas da Universidade de Lisboa.

Abstract

The oncology department is a complex environment requiring multiple professionals and departments coordination, and the limited budget create a complex decision for administrators in the healthcare field to increase efficiency with the existent resources. This isolated process structure in each service hinders the timely treatment of the patient and, in the case of disease situations with oncological pathology, this out-of-time treatment can significantly worsen the patient's health condition and undermine recovery.

The largest hospital in Portugal specialized in oncology is the Portuguese Institute of Oncology Francisco Gentil, and its center located in Lisbon (IPOLFG) is the hospital in analysis in this study. Due to the complexity of processes in the hospital environment the research focus on the reference center of oesophagus and stomach cancer, being one of the most severe pathologies and with a more aggressive diagnosis for the patient.

Thus, the aim of this dissertation is to implement a Multi-Priority Integer Programming model for the referenced organization to optimize the patient flow and the process time of the operations in the RCOS providing an increased patient satisfaction and serving patient's wait time targets.

The results obtained with the present study provide sufficient evidence that addressing priorities through the demand of patients in the department is more efficient than the patient scheduling method that is currently used in the department and the present implementation could improve the results in terms of care delivery and the consequent improvement in the patient health status.

Keywords: Oncology, Patient Flow, Multi-Appointment, Patient Priorities, Optimization, Mathematical Model

Resumo

O departamento de oncologia possui um ambiente complexo que requer a coordenação de diversos profissionais e departamentos, e o orçamento limitado cria uma elevada complexidade para os administradores da área da saúde aumentarem a eficiência dos processos com os recursos disponíveis. Esta estrutura de processos isolada em cada serviço dificulta o tratamento atempado do paciente e, no caso de situações de doença com patologia oncológica, este tratamento desajustado pode agravar significativamente o estado de saúde do paciente e prejudicar a sua recuperação.

O maior hospital em Portugal especializado em oncologia é o Instituto Português de Oncologia Francisco Gentil, e o seu centro localizado em Lisboa (IPOLFG) é o hospital em análise neste estudo. Devido à complexidade dos processos no ambiente hospitalar, o presente estudo foca-se no centro de referência do cancro do esôfago e estômago, sendo uma das patologias mais graves e com um diagnóstico mais agressivo para o paciente.

O objetivo da presente dissertação é implementar um modelo de programação linear de multi-prioridades para a organização referenciada de modo a otimizar o fluxo de pacientes e o tempo de processo das operações no RCOS proporcionando uma maior satisfação dos pacientes e atendendo às expectativas de tempo de espera dos mesmos.

Os resultados obtidos com o presente estudo fornecem evidências suficientes de que considerar diferentes níveis de prioridade para a procura de pacientes no departamento é mais eficiente do que o método de marcação usado atualmente no hospital, e a presente implementação poderia melhorar os resultados em termos de atendimento e a consequente a melhoria do estado de saúde do mesmo.

Palavras-chave: Oncologia, Percurso do Paciente, Prioridades de Pacientes, Otimização, Consultas Múltiplas, Modelo Matemático

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At the end of this journey, I would like to take the opportunity to thank all the people that help me to reach this accomplish in my life.

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I also want to express my gratitude to all my friend and colleagues from IST, especially my close friends. You made this journey happier and easier, and I hope that I could take you for life. Additionally, my high school friends for always being there for me, even in the most difficult moments and helping me to never give up and focus on my goals. For all of you, thanks for always inspiring me, you know what you mean to me.

Last, but certainly not least, I would like to thank all my family for their support and motivation through this important achieve of my life. For my parents, Maria and Pedro, thanks for your love and support through my life and teaching me to be better in whatever I want to be. To my brother João, thanks for your support and fellowship and to always be by my side celebrating my achievements. Also, a special word to my aunt Fátima, my grandmother Antónia and my godmother Cândida, you always carry me forward in my ambitions and support all my decisions. You are all my role-models and without your love it would not have been possible.

Ainda uma palavra especial para a minha avó Emília, espero que estejas orgulhosa de mim.

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List of Acronyms

DGS	Direção Geral de Saúde
EDA	Endoscopia Digestiva Alta
GAREF	Gabinete de Referenciação
GMCEE	Grupo Multidisciplinar Centro Referência Esófago e Estômago
IPOLFG	Instituto Português de Oncologia Lisboa Francisco Gentil
LEC	Lista de Espera de Consulta
MAPHSH's	Multi-appointment Scheduling Problems in Healthcare
MCDT	Meio Complementar de Diagnóstico ou Terapêutica
MIP	Mixed-Integer Programming
OR	Operational Research
PAI	Processo Assistencial Integrado
RC	Reference Center
RCOS	Reference Center of Oesophagus and Stomach
ROR	Registo Oncológico Regional
SNS	Serviço Nacional de Saúde

1. INTRODUCTION

The aim of this chapter is to introduce this dissertation, motivating the problem to be addressed and the goals of this research. This chapter is divided in four parts: section 1.1 develops and provides context on the problem under evaluation, section 1.2 focuses on the main goals of the dissertation, section 1.3 presents the research methodology and finally section 1.4 the structure of the remaining chapters.

1.1 Problem context

Cancer is considered the second leading cause of death globally and is responsible for an estimated 9.6 million deaths worldwide (World Health Organisation, 2018). In Portugal, cancer is the second most common cause of death. Providing optimal and effective methods to optimize this dangerous condition is a major challenge to healthcare organisations. The oncology is a multi-disciplinary department in charge of the research and treatment of cancer, and due to the severity and mortal condition of this disease methods to optimize the healthcare delivery in this department have been under research in the recent years. This multi-facility environment creates a difficult decision for clinical administrators to improve efficiency, since the coordination of these services and resources is critical for timely and efficient treatment of patients. A critic analysis focused on the patient path and the scheduling and timing of activities are necessary tasks to increase the potential results and meet the expectations of the patients. For that purpose, the dissertation focusses on the implementation of a mathematical model of optimization in order to fulfil patients scheduling priorities. In the case of Portugal, the biggest hospital in this field is Intituto Português de Oncologia, and for the purpose of the dissertation the center positioned in Lisbon (IPO Lisboa Francisco Gentil, IPOLFG) is the main motivator and supporter of the work. IPOLFG receives around 14.000 new patients/year and has currently in the system more than 57.000 patients (IPOLFG,2020). These numbers tend to increase due to the increasing number of cancer patients worldwide (World Health Organisation, 2018). Nevertheless, due to the complexity of processes in IPOLFG and the many departments it is important to focus the work in a reference center in order to obtain more concise and patient directed results. The one debated with the IPO Administration and selected under conditions such as priority and necessity for the IPOLFG is the oesophagus and stomach reference center (RCOS). This institution receives the highest volume of patients with oesophagus and stomach cancer in the country (120 new patients/year for oesophagus and 100 new patients/years for stomach), providing responsibilities to the area in the implementation, development and divulgation of strategies in the approach and treatment of patients. Furthermore, an analysis in the hospital ground is developed to understand the patient path with the purpose of identifying difficulties in the flow of the patients and give insights to further studies. In this context, the usage of sophisticated methods to support de decision-making in the hospital environment could potentially lead to more effective and efficient solutions and enhance the procedures and processes in the IPOLFG always aligned with the patient's expectation and performance levels that are a standard of excellence in this organization.

1.2 Dissertation Goals

The main goal of this study is to develop and use Operations Research (OR) methods to optimize the IPOLFG operations with focus in the oesophagus and stomach reference center. The model must allow understanding on the patient path, aligning with his/her expectations in the process. Must also manage effectively all the relevant scheduling process of consultations, coordinate all the multidisciplinary resources involved in the patient path and provide insights in the impact of the alternatives in the systems performance. The research goals of this dissertation include:

- Characterising the IPOLFG, focusing on the RCOS. The purpose is clarifying the most important components of the oesophagus and stomach reference center operations and the path of the patient, highlighting the multidisciplinary and complex nature of the decisions and planning processes that are already implemented.
- Reviewing previous researches in the field of oncology, centred in modelling approaches and their insights, in order to understand the work that was conducted by other researchers and understand how these studies may impact and support the development of the model to be structured in the dissertation.
- Identifying potential gaps in the literature related to the needs of the case-study and proposing alternative modelling approaches.
- Contributing to the existing literature by modelling, formulating, and implementing an optimization model in a real context.

1.3 Research Methodology

To achieve the above, the proposed research methodology includes five fundamental steps, as outlined in Figure 1.

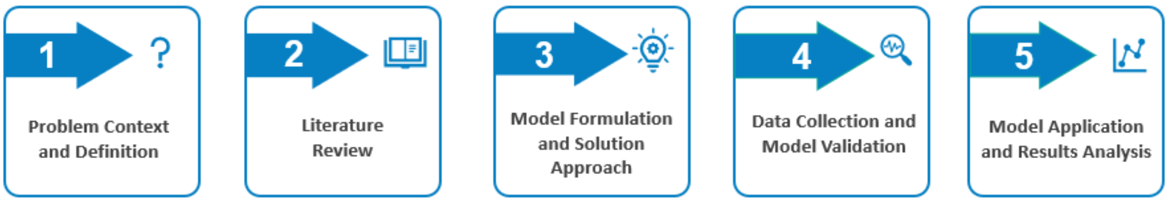


Figure 1 Purposed Methodology

- **Step 1 – Problem Context and Definition**

This step seeks to introduce the IPOLFG Oesophageal and Stomach department which serves as a case-study for this dissertation. It is highlighted its main objectives and features and described existing processes and performance indicators and the problem statement can be refined.

- **Step 2 – Literature Review**

The goal of the literature review is to survey the state-of-the-art of Patient Flow and Multi-Appointment Scheduling concerning the oncology department. A brief overview of the typical response process and associated metrics provides the theoretical foundation to present the wide range of optimization models available in the literature while also mentioning relevant solution techniques and applications for support studies not related with the oncology department namely in the patient priorities and selection from a waiting list.

- **Step 3 – Model Formulation and Solution Approach**

Considering the problem definition and relevant models in the literature, assumptions are stated, and a model is formulated. The Mathematical Programming model is developed under collaboration with IPOLFG, to ensure that it adequately addresses their needs.

- **Step 4 – Data Collection and Model Validation**

Relevant data for the model is collected with IPOLFG and treated. The model is then tested on real data to ensure its validity. Here, the impact of each major assumption should be tested. This step requires strict collaboration with IPOLFG and, likely, iteration with the previous step to refine the model to accurately describes the hospital environment.

- **Step 5 – Model Application and Result Analysis**

The model is applied to the case-study of to produce recommendations. Results are then analysed and discussed, and experiments are made to understand the impact of different constraints and scenarios on the performance of the system.

1.4 Structure of the report

To achieve these goals, the project is organized in seven chapters:

- **Chapter 1 – Introduction**

  Corresponding to the present chapter, it introduces and motivates the topic of this study, highlights the main goals to be achieved and outlines the report structure.

- **Chapter 2 – Case Study Description**

  The second chapter seeks to describe the case study in analysis in this dissertation. An overview on cancer is provided, followed by the presentation of the IPOLFG. Lastly the focus is the oesophagus and stomach reference center and information on the department operations.

- **Chapter 3 – Literature Review**

  The third chapter seeks to search the existing literature on OR methods with special focus on optimization models that could be applied in the oncology department field. This chapter presents several models focusing on the patient path and the scheduling process. Additionally a review on patient priorities and patient selection from a waiting list is developed.

- **Chapter 4 – Model Formulation**

  In chapter 4, insights gathered from the literature review and the description of the case study are leveraged to refine the problem statement and develop an optimization model aimed at supporting addressing patient scheduling in the IPOLFG oesophageal and stomach department.

- **Chapter 5 – Data Collection**

  This chapter details the data collection and treatment procedures required to apply the model to the case study. Underlying limitations and necessary assumptions in the data are described. Summary tables are presented with the input parameters resulting from these procedures.

- **Chapter 6- Case Study Results**

  Chapter 6 describes the implementation and computational experiments performed with the proposed model and solution approach. The main conclusions and findings of these experiments are described and recommendations for the department under study in the case study.

- **Chapter 7- Conclusions and Future Work**

  The last chapter summarises the most relevant features and conclusions of this study, highlighting opportunities for future research.

2. CASE-STUDY DESCRIPTION

The aim of this chapter is to describe the case study under analysis. The first section 2.1 is composed by an overview about the cancer disease that is the main issue that the oncology area tries to respond. Through subsections 2.1.1 to 2.1.3 it is analysed what cancer is, an analysis of the impact of the disease in Portugal and in the world and the principal treatment methods that are available nowadays. Furthermore, in section 2.2 introduces the hospital which motivates this work (IPOLFG). Through subsections 2.2.1 to 2.2.4 it is discussed the mission, vision and values of the organisation, the organisational structure, the principal milestones of the hospital in Portugal and the ways of access to the hospital. In section 2.3, and due to the complex number of services provided by the hospital, the analysis relies on the areas of interest in this work: oesophagus and stomach. Through subsections 2.3.1 to 2.3.5 all the operational components of the departments are analysed. Moreover, the problem under study is defined in section 2.4. Finally, chapter conclusions are made in section 2.5.

2.1 The Cancer Disease: Overview

In this section the main goal is to define the disease recognised as cancer. Firstly, cancer is defined and how it affects the human body (subsection 2.1.1). After that, an overview about the incidence of this disease in the world and with special focus in Portugal is conducted (subsection 2.1.2). The main insights of the process of treatment of this disease are defined in subsection 2.1.3.

2.1.1 What is the cancer disease?

The cancer disease is an abnormal proliferation of cells. The cancer starts in the cells, and then a set of existent cells form a tissue, and, in turn, the tissues form the organs of our body. Normally, cells grow and divide to form new cells, and in their life cycle, cells age, die and are replaced by new cells. Sometimes this orderly and controlled process goes wrong and new cells are formed without need for the organism and at the same time the existent cells don't die. This extra and not necessary group of cells form a tumour (National Cancer Institute,2015). In fact, not all the tumour corresponds to cancer. There are two types of tumours. Benign tumours, that are not known as cancer, rarely put in risk the human life and in general can be removed and most of times regress. The cells of the benign tumour don't proliferate, so they don't disseminate for the tissues around them or other organs. The other type of tumours is known as malign tumours, that are responsible for cancer. They could put the patient life in risk, because despite they can be removed in some cases (anticipate diagnosis), they also could grow again, and the cells of this tumours could invade and danificate other tissues and organs around them. Another dangerous condition of this tumour is that they could get off the primary tumour and enter in the blood stream or in the lymphatic system forming new tumours in other organs (metastasizing), complication the well-being of the patient. The name of the cancer is generally due to its source, for example, stomach cancer starts in the stomach. It is also known 5 types of cancer levels depending on his stage, and this description is referenced in the Table 1.

Table 1 Levels of cancer, National Cancer Institute (2015)

Level	Condition of the patient
0	There's no cancer, only abnormal cells with the potential to become cancer
I	The cancer is small and only in one area. This is also called early-stage cancer.
II and III	The cancer is larger and has grown into nearby tissues or lymph nodes
IV	The cancer has spread to other parts of the body. It's also called advanced or metastatic cancer.

Sometimes, some doctors could not reach an agreement for the reason of a patient developing cancer. Nevertheless, there are some risk factors that could contribute to the beginning of the cancer disease: aging, consuming tobacco and alcohol, sun or ionizing radiation, chemical exposure, virus and bacterium, hormones and also poor diet, lack of physical activity or excess of height. An analysis of the cancer situation with special focus on Portugal is evaluated in the further section.

2.1.2 Cancer Analysis

Cancer is considered the second leading cause of death globally and is responsible for an estimated 9.6 million deaths (World Health Organisation, 2018). Globally, about 1 in 6 deaths is due to cancer, so it's visible that is a major challenge to healthcare organisation to tackle this disease. The most common types of cancer worldwide are lung (2.09 million cases), breast (2.09 million cases), colorectal (1.8 million cases), prostate (1.28 million cases), skin cancer (1.04 million cases) and stomach (1.03 million cases). Approximately 70% of deaths from cancer occur in low and middle-income countries (World Healthcare Organisation,2018). The five countries with more incidence of global cancer rate per 100.00 habitants are Australia (468 cases), New Zeeland (438.1 cases), Ireland (373.7 cases), Hungary (368.1 cases) and US (352.2 cases) (Global Cancer Observatory,2018). In the specific case of Portugal, cancer is the second most common cause of death in the country and his incidence grow 3% per year (Global Cancer Observatory, 2018). Is a fact that in Portugal ¼ of the population has the risk of contracting cancer in the age of 75 and 10% could die due to the disease condition (World Health Organisation,2018). Another relevant stat is that 25% of the deaths in Portugal are due to cancer. The most common type of cancer in the country is Colorectum with 10270 new cases registered having a weight of 17,6 percent of the total types of cancer, and the other most common types are breast (12%), prostate (11,4%), lung (9,1%) and stomach (5%). A chart with that information can be observed in the Figure 2.

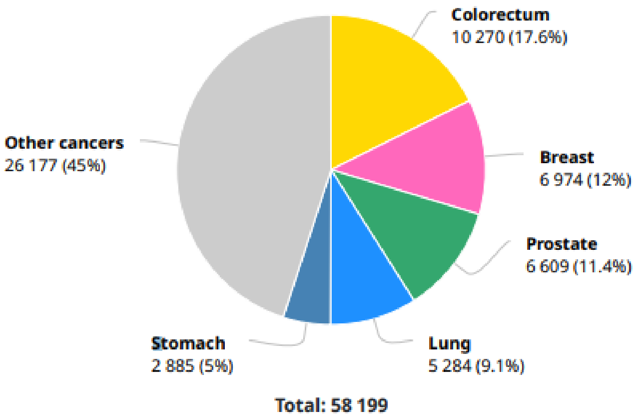


Figure 2 Most common types of cancer in Portugal, Global Cancer Observatory (2018)

A more detailed analysis can be observed in the Table 2, concerning the incidence of the disease in a specific gender. It can be observed that the type of cancer with more incidence in males is prostate while in females is breast. Furthermore, the number of cases is higher in females in Portugal, while males has a higher risk of developing cancer before the age of 75, and the number of death cases is also higher in males. Furthermore, in five years is estimated that the number of prevalent cases in males will be higher than in females. For further analysis is also important to note that stomach cancer is also a very common type of cancer in Portugal with incidence in females and males.

Table 2 Cancer analysis in Portugal, Global Cancer Observatory (2018)

	Males	***Females***	***Both Sexes***
Population	4 871 173	5 420 025	10 291 198
Number of new cases	32 475	25 724	58 199
Age-standardizes incidence rate (World)	312.1	218.4	259.5
Risk of developing cancer before the age of 75 years (%)	30.8	20.9	25.6
Number of cancer deaths	17 607	11 353	28 960
Age standardized mortality rate (World)	147.4	68.7	10.6
Risk of dying from cancer before the age of 75 years (%)	14.7	6.9	10.6
5 years prevalent cases	79.608	76 037	155 645
Top 5 frequent cancers excluding non-melanoma skin cancer (ranked by cases)	Prostate Colorectum Lung Bladder Stomach	Breast Colorectum Thyroid Lung Stomach	Colorectum Breast Prostate Lung Stomach

Despite all the data observed, this field suffered a major advance in recent years and today there are some efficient and high-quality treatments and specialized centres to tackle this disease. In the next section, it is analysed the principal types of cancer treatment available and the general process of treatment in an oncologic patient.

2.1.3 Cancer Treatment

The field that studies and treats cancer patients is known as oncology. Oncology is the branch of medicine that researches, identifies, and treats cancer. A physician who works in the field of oncology is an oncologist (Healio, 2017). The process of treating an oncologic patient is a complex network and involves series of steps.

The first step is known as the diagnosis. In that case, if the patient has a specific symptom or the result of some screening test suggest the exitance of a tumour, it is necessary that a doctor verify if is related to cancer or some other motive. The oncologist could suggest some questions to the patient related to his/her clinic and familiar history as a physic exam. Also, can be necessary to do some other exams like blood/urine/other fluids analysis, x-ray exams or others. In the most common cases it's necessary to do a biopsy to diagnosis the cancer, it consists in the removal of a sample of a tissue and analysed in laboratory. After being concluded the diagnosis, and if it is confirmed it's cancer, the treatment plan begins. The doctor could suggest an appointment with a specialist. The treatment can include a vast number of specialists: oncologist, gynaecologist, pneumologist, intern medicine, radiotherapist and the patient can have different types of specialists during his treatment process regarding the required procedures. The treatment begins, generally, a few weeks after the diagnosis of cancer, giving time to the patient to talk with the doctor about the options of treatment and in the most cases is recommended to listen a second opinion with another specialist. The treatment plan depends mainly on the stage of the disease. The doctor has also in consideration the age and the general health state of the patient. Frequently the purpose of the treatment is to cure the cancer, but in some other more difficult cases, the purpose is to control the disease and reduce the symptoms the longest time frame possible. Also, the plan of treatment can be changed during the time. So, with that in mind, cancer treatments may be used as (Mayo Clinic Family Health,2018):

- **Primary treatment**: The goal of a primary treatment is to completely remove the cancer from the patient body or kill all the cancer cells. Any cancer treatment can be used as a primary treatment, but the most common primary cancer treatment for the most common types of cancer is surgery. If the cancer is particularly sensitive to radiation therapy or chemotherapy, the patient may receive one of those therapies as a primary treatment.
- **Adjuvant treatment:** The goal of adjuvant therapy is to kill any cancer cells that may remain after primary treatment in order to reduce the chance that the cancer will recur. Any cancer treatment can be used as an adjuvant therapy. Common adjuvant therapies include chemotherapy, radiation therapy and hormone therapy. Neoadjuvant therapy is

similar, but treatments are used before the primary treatment in order to make the primary treatment easier or more effective.

- **Palliative treatment**: Palliative treatments may help relieve side effects of treatment or signs and symptoms caused by cancer itself. Surgery, radiation, chemotherapy and hormone therapy can all be used to relieve symptoms. Other medications may relieve symptoms such as pain and shortness of breath. Palliative treatment can be used at the same time as other treatments intended to cure your cancer.

As already mentioned, the most common types of treatment for cancer are explained in the Table 3 and some additional treatment procedures.

Table 3 Types of cancer treatment, National Cancer Institute (2015)

Type of treatment	*Process*
Surgery	Procedure in which a surgeon removes the cancer from the patient body
cHEMOTHERAPY	Use of drugs to kill cancer cells
radiation theraphy	Use of high doses of radiation to kill cancer cells and shrink tumours
immunotheraphy to treat cancer	Helps the patient immune system fight cancer
targeted terapy	Targets the changes in cancer cells that help them grow, divide, and spread
hormone terapy	Slows or stops the growth of breast and prostate cancers that use hormones to grow
steam cells transplant	Procedures that restore blood-forming stem cells in cancer patients who have had theirs destroyed by very high doses of chemotherapy or radiation therapy.
Precision Medicine	Precision medicine helps doctors select treatments that are most likely to help patients based on a genetic understanding of their disease

The next section analyses the biggest Portuguese hospital in the field of oncology recognised in Portugal, that is the focus and the main motivator and supporter of this dissertation.

2.2 The Hospital: IPOLFG

The Portuguese Institute of Oncology Francisco Gentil (IPOLFG) is a public multidisciplinary oncologic centre under the surveillance of the Portuguese National Health Service (Serviço Nacional de Saúde, SNS). IPOLFG is responsible for the delivery of healthcare services in the field of oncology, with further activity in the areas of research, education, prevention, diagnostic, treatment and rehabilitation making sure that each patient is addressed with properly care that reach his necessities and the usage of best clinical practices with efficient utilization of the available resources. In this section the mission, vision and values of the organisation are stated (subsection 2.2.1) as well as the organisational structure (subsection 2.2.2) and the principal milestones of the hospital in Portugal (subsection 2.2.3). Lastly is defined how the patients enter in the hospital system through the reference system explanation (subsection 2.2.4).

2.2.1 Mission, Vision and Values

The mission of IPOLFG is defined as to "achieve excellence in the healthcare delivery through all the intervention domains, promotion and contribution to education and instigate the investigation with concrete standards of scientific principles, humanization, motivation and presence for all the citizens and professionals" stating the high-quality standards that the hospital aims to pursue (IPO Lisboa,2020). Furthermore, the vision of the hospital is to "become a reference model in the SNS namely in healthcare delivery, education and investigation in oncology" and moreover "provide creation of value through policies of sustainability, efficiency and external recognition" (IPO Lisboa,2020).

The principal values that the organisation is compromised for conducting its activities are structured with the purpose of always putting the patient in the first place. The values are: respect the patients, humanized practices, respect the access rules, technical patterns of excellent (reference centre in national and international level), innovation and continuous improvement in quality, valorisation of the collaborators and efficiency. After clearly defining the mission, vision and values of this institution, the next chapter provides the explanation of its organisational structure.

2.2.2 Organisational Structure

The IPOIFG is divided in three major areas, and all of them are under the Administration Board composed by the president, clinic director, nurse director, financial vogal and vogal. Under the administration council there are three major areas: Clinical Area, Research and Education Area and Information Management and Logistic Support Area. In order to support the decisions of the Administration Board there are two areas: the consultive council and the fiscalization organ providing services of internal auditory. In this dissertation the focus is the optimization of the processes in the Clinical Area, that is going to be the group in analysis. Regarding the Clinical Area the IPOLFG is reference center for services provided in the following areas: colon, rectum and anal channel cancer, testicular cancer, paediatric oncology, bones sarcoma and soft parts and finally in the oesophagus and stomach cancer. Being a RC (Reference Center) means that the IPOLFG gathers the highest exponent of competencies in the provision of high quality healthcare in clinical situations that require a concentration of highly differentiated human, technical and technological resources, knowledge and experience due to the complexity of diagnosis, treatment and high costs, while still being able to conduct postgraduate training and scientific research in the respective medical fields (IPO Lisboa,2020).The focus of this dissertation relies on the reference center of the oesophagus and cancer (RCOS) pathology, and a dissection on this center is explained in the section 2.3 of this dissertation.

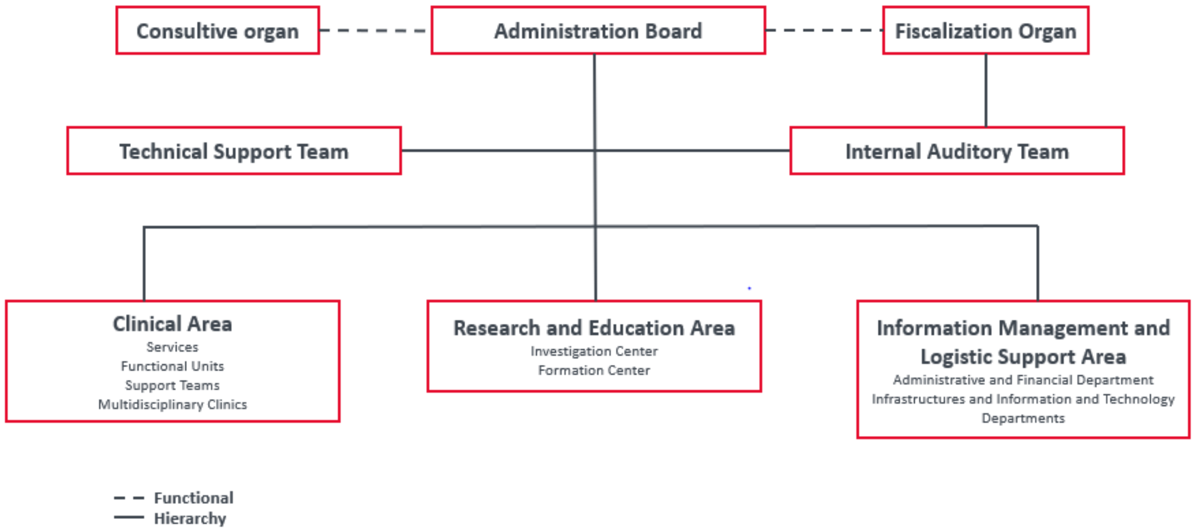


Figure 3 IPOLFG Organogram, IPOLFG oficial website 2020

2.2.3 Milestones in Portugal

The history of the institution turns back to 1923 with the foundation of the "Portuguese Institute for Cancer Research" based on the more advanced studies for the oncology area in order to give assistance for the cancer research in Portugal. In 1931, and to mobilize the civil society to this concern the "Commission of Particular Initiative in the Fight Against Cancer" is created. Another important mark in the history dates to 1940 where the first school for technical nurses is created providing qualified and trained personnel for this cause and in 1941 the "Portuguese League against Cancer" arises. The 1960s are marked by the formation of the paediatric unit in the hospital, in order to help children until 15 years old with oncologic problems and in 1961 the hospital founder and one of the most mediatic persons in this field in Portugal, Francisco Gentil, is named the director. This personality became sick with cancer years later and in 1965 due to his death the hospital is renamed to "Instituto Português de Oncologia Francisco Gentil" in his honour to gratify all his life work. Later, in 1983 the Oncology is recognised and created as an isolated discipline in the course of medicine and in 1992 the Medical Order recognises Oncology as an autonomous specialty. In recent years the IPOLFG is becoming recognised by different organisations in the oncology field. In 2011 the hospital was certified by the Organisation of European Cancer Institute by the quality of its services. Later in 2015 the hospital receives the gold medal for distinct services by the Ministry of Health and was certified by the European Society of Oncology Medicine as an integrated center for palliative care. Furthermore, in 2017 was officially recognised for the Ministry of Health as a reference center for adult oncology. In order to continuously improve their services despite all the recognise that the IPOFG already has, in 2018 the hospital began a plan of investment focused on the modernization of the facilities and the comfort of the patients and doctors focused on health technology and information and communication technology. These milestones can be observed in the Figure 4. The next section focusses in the different ways of reference to the hospital in order to enable the entrance of the patient in the system.

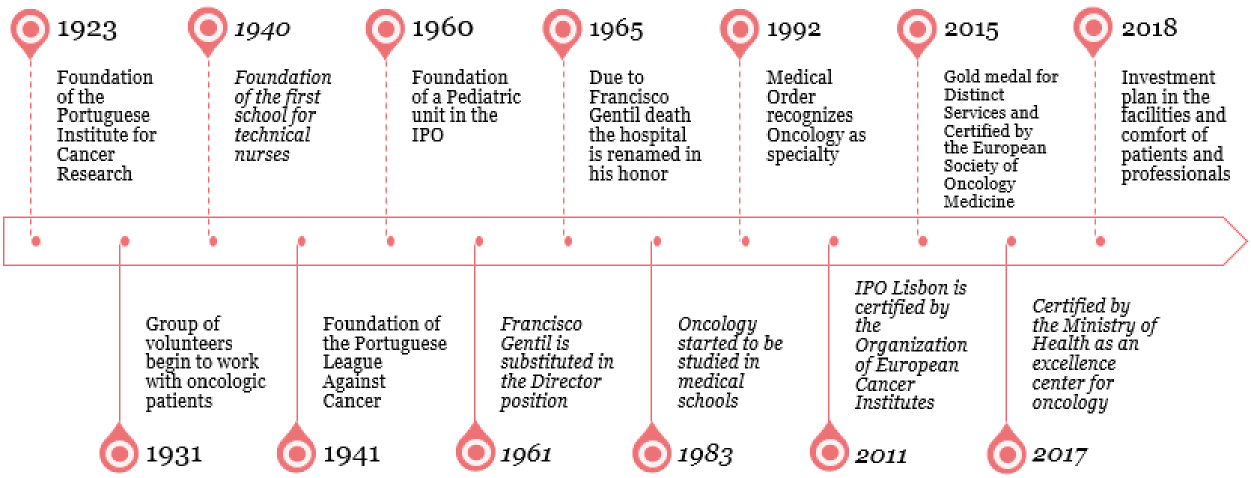


Figure 4 Principal Milestones in Portugal of IPOLFG, IPOLFG official website 2020

2.2.4 Access to IPOLFG

In order to access IPOLFG, the patients need to be referenced by different organisations, because the hospital doesn't provide an emergency department. This reference could be proceeded by four different types and all this process is represented by the flowchart in the Appendix A.

- **Referencing by ALERT:** The referencing of patients by the ALERT system occurs when a patient is referenced by a primary health center to IPOLFG, with sending of information of consultation via informatic system. This request is redirected to the hospital by the informatic tool ALERT P1 and must be sent with detailed clinic information of the patient and complementary exams.

- **Referencing by GAREF:** The GAREF (Gabinete de Referenciação) corresponds to the reference of patients to the hospital via Health Centers, Hospitals, Embassies, Private Doctors and the Portuguese Directorate of Health (Direção Geral de Saúde, DGS). The consultation booking is sent to the hospital through email, fax or letter to the GAREF with also detailed clinic information of the patients and complementary exams requested.

- **Direct Reference:** The direct reference corresponds to the reference that is done directly by the patient, Health Centers and other institutions in the IPOLFG presencially. In that case is requested to deliver to the patient specific documents for him/her to fill and deliver to the secretary. After all the documents have been filled, the information is sent to a triage doctor. That triage doctor analyses the request, refusing or booking a consultation.

- **Internal Reference:** This type of refence corresponds to the one that is done between the different services provided by IPOLFG.

With that information is concluded that the entry of a patient can be very different and can conditionate all the path that this patient has in the hospital. This process is important to be under evaluation when analysing the reference of the patient to the RCOS that is going to be analysed in the next section and is the purposed area of analysis in this project.

2.3 Reference center: oesophagus and stomach

Due to the complexity of processes in IPOLFG and the numerous existences of departments is necessary to focus the work in a reference center: oesophagus and stomach. This reference center was selected with the IPOLFG Administration Board under conditions such as priority and necessity of the IPOLFG, and the condition of being a reference center as already explained highlights this decision.

The oesophagus is a part of the digestive tube that transport the aliments from the mouth to the stomach. The principal symptom of oesophagus cancer is difficulty to swallow, that generates abnormal loss of weight and is generally diagnosed lately. The oesophagus carcinoma is a type of cancer with one of the most severe prognostic, with a global survivance rate of 15-30% in 5 years, being the 8th most common in the world (World Cancer Observatory,2018). The patients diagnosed with this disease generally are already in an advanced state. Approximately 50% of the patients in the diagnosis process show metastasizing advanced and 25% will develop metastasizing (PAI Oesophagus and Stomach,2018). Regarding the treatment of this disease it could be involved by different therapeutic modalities. In the most cases chemotherapy and radiotherapy is needed to reduce the size of the tumour and then a surgery is often required. The IPOLFG receives 120 new patients/year with oesophagus pathology diagnosis (corresponding to 1/3 of the cases identified in the south region of Portugal (Registo Oncológico Regional, ROR)).

The stomach cancer or gastric cancer is the 5th most common cancer worldwide (World Cancer Observatory,2018). Early stage stomach cancer rarely causes symptoms, making early detection very difficult. Stomach cancer may or may not present with vague gastrointestinal symptoms, including indigestion, abdominal pain or discomfort, nausea and vomiting, bloating, or the feeling of fullness when eating a meal (also called early satiety) (World Cancer Observatory,2018). The overall 5-year survival rate is 29.3% (PAI Oesophagus and Stomach,2018). Stomach cancer is treated with surgery, chemotherapy, radiation, or a combination of these. Surgical options depend on the extent of cancer within the stomach and include partial or total gastrectomy (removal of the stomach). IPOLFG receives 100 new patients/year with gastric cancer diagnosis all followed in this reference area (Pai Oesophagus and Stomach,2018)

The PAI (Processo Assistencial Integrado) is a work tool used in the hospital that organises the diverse components of the oesophagus and stomach area defining objectives, risks, performance indicators and flow of patients to every actuation level. With this is possible to obtain homogenization of the diagnosis and results with a continuous improvement of quality standards.

This section is structured in order to identify all the processes in the oesophagus and stomach reference center. Firstly, is defined the departments and services provided (section 2.3.1). Then the patient path in the hospital environment is analysed (section 2.3.2). Also, the principal objectives of the PAI (section 2.3.3) and the performance measures of this area (2.3.4). Finally, the multi-appointment scheduling coordination is studied (section 2.3.5).

2.3.1 Departments and Services

The RCOS coordinate his activities with different other departments and services with proposes to help the patient in all his flow in the hospital. The approach in the oesophagus and stomach area is multidisciplinary, integrating in a formal way all the specialties involved in the diagnosis, treatment and vigilance of all the patients with this pathology. The departments involved in this process are described in this section and also all the responsibilities that they have.

Gastroenterology: This area concerns professionals from all the problems regarding the digestive system and as principal consequence the stomach and oesophagus. In the decision process, gastroenterology is responsible for the admission of patients in the IPOLFG for consultation of diagnosis effect and if necessary, the requisition of exams in order to analyse the stage of cancer that the patient is in. This department must also participate in the discussion for the diagnosis approach, stage and therapeutic orientation and following the patients analysed in the group consultation and also give a fundamented proposal of treatment, attending the elements discussed and articulated with other specialty areas as referenced for a final decision regarding the global therapeutic plan. Mus also program gastroenterology bookings for the following of the patient when decided by the group.

General Surgery: This specialty axialite the gastroenterology department in the admission of patients in the IPOLFG for stomach and oesophagus cancer and can also report the requisition of stage exams. Is one of the departments that participate in the group consultation. Must also book a surgery consultation when decided by the group.

Radiology: This area is responsible for the evaluation of the imageology exams done outside the hospital and discussion of the exams done in the hospital. Must also propose/book new exams when is suited and necessary. The comprehension of the process from this area is also favourable and necessary in the discussion of clinical diagnosis, staging and following of patients evaluated.

Nuclear Medicine: In the department of nuclear medicine, the principal responsibilities are evaluation of the exam results done by the patient and discussed in the consultation. Also booking of new exams when necessary for the patient.

Pathologic Anatomy: The pathologic anatomy department analyses the results of anatomic-pathologic exams done by the patient and discussed in the consultation in the date of diagnosis or in the evaluation of therapeutic response when referenced and with booking of additional studies when necessary and suitable.

Medical Oncology: The medical oncology department must also participate in the discussion of clinical diagnosis, staging and following of patients evaluated in the consultation. Their insights are fundamental for the proposal of treatment, attending the elements discussed and in articulation with other specialties when referenced with the goal of a group final decision of the general therapeutic plan. Is also relevant the planning of the medical oncologic consultation for the therapeutic planning and following of the patient when is requested and decided by the group

Radiotherapy: The principal responsibility of this department is the booking of the radiotherapy consultation plan when is decided by the group and participate in the group consultation.

Anaesthesiology: The notable insight of this department in the diagnosis and therapeutic approach is regarding the risk evaluation in chirurgical anaesthesia for chirurgical procedures and booking of specific interventions when necessary.

Internal Medicine: Internal Medicine Department participates in the discussion of diagnosis and therapeutic approach namely in terms of comorbidity evaluation and booking of specific interventions when necessary. The department must also manage the patient in the after operatory frame in function of the comorbidities**.**

Nutrition: This department is in charge of the evaluation of the initial nutrition state of the patient. The participation in the discussion of diagnostic approach namely in the evaluation of nutrition state and programming of therapeutic interventions in this field when requested in all the treatment process of the patient is the biggest input of this department in the process.

Social Assistance: This department is also important for the monitoring of the general condition of the patient namely in the evaluation of the initial social state and programming of intervention in this field when is considered necessary.

After analysing the departments involved in the process and their principal responsibilities the next step is to identify all the path of the patient in the reference center with the flowchart evaluation that is going to be the next section scope.

2.3.2 Patient Flow

The flow of patients involves the sequential activities for the diagnosis, staging, treatment and monitoring of the patient with oesophagus or stomach cancer. The flowchart of the patient flow within the oesophagus and stomach reference center can be observed in the Figure 4.

Firstly, is necessary to clearly define the boundaries of the system in analysis. The boundaries of the flowchart represented in the Figure 5 can be presented as:

- **Boundary of entrance:** All the patients with oesophagus or stomach cancer diagnosis, established by evaluation of different support exams (biopsy, cytology, etc) reference by the IPOLFG.
- **Boundary of exit:** Death of the patient, 5 years of vigilance after final therapeutic without evidence of active disease or therapeutic complications that obliges hospital follow up or patient willing of leaving the treatment.
- **Marginal Boundary:** Genetic risk of stomach cancer, other origin tumours that affect the stomach or oesophagus and patients with diagnosis of injury pre-malignant

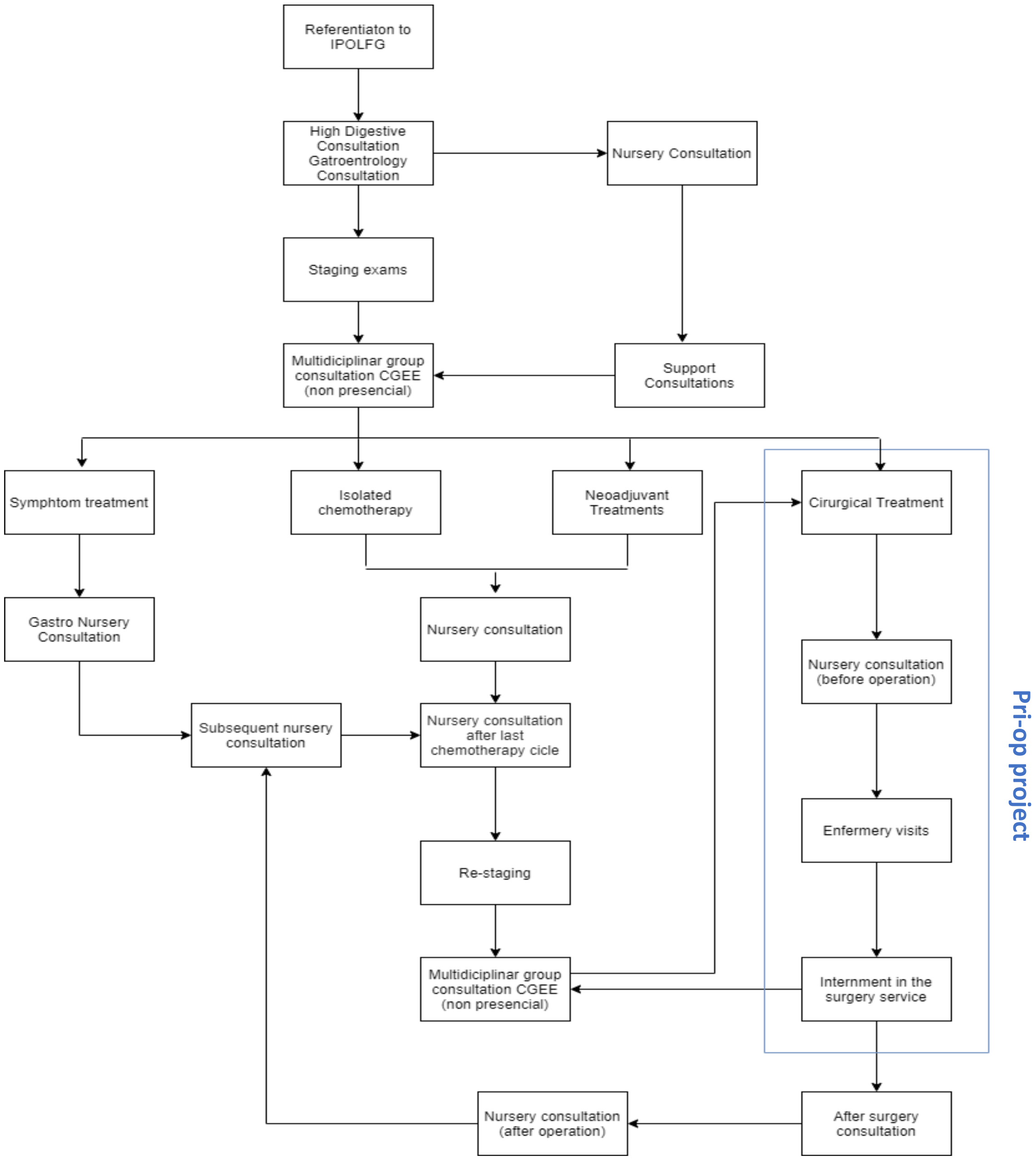


Figure 5 Flowchart of the patient on both oesophagus and stomach area, (OSRC,2019)

First the patient enters in the system with diagnosed pathology of oesophagus or stomach cancer. For the purpose of this flowchart is considered that the patient is already registered and in the system of the hospital. After that, is provided to the patient a first consultation in the reference center where the medical staff such as the gastroenterology professionals, medical oncology and radiotherapy professional are in charge of reviewing the clinical history of the patient and register the exams that are already done or request some more for detailed information and evaluation of the social and nutritional state of the patient. After that is necessary to confirm the diagnosis and thus may be necessary some complementary exams of pathologic anatomy in order to evaluate the stage of the cancer. In parallel a nursery consultation is performed where the functional status of the patient is analysed and some support consultations as nutritional or social are booked in order to fulfil all the exams to the group consultation. Furthermore, after all the exams are completed, is necessary to develop a group consultation where a revision of the complementary exams and the discussion of therapeutic plan of treatment is provided. This discussion is followed with the presence of different department professionals' reference in the section 2.3.1. Is also in this point that the patient could leave the hospital system and the path is finished if some of the exit boundary factors are involved in that stage. The results of the group consultation are communicated to the patient and another consultation is needed to discuss the proposal of treatment with the patient and to discuss the plan of monitoring after and before the treatment. After all that done the patient begins his treatment phase and in the specific case of the RCOS it can be one of the four options represented in the Figure 4 or a series of them: symptom treatment, isolated chemotherapy, neoadjuvant treatments or chirurgical treatment. Regarding the chirurgical treatment, the pri-op project is a serie of procedures that help the patient to be prepared for the surgery. This is a continuous process of planning that fulfil all the steps needed before the actual surgery. After the treatment stage the patient is revaluated with another staging exam which is checked by the professionals in the group consultation to confirm if the process is finished or if the patient needs to continue the treatment process.

The optimization of the processes in this system is a challenge to the organisation since the IPOLFG is the national center that receives the highest volume of patients with oesophagus and stomach cancer, providing responsibilities to the area in the implementation, development and divulgation of strategies in the approach and treatment. In order to control the quality of the system the RCOS have defined objectives aligned with the patient expectations of the process that is going to be analysed in the further section.

2.3.3 Objectives of the RCOS

An evaluation regarding the patient expectations and consequently his/her family and the response that the department can give to them is provided by the RCOS. The department provides consultations done systematically and satisfaction questionnaires to the patients for them to fill and evaluation of results by all the professionals in the institution. The Table 4 represents the main expectations of the patients and his/her families in all the clinical process and the objectives that the RCOS commit to fulfil in order to satisfy the patients requests.

Table 4 Expectations of the Patients vs Objectives of the RCOS, OSRC 2018

Expectations of the Patients and Families	Objectives
Fast patient care	• Booking of the first consultation and date of the consultation in the IPOLFG (2 weeks) • Date of the first consultation and discussion of the GMCEE (15 days) • Date of the therapeutic decision by the GMCEE and beginning of treatment (5 weeks)
Access to the best diagnosis and therapeutic options	• Protocols of clinic actuation based in the best scientific evidences • Assure the monitorization of protocol faults • Assure the monitorization of the results/indicators of performance
Guarantee of security in all the procedures	• Define risks of every step in the patient flow • Make strategies to prevent risks
Access to personalized care adapted for specific clinic necessities and also psychologic and social	• Guarantee the access to services of support that include evaluation of social, nutritional and psychological support to patients and family

These objectives are evaluated by performance measures established by the RCOS and discussed in the next section since one of the biggest challenges of this area is to align the patient expectations with the complexity of treatment.

2.3.4 Performance Measures

A performance indicator is a type of indicator that strives to analyse the performance of a system. In this specific case, and regarding the more convenient indicators for the purposed model, they can be divided in two categories: result indicators (corresponds directly to the result of the system) and process indicators (corresponds to the indicator that gave the performance of a certain branch of the process).

Regarding the result indicators an analysis could be observed in the Table 5. These indicators refer the performance rate of the department regarding their accuracy in establishing the processes. When analysing these indicators, the satisfaction rate is considered high with 75% of the patients showing that they are satisfied with the path in the hospital. Another relevant stat to take into consideration is that this department makes at least 20 operation per year (oesophagus and stomach), that isn't considered a high number of procedures and although is verified some complications after the operation for 40% of patients, so it states that is important to follow the patient after the treatment is concluded, a process that could be a major struggle for the department in managing the regulation of the patients in the system.

Table 5 Result indicators, OSRC 2018

Performance Indicator	Descriprion	Pattern	Priority
Satisfaction rate	$\frac{\text{Sum of the patients that respond “Satisfacted” or “Very satisfacted” in the survey}}{\text{nº of specialties}} \times 100$	75% in every parameter	High
Nº of new surgery's/year	Number of patients that are diagnosed with oesophagus cancer and submitted to surgery and patients that are submitted to surgery of primary tumour recession in a 12 months frame	Minimum 20 for oesophagus and stomach	High
Rate of after operatory complications	$\frac{\text{Patients submited to surgery in IPOLFG and registered with complications of surgery}}{\text{Patients submited to surgery in IPOLFG}} \times 100$	40%	Medium

Regarding the optic of fast patient care is important to analyse the process indicators that focus on the time between the decisions and procedures to be done before the patient start the treatment. The Table 6 concerns this type of indicators.

Table 6 Result indicators, OSRC 2018

Performance Indicator	Description	Pattern	Priority
Patients with therapeutic validated by the GMCEE	$\frac{\text{Patients with oesopaghus and gastric cancer evaluated in IPOLFG before starting treatment}}{\text{Patients with oesophagus and gastric cancer that has done any active treatment in IPOLFG}} \times 100$	95%	High
Time between the 1st consultation and therapeutic decision by the GMCEE	Average and median of the rime frame between the date of the 1st consultation and the date of the consultation when is decided the therapeutic process	4 weeks to 90% of patients	High
Time between therapeutic decision by the GMCEE and beginning of treatment	Average and median of the rime frame between the date of the consultation that is done the therapeutic decision and the date of the 1st treatment	5 weeks to 90% of patients	High

We can observe that the entrance rate is very high since 95% of the patients that have therapeutic evaluated in the GMCEE are validated to the process, so it means that the diagnosis phase for the referring of the patient to the OSRC treatment is very efficient. Regarding the times that are more relevant to analyse this process, the time between the first consultation and the therapeutic decision and the time between this therapeutic decision and the beginning of treatment, for a big group of patients (90%) are too long. The optimization of this time is going to be an analysis in the further dissertation.

The next section is conducted in order to analyse how is managed the scheduling management in the patient path, speciality in the timing between consultations that is a critic process that majorly affects the patient flow due to the multi-appointment problematic in this field.

2.3.5 Multi-Appointment Scheduling

Another level of concern is the multi-appointment scheduling management. As verified in the section 3.2.2 the patient in his path in the reference center needs multiple consultations, and the timely management of those bookings has a major importance in the efficiency of the system, namely in the timing between the first consultation and the therapeutic decision and the time between this therapeutic decision and the first treatment.

In this section is done an analysis for that purpose. In the Figure 6 we can observe the time between the first consultation and the therapeutic decision. It is visible that in the time frame in analysis this procedure drops in terms of time significatively in the oesophagus and stomach cancer reference center. Since 2016 there was an effort by this department to diminish the most possible the time that was considerably high (49 days for oesophagus and 48 days for stomach), In 2020 the progress is visible (7 days for oesophagus and 9 days for stomach) but the tendency is always to decrease this time and the optimization of this process is the way to do it. Although is important to notice that, in this indicator, the department is exceeding the objectives purposed in the section 2.3.4 (See Table 6).

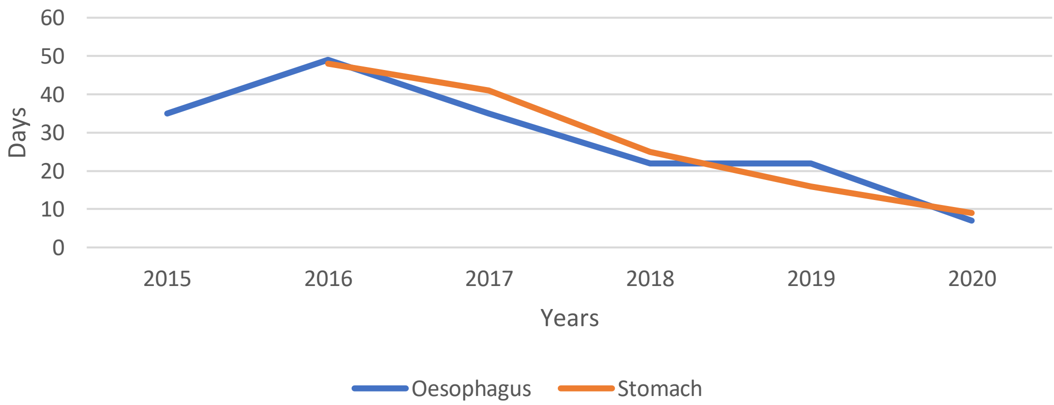


Figure 6 Time between first consultation and therapeutic decision, OSRC 2020

Another important process time is the time between the therapeutic decision and the beginning of the first treatment, and the relevant data is showed in the Table 7. In this analysis is important to categorize the patient’s treatment because the process is individual. There are three types of treatments that are analysed: surgery, chemotherapy and EDA (Endoscopia Digestiva Alta) that is a procedure of treatment very common in this area. The analysis is conducted in this type of treatments due to the information that was provided by the RFOS department but there is other type of treatments that must be evaluated in the further dissertation. For the purpose of this analysis the gaps in the table correspond to absence of information. Is visible that despite in surgery the number of days show a significative decrease, in the other types of treatment they are a significatively high. Focusing on the year of 2018 the palliative chemotherapy for stomach had 97 days of waiting while EDA Treatment for stomach had 53 days. Although the tendency shown is to decrease the days of process an analysis of this indicator is important for the further optimizing process. With the overview of the processes in the oesophagus and stomach center the next section will be focused on the problem defenition that this dissertation strives to pursue.

Table 7 Time between therapeutic decision and 1º treatment (days), OSRC 2020

	Type of treatment					
Year	Surgery		Chemotherapy		EDA Treatment	
	Oesophagus	Stomach	Neoadjuvant for Oesophagus	Palliative for Stomach	Oesophagus	Stomach
2016	65	-	-	-	-	-
2017	34	23	22	-	-	-
2018	24	36	24	97	22	53
2019	23	29	28	32	13	-
2020	7	-	-	-	-	-

2.4 Problem Definition

The aim of this dissertation is to develop and apply a mathematical model in order to help the IPOLFG to the optimize patient flow, the process time of the operations in order to achieve patient lead-time, namely in the multi-appointment scheduling, in the RCOS providing an increased patient satisfaction and serving patient’s wait time targets.

In the model is important to take into consideration the complexity in the approach of the patients, since the diagnostic process is different for an individual person and the condition of the disease could change at every stage, increasing the complexity and emergence necessity of effective operations. Furthermore, this complexity should always be aligned with the patient expectations on the process since the levels that the hospital compromises to attend should never be lower than the patient expectation. The model should carefully consider the wait time targets, considering the mortal condition of the cancer disease. The model must also consider some restrictions as limited resources, difficulty of coordination and communication in departments with different levels of expertise.

For the purpose of this analysis the reference center chosen was the oesophagus and stomach reference center. This reference center is selected not from being the most prevalent type of cancer but is one of the most aggressive pathology's in the field and the optimization of the process could help the patients to obtain a better experience in the process and help the healthcare providers to fully address the patient necessities. The PAI is an example of the effort of the hospital in optimizing their departments. Although is verified that the performance level is not already optimized to their highest peak, serving as motivation to this investigation.

The model in elaboration take into consideration important decisions to evaluate in the department (referenced in the model as decision variables), the objectives that the RCOS wants to fulfil (in the model referenced as objective function) and lastly the restrictions addressed to the model. With that said, is already clear that the decision variables are going to be under the multi-appointment scheduling and patient flow. The objective function is going to minimize the patient path through minimizing the time between the consultations, but always maximizing the patient expectations of the process. Some restriction associated to the model are going to be the patient wait time targets, available capacity and patient priorities. The next section presents the conclusions of this chapter.

2.5 Chapter Conclusions

The IPOLFG is an hospital highly referenced in the field of oncology. The history of this hospital provides a conclusive view of the evolution of the field in Portugal due to the excellence work of this organisation. The severity and mortal condition of the cancer disease point out the necessity of optimizing the processes in order to help the patient to timely and effectively surpass this condition. The goal of this work is to address the reference center of oesophagus and stomach cancer applying a mathematical model that is capable of suggest an optimal path for the patients achieving better timing in the operations and better coordination among the departments. At this stage is important to give an overview on the existing literature in OR used in healthcare providers focused on the cancer research in order to understand the approaches that could be done to address this problem. The information that supports the development of the methodology is analysed in chapter 3.

3. LITERATURE REVIEW

This chapter is structed in order to review the literature that strive to optimize the healthcare delivery processes within the healthcare system with special focus in the patients with oncologic pathology. In the section 3.1 is described decision strategies with the main objective of improving the healthcare delivery through optimization. Thus, de decision levels in healthcare are explained in section 3.1.1, and an introduction to patient flow (section 3.1.2) and multi-appointment scheduling problems (section 3.1.3) is provided. Moving forward, the section 3.2 focus in the oncology department and his literature review. The operations and the main concern topics regarding patient flow (section 3.2.1) and multi-appointment scheduling (section 3.2.2) are exploited. An analysis of other studies that could add valuable information for the purpose of this research are explored in the section 3.3. The main conclusions of the chapter and a critical analysis to the literature are described in the section 3.4. The research method was developed in the platforms EBSCO, Google Scholar, Scopus, Taylor&Francis and ScienceDirect and as defined in the last chapter, the goal is to identify the path of the patient and understand multi-appointment management, and to do so the keywords used was 'patient flow', 'patient-centred', 'multi-appointment' and 'oncology' contributing to the literature of this chapter.

3.1 Healthcare Delivery and Optimization

Is clear that the performance of healthcare has a major importance in humans health. Healthcare systems have been challenged in recent years to deliver high quality care with limited resources (Hall et al.,2006)**.** So, with that in mind, is imperative to achieve efficiency and effectiveness on the operations due to the limited resources that are available and the increasing demand that the services are dealing with (Organisation of Economic Co-operation and Development, 2012). Planning and control decisions are made by health care organizations to design and operate the healthcare delivery process (Hulshof et al., 2012). It requires coordinated long-term, medium-term and short-term decision making in multiple managerial areas, playing a big role in the healthcare delivery organisations. Furthermore, costs have risen has a result of new healthcare technologies and procedures (Brandeau et al., 2004). Although, and with the goal of reducing costs, healthcare has the challenge to understand his processes to optimize the patient satisfaction. The next sections propose to address the decision levels in healthcare delivery (section 3.1.1) in order to give a context to the literature in a hierarchical mode and moreover to give an overview of the problems that are more critical for the optimization process in oncology that after an exhaustive research are concluded as being the patient flow (section 3.1.3) and multi-appointment schedule (section 3.1.3).

3.1.1 Decision levels in healthcare

Brandeau et all (2004) stated that the decision levels in healthcare have different layers and suggested a framework that strives to explain the planning and management decisions in healthcare and for the purpose of their research, they suggested that this can be grouped in two areas: The first area is Healthcare Planning and the second is Structure Decisions and Healthcare Delivery. The first one mentioned concerns high level decisions such as economic of health care where is determined the level of resources available to the departments and structural decisions as the ultimate goal is to define which goods and services they will provide and to whom they will be provided, and finally other policy issues that could have a broad effect on the delivery of healthcare such as regional diseases screening and prevention programs. Furthermore, the Healthcare Delivery, is divided in two categories for the authors. The first one is Operations Management for Healthcare Delivery that include problems such as design of services, supply chain or capacity planning. The other dimension of Healthcare Delivery is Clinical Practice, and the main concern is that the clinicians must design and plan treatment for their patients making this dimension a very important one to achieve high quality treatments near the patient. The overview of this framework can be observed in the Figure 6.

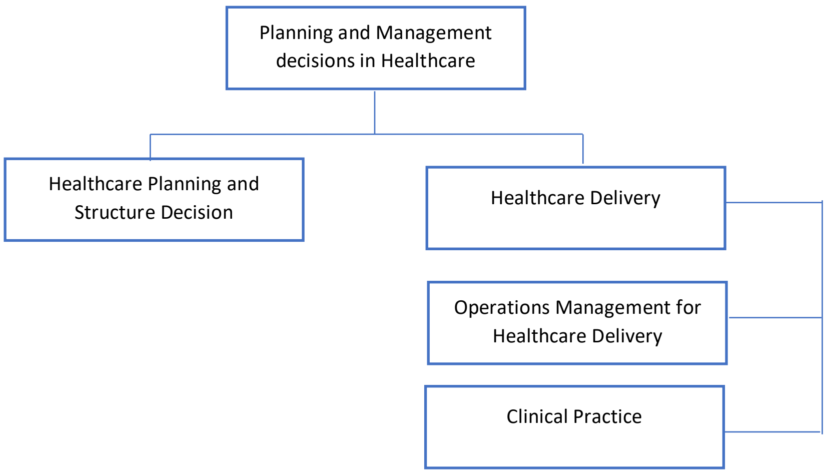


Figure 7 Brandeau et all (2004) vision of healthcare problems

Furthermore, Hans et all (2012), proposed a distinct four-by-four framework for healthcare planning and control that divided four hierarchical levels of control and four managerial areas. In this approach the authors included not only hospitals but several other healthcare facilities and management areas. As showed in Figure 7 the four hierarchical levels are Strategic (structural decision making), Tactical (organisation of the operations), Offline Operational (short-term decision making related to the execution of healthcare delivery process) and Online Operational (control mechanisms and reacting to unanticipated events) and the managerial areas are Medical planning (decision making by clinicians), Resource capacity planning (controlling and monitoring resources), Materials panning (acquisition and distribution of resources) and Financial Planning (managing costs and revenues).

	Medical planning	Resource capacity planning	Materials planning	Financial planning
Strategic	Research, development of medical protocols	Case mix planning, capacity dimensioning, workforce planning	Supply chain and warehouse design	Investment plans, contracting with insurance companies
Tactical	Treatment selection, protocol selection	Block planning, staffing, admission planning	Supplier selection, tendering	Budget and cost allocation
Offline operational	Diagnosis and planning of an individual treatment	Appointment scheduling, workforce scheduling	Materials purchasing, determining order sizes	DRG billing, cash flow analysis
Online operational	Triage, diagnosing emergencies and complications	Monitoring, emergency coordination	Rush ordering, inventory replenishing	Billing complications and changes

← managerial areas →

↑ hierarchical decomposition ↓

Figure 8 Healthcare planning and control by Hans et all (2012)

In addition, this framework considers that the organisation can be influenced by the external environment, so we must consider the effect of different factors such as:

- Social factors (education, social mobility, religious attitudes)
- Technology (medical innovation, transport infrastructure)
- Economic factors (change in health finance system)
- Environmental factors (ecological, recycling)
- Political factors (change of government policy, privatization)
- Legislation/Legal (business regulations, quality regulations)
- Ethical factors (business ethics, confidentiality, safety)
- Demographics (graying population, life expectancy, obesity)

These factors need to be under consideration because they can affect the processes optimization in healthcare environment, for example the IPOLFG is under the surveillance of the SNS so needs to take into consideration the legislation of this organ. Such factors as technology and economic policies also are valid for the case study in analysis. These factors must contribute for the restrictions in the mathematical model purposed. The next section focusses on the first component proposed to be optimized, the patient path of the patient reference in the literature as patient flow.

3.1.2 Patient Flow: Flow of Patients in the Network

Long waits, delays, cancellations and resource overloads have become commonplace in healthcare (Hall et all, 2006). In the recent years, the purpose of the healthcare providers was simply to add more resources to solve this problem, but this approach has become impractical due to the shortage of human resources and the limited finances available. Nowadays, healthcare providers are forced to look at different approaches to solve this problem and evaluating the patient flow is a procedure that is increasingly gaining importance.

Flow implies progressive movement and it refers to the movement of people, equipment, or information, but in healthcare it generally refers to the movement of people (Health Foundation, 2013). Is also considered that flow could serve as property for healthcare systems (Hall et all,2006). If the healthcare providers can achieve an optimal flow this could result in minimized waiting times, increasing quality care and additionally improved patient safety and satisfaction. Is also stated that healthcare providers experienced improved satisfaction when there is optimal flow (Litvak et all,2010). With the purpose of understanding the patient flow within hospitals and with focus on the oncologic department is important to classify the patients, since they have different flows inside the hospital. The patients can be grouped in three categories that are: outpatient, inpatient and emergency patients (Brandeau et al.,2004).

First, outpatients are those who don't spend the night in the hospital (Zonderland,2014). This characteristic implies that the patients return to his/her home after all necessary services have been provided. In the reverse side, inpatients are those who do spend the night in the hospital, and in this case the patient requires additional resources, namely a bed, and to manage this flow efficiently other important variables, for instance, the length-of-stay (total number of days that a patient occupies a bed) need to be controlled with the focus on minimizing the time that a patient complete the total path (makespan). Additionally, there is emergency patients. These patients are important to consider because they could influence the flow of outpatients and inpatients especially in the capacity side, because the healthcare providers need to assure that there is enough remaining capacity to intake emergency patients without compromising others. Insufficient remaining capacity could result in overtime and delayed appointments (Marynissen & Demeulemeester,2019). In the specific case of this dissertation the path of the patient is composed majorly by outpatients because in this field the patients usually don't spend the night in the hospital, only in the special case of patients before surgery, that can be temporarily interned in the hospital (IPO, 2019) and being evaluated as inpatient.

In the model proposed by Hans et all (2012), the concerns about the patient flow needed to be positioned in the Operational Level. The applications of the patient flow optimization using OR methods are going to be explored in the further section 3.2 when focusing on the oncology department. The next chapter focus on another level on concern in the case study analysis, namely the time management in the process described in the literature as multi-appointment scheduling.

3.1.3 Multi-Appointment Scheduling

Multi-Appointment Scheduling Problems in Healthcare (MAPSPHs) are design to act as an umbrella for both combination appointments: those which patients need multiple appointments, preferably in the same day and appointment series in which patients need to revisit the same set of resources several times (Hulshof et al.,2012). This definition fits in the oncology research field due to the complex network of treatments that the patient need and the various resources and departments coordination that are in the patient path through the system. Therefore, each patient need to be assigned a specific path over a subset of the considered resources and each step needs to be scheduled in order to obtain a timely care (Marynissen & Demeulemeester, 2019). This is an important issue in healthcare delivery because delayed diagnosis and treatment may result in adverse effects in the patient health and with the application of this methods the hospitals could increase the patient satisfaction and reduce the patient visits to the hospital.

The MASPH have several applications in different departments in the hospital. First, it can be found in rehabilitation departments where patients recover from physical injuries, drug addictions or others and requires multiple specialist's and devices from several departments. A second application occurs when patients need to be scheduled for diagnostic tests, because this kind of tests often don't take a long time and it's possible to patients to attend multiple tests in the same day. A third application of MASPHs are in the oncology department, motivated by the idea that delaying treatment could have adverse effects on the patient due to the condition of his disease and consultation and treatments must be well coordinated with diverse resources and capabilities (Ragaz et all,2005).

Concerning Multi-Appointment Scheduling, all the decision levels proposed by Hans et all (2012) are relevant, namely in scheduling problems. Optimization must start at the strategic level to achieve a maximum optimum in the operational level. An overview of OR models and optimization focusing in the oncology field are explored in the section 3.2.

3.2 Literature Review: The complexity of the oncology field

The oncology is a multi-disciplinary specialty, and due to the severity and mortal condition of the cancer disease methods to optimize the healthcare delivery in the various departments of this field have been under research in the recent years. A patient with cancer often receives multiple treatments including chemotherapy, radiotherapy and surgery from different specialists for extended periods of time. Additionally, some other services such as blood tests, exams and drug preparation are required, and these services are performed in different facilities like laboratories, clinics, pharmacies and treatment rooms. The services are provided by multiple human resources like nurses, pharmacists and medical oncologists. This multi-facility environment creates a difficult decision for clinical administrators to improve efficiency, since the coordination of these services and resources is critical for timely and efficient treatment of patients. The present section presents a literature review of the research methods in the oncology specialty, namely on simulation that is one of the most used approaches to model hospital environments with several complexities. In oncology clinics, simulation is used to find the best scheduling method, test the impact of different scheduling methods on clinic performance and determine the optimal resource levels and patient flow (Liang, Turkcan, Ceyhan, and Stuart.,2015).

Furthermore, is important to note that MASPHs cannot be completely separated from patient flow problems. Hospital units share, for example, resources with other departments such that the clinical pathway of a patient can be a combination of those resources for which an appointment is needed (for example consultation) and other resources for which a queuing principle is applied. When the actual set of resources is larger than the set of resources that require scheduling, integrated scheduling techniques may still be applicable. The focus of MASPHs literature lies on those problems for which the patient needs to visit multiple resources in the scheduling problem and in the patient flow literature, researchers often try to optimize the way in which patients consume a set of predefined resources (Hall, 2013), but when doing so, patients don't require an appointment and instead patients start queuing for the next resource as soon as their demand for service on the previous resource has been satisfied. In concrete, other than admission planning, no scheduling occurs. The goal in these problems is to reduce the patient wait time, increase the patient throughput or align the capacity of resources with the demand for services (Hall, 2013). For that purpose, the literature analysed in this project that relies on scheduling problems will be situated on the multi-appointment section (3.2.2), and literature that concerns patient wait time, patient throughput and capacity of resources with the demand for services will be aligned in the patient flow section (3.2.1). Is important also to notice that hybrid models will also be positioned in the multi-appointment scheduling section if it involves multi department coordination.

Considering this overview an analysis of the literature focused on the patient flow and multi-appointment scheduling in the oncology field the further section strives to identify the solutions provided by various author in this thematic. The next section center the attention in the first component, the patient flow.

3.2.1 Patient Flow review

In the early 2000's, in order to analyse the patient flow and helping the decision maker to identify bottlenecks through a cancer treatment centre (Sepulveda et al.,1999) developed a discrete event simulation to determine the impact of alternative layouts, number of patients scheduled per day and new building plan for this purpose. Additionally, (Baesler and Sepulveda,2001) also used discrete event simulation to find the best combinations of control variables (resources) to meet the predetermined goals of patient waiting time, chair utilisation, clinic total working time and nurse utilisation. Another distinct model using multi-objective integer programming model contemplating discrete event simulation to allocate all patients considering the nurse capacity with the objective of satisfying patient's time preferences, pharmacy capacity, balance workload between nurses and the workload throughput the day and assigning clinical trial patients to specialised nurses was conducted by Santibáñez et al. (2012). In this research the condition of adding patient's preferences was a valuable addiction for further research. Woodall et al. (2013) use simulation-based optimization based on discrete-event simulation and mixed-integer programming (MIP**)** to determine the optimal nurse allocation with the objective of minimising expected waiting times.

Later, Tanaka (2013) used simulation to test appointment rules based on another technique defined as bin-packing heuristic algorithm and with that determine the time allocated for pre-treatment process, preparation and nursing. Furthermore, Sevinc, Sanli, and Goker (2013) proposed a two-heuristic also based on best-fit bin-packing algorithm (classical combinatorial optimization problem in which are given an instance consisting of a sequence of items with rational sizes between 0 and 1, and the goal is to pack these items into the smallest possible number of bins of unit size) for online allocation where patients are added to the schedule dynamically but differentiate with a multiple knapsack model (assigning a subset of n items to m distinct knapsacks without exceeding the capacity of each of the knapsacks) for offline scheduling that assumes that all patients are known.

Some other models use different technique of simulation named goal programming with the purpose of determine best appointment rules by changing arrival rates and changing the number of nurses in each time interval with the purpose of minimizing patient wait time and maximizing throughput (Ahmed, El Mekkawy, and Bates (2011) and Yokouchi et al. (2012)).

The study by Hahn-Goldberg et al. (2014) use constraint programming to develop a template schedule based on historical data and update the template dynamically, when appointment requests that don't fit those of artificial appointments already scheduled in the template. Although the proposed model determines the start times of drug preparation and treatment stages while not exceeding the pharmacy, nurse and chair capacities at any time throughout the day they didn't specifically determine which nurse would be on duty and monitor the patient and which chair would be assigned, and that information is essential when a partially filled appointment schedule is in use and it is being updated frequently to achieve optimal resource allocation.

Furthermore, the authors Turkcan, Zeng, and Lawley (2012) contributed to develop integer programming models to address chemotherapy problems that consider acuity levels of patients, with the goal of minimizing treatment delays, reducing staff overtime and maximizing staff utilization. For that purpose, they assumed that each request was for a single appointment and, as stated before, in the oncology centres mostly is required multiple appointment with rest periods between treatments. In a similar study, Condotta and Shakhlevich (2014) proposed creating multi-level templates to accommodate patient requests for chemotherapy appointments. Their goal was to minimize wait times and balance nurse workloads. Using integer linear programming models and data generated from artificial patients, they determined the day, time slot, and nurse of each patient; however, the template did not consider patients preferences for appointment start times.

Another relevant study was developed by Liang and Turkan (2016) that strive to address the daily flow of patients considering nurse assignments, and for that purpose they assumed two different modes: functional care models, that the patients would not be necessarily assigned to their primary nurses, and in the reverse side primary care models. However, they didn't consider chair capacity and assignment of patients to a specific chair room. It was also proposed a multi-objective optimization model with the goal of minimizing the patient wait time, total nurse overtime and excessive workloads.

Another level of study and regarding more recent technology was developed by Heshmat, Nakata, and Eltawil (2018) that considered the patient appointment and proposed an approach inspired on cellular manufacturing that involved creating clusters of patients using a mathematical programming model. With the creation of this clusters each nurse was first assigned to a cluster and then to a group of chairs with the aim of achieving the minimum makespan (competition of

job to leave the system). Although with the simplification of the problem important factors such as optimal sequence of patients within a cluster, care delivery system and patient preferences were not considered.
Considering the understanding on the patient flow literature in the oncology field the next section focusses in the second problematic in study, the difficulty of managing the coordination of consultations and resources and identified in the literature as “multi-appointment scheduling” problems.

3.2.2 Multi-Appointment review

Regarding the study of multi-appointment scheduling problems in the oncology field, there is a vast number of techniques used and very heterogeneous and with different optimization purposes. Introducing this problematic, the authors Sadki, Xie, and Chauvin (2011) studied the scheduling of patients for chemotherapy treatments and oncologist consultations simultaneously using a mixed-integer programming (MIP**)** model. The proposed MIP model determines the oncologist start times, patient appointment times and injection start times with the objective of minimising a weighted combination of patient waiting time and makespan. The proposed model assumes punctual arrivals, no idle time between patients of the same oncologist (oncologist wait time) and no cancellations: That kind of assumptions in a real context may not be pratical. The patients see their oncologist as soon as they arrive. The chemotherapy treatment starts after the oncologist sees the patient, the pharmacy prepares the drug and a chemotherapy bed becomes available. The nurses and pharmacists are assumed to have enough capacity and their availability is not considered in the proposed model. In another study Shashaani (2011) determined the appointment schedule using a deterministic integer programming model and then it is used as input to the simulation model in order to evaluate the impact of variability in the service time in key performance measures such as patient waiting times. In this study it was considered oncologist appointment times while determining optimal appointment times. Another example was conducted in radiation therapy (Sauré et all, 2012) using an approximate dynamic programming to solve a mainly deterministic multi-day problem with the only uncertainty on the number of new requests for each type of radiotherapy treatments. In the same models Gocgun and Puterman (2014) also proposed formulating a problem as a Markov decision process model (mathematical framework for modelling decision making in situations where outcomes are partly random and partly under the control of a decision maker) and proposing approximate schemes to solve instances of real size. The goal of this research was to observe available treatment capacity to incoming demand to obtain the day of arriving request. This study only lacks on assignment of time slots, nurse or chair appointment request.

For the purpose of solving a dynamic multi-day appointment problem Balasubramanian et al. (2014) addressed that the physicians schedule consists of pre-scheduled appointments whit their long-term patients and hoc appointments (short-term) with walk-in patients that can be either long-term or new. This stochastic dynamic programme was designed to maximise a weighted function that compress the number of same-day patients scheduled and patient assignment frequencies with their familiar physician. Some simple heuristic rules for practice were designed and tested. Although an adaptive threshold heuristic is found to be most effective. The adaptive heuristic in this work reassigns patients probabilistically based on the average waiting time by procedure, time block and patient class with the aim to adjust to dynamic bottlenecks. Regarding this problem, a two-staged stochastic programming problem was conducted by Castaing, Cohn, Denton, and Weizer (2016) for scheduling patients in an outpatient cancer centre but in a daily basis view (without considering planning horizon). This study was important because it was the first that also considered uncertainty duration of the appointments and developed a heuristic to solve the problems in a reasonable amount of time with some predefined number of scenarios. Alvaro and Ntaimo (2018) used mean-risk stochastic IP models to formulate the problem of scheduling chemotherapy appointments, considering uncertainty in the acuity level of patients, availability of nurses and treatment duration. Also, the functional care model was considered.

More work in this field were conducted by Liang, Turkcan, Ceyhan, and Stuart (2015) and Liu et al. (2019) that used simulation and optimisation models to analyse the scheduling, staffing, and flow process stages inside an oncology clinic and to identify bottlenecks where improvements can be made for a single day but not for a planning horizon. Furthermore, when optimizing scheduling and patient flow in the oncology department it’s relevant to consider the patient flow in the upstream stages (oncologist appointment) for the reason that patient flow from upstream stages could incur start time limits, uncertainties (cancelations, add-ons) and delays in downstream stages (treatment) (Liang, Turkcan, Ceyhan, and Stuart.,2015). So, it’s important to consider both stages (oncologist and infusion appointments) simultaneously for better coordination of schedules, improving patient flow and use the resources in a more balanced way. Note as well that specially radiotherapy and chemotherapy scheduling is a field of study in which appointment series play an important role, as patients usually require more than one visit to the oncology department in order to treat or to limit the growth of the tumour. As such, scheduling patients for their entire treatment pathway may also be important in these problems. With that in mind, (Dobish,2003) proposed a two-day treatment process to reduce patient waiting time in a cancer treatment centre, since the patients were examined by their oncologists and then were given appointments for chemotherapy treatment for the following day. Another simulation was conducted to evaluate the impact of different patient arrival rates, resource levels (nurses, doctors) and queuing policies (Matta and Patterson,2007). Ramos, Cataldo, and Ferrer (2018) studied two sequential decision problems: a capacity planning problem for assigning a date to appointment requests, and a daily patient-scheduling problem for allocating a chair and time slot for each patient on each day. For that purpose, the authors used the procedure introduced by Saure et al. (2012) to deal with the first part of the problem over an infinite horizon and developed an IP model to solve the second part. In their proposed methodology, once the number of patients for a specific day was known, different patterns of possible patient allocation to chairs were generated to produce a daily schedule. Although using this sequential approach might help to reduce the number of decision variables, implementation can be difficult when partially filled appointment schedules were considered in which some appointment requests had already been accommodated. Furthermore, although the authors took nurse availability into account, they did not distinguish between the part of infusion time when the assigned nurse sets up patient treatment from the part during which the nurse can monitor several patients.

In the recent years Garaix, Rostami, and Xie (2019) proposed a heuristic that uses a greedy randomized adaptative search procedure algorithm to solve the multistage problem of scheduling patient appointments for chemotherapy and consultation and considering drug preparation times. In this research the author assumed that the sequence of patients for the treatment stage and for the consultation were the same and that assumption might not be practical. Furthermore, Benzaid, Lahrichi, and Rousseau (2019) consider a distinct three-stage procedure problem through the examination of chemotherapy appointment scheduling problem, a nurse planning problem, and a daily nurse-patient assignment. The goal of the first stage was to determine a date and start time for each new patient with the aim of maximizing the number of patients starting their treatments. Further, in the second stage they try to assign patients to nurses in a way that the required staffing level and length of waiting list were minimized. Finally, in the third stage, after simulating last-minute changes including cancellations and nurse absences, the daily assignment problem was executed for the final set of patients and nurses. It was assumed that, in order to deal with the simulated last-minute changes, only the assignment of patients to nurses could change, but , in actual practice, the assignment of patients to chairs and even their start time might change within an acceptable tolerance (for instance, by up to one hour). Moreover, the authors relaxed the limitation on nurse workload, reassigning patients to nurses to find feasible solutions, which might be unrealistic in some worst-case scenarios for last-minute changes.

Most recently, Pedram Hooshang-Tabriziab, Ivan Contrerasab, Nadia Bhuiyana and Gerald Batistc (2020), studied another chemotherapy scheduling problem. The first dimension came from the fact that appointment requests arrive dynamically (as an online waiting list that contains multiple requests and is continually updated) and for the record, the exact number of appointments is not known in advance. Depending on the prescribed method of treatment for a patient during a consultation, an oncologist may request a series of appointments with rest periods of specific lengths between treatments and may also request a specific set of chairs where the patient will receive treatment. Furthermore, a patient may have preferences for the start time of treatments, and a nurse is fully occupied with one patient during the setup phase of treatment. To tackle these difficult complexities, a flexible and adaptive scheduling procedure was proposed that strives to schedule incoming appointment requests and reschedules these daily when either new information regarding the request is received or an unexpected last-minute change occurs. Both the scheduling problem and the rescheduling problem were formulated as integer programs. Some important parameters such as deviation from the dates prescribed by the oncologist by a pre-determined schedule for each patient, changing the start time of patients already booked and specifying the maximum number of appointments that can be moved within the schedule were included in the proposed procedure. These parameters allowed a sufficient degree of flexibility in accommodating incoming requests along with last-minute changes.

In the further section is analysed another relevant role of studies, not directly related with the nature of the oncology specialty but could add interesting methodologies for the case in study and namely in the further formulation.

3.3 Related Works

This section was motivated by the research of different studies in the literature of healthcare delivery that are not directly related with the oncology specialty. Despite that, some researches present resolute conclusions that can be adopted in the formulation and some others were used as base of the oncology department works and his mention in the literature review can be a valuable addition to better address the problem, namely in the case of patient priority and patient selection from waiting list.

3.3.1 Patient priority

Particularly in medical facilities problems with heterogeneous patients is usual to determine priorities for various patient groups. There are two major types of patient priorities, which may be called hard and soft. For the first, the patient priorities must be always accomplished, and hard priorities are applied upon patient arrivals. Such priorities are very popular in the queuing system literature where the customers typically come to the system without setting any appointment. Hard priorities can be considered for various groups of walk-ins. For instance, in almost all medical centers, the highest priority is assigned to urgent walk-ins that must be served upon their arrival.

Soft priorities are not applied upon patients' arrivals and are only incorporated in scheduling, deciding appointment day, capacity planning or determining other operational or tactical decisions, in order to put more values on different patient groups who make appointments before their arrivals. A common method to define soft priorities is to assign a different weight to each patient group to reflect its relative importance. In most studies, these weights are represented by waiting-time penalty coefficients (Saure et al., 2012). Is important to notice that, both hard and soft priorities can be considered simultaneously. Although priorities have a significant impact on patient waiting time and on resource utilization (Hulshof et al., 2012), no optimization study has focused on determining patient priorities. The allocation of different patient priorities in the hospital environment is under analysis in the present dissertation.

3.3.2 Patient selection from waiting list

For some problems in the literature, there are more patients on the waiting list than the available capacity, even with overbooking. In such a case, the number of patients to serve should be selected in terms of various criteria, such as the capacity allocated to each patient group, the patient waiting time, and the patient priority levels. Some authors assume that the priority initially assigned to each patient does not change, but in the real world the patient's condition may change during that time (Min & Yih, 2014).

A variation of this decision occurs in some hospital diagnostic facilities (such as magnetic resonance imaging (MRI) and computed tomography (CT)) that serve both inpatients and outpatients. These clinics face the challenge of selecting, in real time, who will be served next when demand comes from three patient groups: inpatients, emergency patients, and pre-scheduled patients, which based on our terminology could be referred to as regular walk-ins, urgent walk-ins, and scheduled patients, respectively (Gocgun et al., 2011). This problem can be also considered a type of dynamic capacity allocation problem for a diagnostic facility. The selection of patients from a waiting list is also a critical aspect that is relevant for the further model implementation. The next section presents the conclusions of the present chapter.

3.4 Chapter conclusions

The oncology department is a complex environment that requests careful attention of all the strategic, tactical and operation level of healthcare planning. Giving the mortal condition of the disease in cause it's no surprise that a variety of models have emerged with the purpose of address this issue and optimize it in the past years.

Along this chapter the literature of the oncology department was reviewed. Simulation methods of different categories were majorly the most appropriate approach pursued from the different authors with some addressing patient flow issues focusing in optimizing the patient wait time, increase the patient throughput, or align the capacity of resources with the demand for services and in other cases multi-appointment problems where the main focus is to optimize the schedule for the patient to efficiently complete the hospital path. For that purpose, simulation methods of the most various types compose a vast array of solution techniques to deal with this problem. Although the literature presents resolute models to address the main issues of the oncology department some additional concerns must be addressed like the patient's priority and selection from a waiting list that can be a critical issue in the performance of healthcare and other aspect that is poorly take in consideration is the patient preferences for the start time and days of the treatment, and that dimension can be an important factor to have in consideration for further work.

The next chapter presents the main conclusion of this project and relies on the purposed methodology specifying the steps to address the oncology department problems in the dissertation project.

4. MODEL FORMULATION

The goal of this chapter is to propose an IP Model to address patient scheduling optimization, in particular, at the IPOLFG oesophageal and stomach department. This model should leverage the previous knowledge regarding the case-study with the wide range of modelling methodologies which have been covered in the literature review.

Section 4.1 restates the problem statement, addressing the principal problem features (section 4.1.1) and a relation to the previous literature (section 4.1.2). Section 4.2 presents the mathematical formulation of the model. After establishing the required notation and sets, subsets, indexed sets and parameters, the objective functions and constraints are presented and explained. Section 4.3 presents the chapter's conclusions.

4.1 Problem Statement

4.1.1 Problem Features

Before presenting the proposed model, it is important to restate the general problem to be addressed. The problem consists of developing a mathematical model in order to help the IPOLFG to optimize the patient flow and the process time of the operations in the RCOS providing an increased patient satisfaction and serving patient's wait time targets. For that purpose, and after several meetings with Dr. Rui Casaca (IPOLFG High Digestive Department Coordinator) and Dr. Cecilia Monteiro (IPOLFG High Digestive Department Hospital Assistant), it was concluded that the major bottleneck in the process was in the indicator *"Time between therapeutic decision by the GMCEE and beginning of treatment"* that is shown in the Table 6 of the chapter 2. As concluded previously the number of days that a patient is waiting to receive the first consultation is considered high, since there are no criteria in the patient selection (the hospital works with a first-in first-out policy) because as referenced by Dr. Rui Casaca it is not ethical in the hospital perspective prioritizing patients. Focusing on this indicator and relaxing the "Time between the first consultation and the therapeutic decision" was articulated with the hospital due to their necessities and the fact that in the current patient admission process this time is considered stabilized and low, focusing the optimization on the critical part of the patient flow. It is visible that this indicator is critical specialty due to the severity of the disease and more robust methods needed to be implemented, despite the limited resources and budget of the hospital. With that in mind, the model proposed to compare the hypothesis of prioritizing some patients in order to understand if the results are able to optimize the patient expectations and waiting lead time, providing to the hospital a tool that is inexistent in the current environment.

Furthermore, in the figure 9 it is highlighted the part of the flowchart of the oesophagus and stomach area that is going to be under optimization in the model.

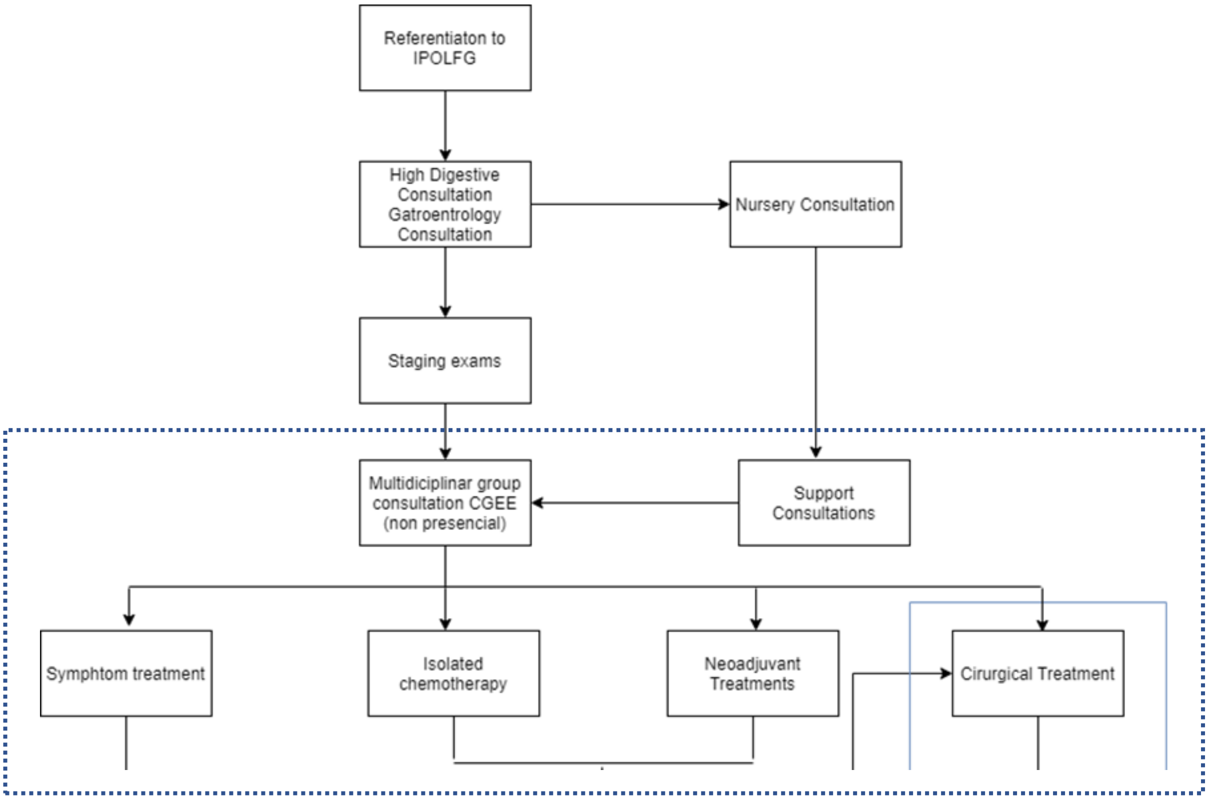


Figure 9 Part of the Flowchart of the patient on both oesophagus and stomach area under optimization, (OSRC,2019)

When analysing multi priorities of patients, the appointment scheduling methods that are in practice vary from first come first-served (ordering patients based on their arrival time) and others to a strict policy considering patients with higher priorities to receive service firstly (Gupta,2008). Analysing these methods, we can conclude that neither those two are suitable when wait time targets are considered because the first neglects patient priorities and the second does not respect wait time targets for lower priority patients (Jiang.Y, 2018). As shown in this dissertation, a balanced way to analyse the problem is presenting a framework for multi-class patient scheduling which minimizes the overall waiting time for all patients, while respecting the mandated wait time targets for all different patient priorities.

Therefore, with the purpose of explaining the model that is going to be addressed in the next section, in the figure 10 it is explained how is done the appointment booking in the current environment of the hospital. There are no rules in the appointment booking since the department receives a waiting list and the first patient that is contained in the waiting list is booked for consultation according to the multidisciplinary group consultation. As stated previously, that method may not be the optimal way to increase the efficiency of the patient flow and neglecting patient priorities could lead to catastrophic results due to the condition of the disease in analysis.

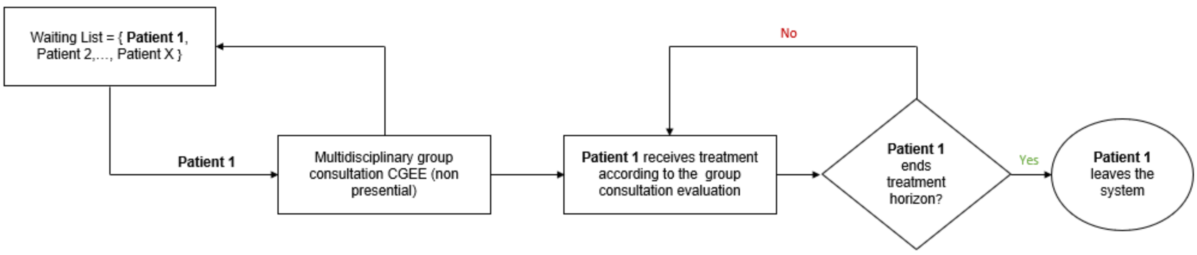


Figure 10 Patient Appointment Booking (AS IS: Fist-In Fist-Out)

Considering that problematic, the purposed model aims to add a step in this process as explained in the Figure 11. Instead of considering no rules in the appointment booking, the model considers different levels of priorities (P) for different patients in a planning horizon (T). Instead of selecting the patient with higher priority the model first minimizes the total wait time for all the priorities of patients, then books appointments for the higher priority patients until a certain service level that the hospital compromises to achieve is fulfilled and assuring that the wait time target of the patient is met according to the total service time available in the hospital.

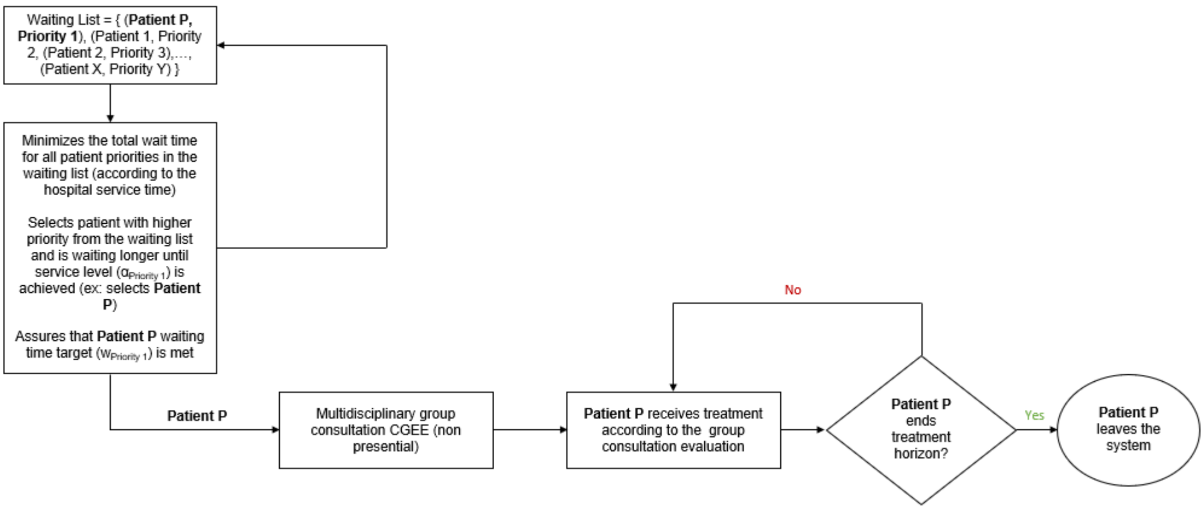


Figure 11 Patient Appointment Booking (TO BE- Patient Priority Selection from a Waiting List)

Addressing the problem, it is relevant to identify the problem in the literature review, presented in the chapter 3.

4.1.2 Relationship to the Literature

After defining the general problem to be addressed, it is important to restate the literature presented in the chapter 3 and highlight the principal insights that contribute to the model formulation. In the section 3.2.1 and 3.2.2 it was reviewed the literature related with the oncology department problems, namely the patient flow and multi-appointment scheduling. Considering that, the major insights that are used to develop the formulation were:

Regarding Patient Flow:

- The work of Santibáñez et al. (2012) presented resolute solutions using a multi-objective integer programming model contemplating discrete event simulation to allocate all patients with the objective of satisfying patient's time preferences.
- The work of Ahmed, El Mekkawy, and Bates (2011) and Yokouchi et al. (2012)) using goal programming with the purpose of determine best appointment rules by changing arrival rates with the purpose of minimizing patient wait time and maximizing throughput

Regarding MAPS:

- The work of Shashaani (2011) determining the appointment schedule using a deterministic integer programming model and then it is used as input to the simulation model in order to evaluate the impact of variability in the service time in key performance measures such as patient waiting times.
- The work of Gocgun and Puterman (2014) proposing formulate a problem as a Markov decision process model and proposing approximate schemes to solve instances of real size with the goal of observing available treatment capacity to incoming demand to obtain the day of arriving request.

At the section 3.3 these problems were addressed to review the literature that is not directly related with the oncology department but present relevant studies for the mathematical formulation, namely regarding patient priority (section 3.3.1) and patient selection form a waiting list (section 3.3.2). Combining these studies with the patient flow and multi-appointment scheduling problems is the goal that the formulation aims to achieve.

In the next section, it is presented the mathematical formulation that strives to solve the multi-priority patient scheduling problem in the oesophageal and stomach department of IPOLFG.

4.2 Mathematical Formulation

In this section, the mathematical formulation of the model is presented, in light of the previous considerations. Before presenting the proposed model, the notation is formally introduced, including sets, indexed sets and parameters. Then, the objective function is presented and, finally, the constraints are introduced.

4.2.1 Sets

t ∈ T set of all time periods, T = {1,…, T}

p ∈ P set of all patient priorities, P = {1,…,P}

n ∈ T number of days that a patient is waiting to receive treatment n = {1,…,n}

4.2.2 Parameters

d_{pt} – Number of patients with priority p who require a service in period t

c_t - Total available time for service in period t

s_p - Service time of patients with priority p

w_p - Wait time target for patients with priority p

α_p- Fraction of priority patients served within their wait time target (service level)

h (n,p) - Penalty cost for delaying patients of priority p for n days

4.2.3 Variables

X_{ptn}- number of priority p patients served in period t after waiting for n periods.

I_{ptn} - number of priority p patients not yet served in period t after waiting for n periods.

4.2.4 Objective Function:

The objective function that the problem strives to optimize is described in the equation (1).

$$\text{Min } \sum_{p=1}^{P} \sum_{T=1}^{T} \sum_{n=1}^{t} h(p,n) I_{ptn} \qquad \textbf{(1)}$$

The objective function (1) minimizes a weighted sum of total wait times of all patients and allow different penalty costs h(p,n) for wait time of different priorities (p) and is a function of the number of days the patients have been waiting (n). The objective is to balance the number of patients that receive treatment according to the different priority levels as stated previously, in order to obtain a balanced schedule for patient admission.

4.2.5 Constraints

In the present sub-section, the constraints that restricts the problem are introduced.

The constraint (2) captures the number of patients of each priority (p) that are still waiting to receive treatment. This function depends on the number of patients with priority (p) who require a service in period (t).

$$I_{ptn} = d_{p,t,n+1} \sum_{i=0}^{n-1} x_{p,t-i,n-i} \; \forall \, \mathrm{p} \in \mathrm{P}, \mathrm{t} \in \mathrm{T}, \mathrm{n} \in \{1, \dots, \mathrm{T}\} \qquad \textbf{(2)}$$

The constraint (3) ensures that are only schedule past patients, not considering future demand. With that constraint we restrict the patient flow since the waiting list isn't dynamic.

$$\sum_{i=0}^{n-1} x_{p,t-i,n-i} \leq d_{p,t-n+1}\, \forall\, \mathrm{p} \in \mathrm{P}\,, \mathrm{t} \in \mathrm{T}\,, \mathrm{n} \in \{1, \ldots, \mathrm{T}\} \qquad \textbf{(3)}$$

The constraint (4) restricts the total daily number of patients who receive service based on the available capacity in each period.

$$\sum_{p=1}^{P}\sum_{n=1}^{T} s_p x_{ptn} \leq c_t\,, \forall\, \mathrm{t} \in \mathrm{T} \qquad \textbf{(4)}$$

The constraint (5) ensures that desired service level $\alpha_{p,}$ for serving patients within their wait time targets is met for each priority

$$\sum_{n=1}^{wp}\sum_{t=1}^{T} x_{ptn} \geq \alpha \mathrm{p} \sum_{t-1}^{T} d_{pt}\ ,, \forall\, \mathrm{p} \in \mathrm{P} \qquad \textbf{(5)}$$

The constraint (6) ensures that the number of served patients is a non-negative integer, which is captured in the sign constraint.

$$\mathrm{Xptn}\ \geq\ 0\ \ \mathrm{integer}\, \forall\, \mathrm{p} \in \mathrm{P}\,, \mathrm{t} \in \mathrm{T}\,, \mathrm{n} \in \{1, \ldots, \mathrm{T}\} \qquad \textbf{(6)}$$

The next section presents the conclusion of the present chapter.

4.3 Chapter Conclusions

In this chapter, the problem is restated, and a Multi-Priority Integer Programming model is developed. This model is proposed to optimize the RCOS scheduling in which patients are prioritized based on their acuity level, assuming that there is a wait time target for each acuity level and with that achieving a balance scheduling for all patients. The following chapter describes the data collection and treatment procedures required to apply the proposed model to the case study.

5. DATA COLLECTION

This chapter introduces the data collection required to apply the model to the case study. Since not all necessary data could be made available by IPOLFG, section 5.1 lists all the assumptions required to estimate model inputs from available data and the limitations of the formulation. Section 5.2 describes data collection procedures, while section 5.3 describes the required methods to transform the data into parameters. Finally, section 5.4 presents the chapter's conclusions

.5.1 Assumptions and Limitations

Considering the problem that is being under optimization in the department, it represents an innovation in the current processes of the hospital, since that type of prioritization isn't being considered. Stating that, is predictable that the amount of data that the hospital is able to provide is scarce and some assumptions need to be taken in order to analyse the case study. Although, the amount of data provided is based in credible platforms (previous works, legislations, hospital protocols) with the purpose of simulating concisely the model and obtain concise results.

The main assumptions needed to be taken in consideration are:

- Patients that are not served at the end of the horizon must be served in the next planning horizon.
- The demand is known in advance for the entire horizon.
- Patients do not choose between appointment dates. In the purposed model it is just defined considering the maximum expected appointment time.
- Additional resources availability as nurses, doctors are not being considered in the model.
- No-shows and unpunctuality are not being considered in the model.

Those assumptions restrict the problem solution and are going to be restated in a further section as future work to take into consideration. The next section highlights the main procedures to collect the input data of the model.

5.2 Data Collection Procedures

To apply the proposed model to IPOLFG oesophageal and stomach department case-study, relevant data needs to be collected and treated to generate model inputs. Employed data collection procedures include:

1. **Meetings with IPOLFG Oesophageal and Stomach Department:** To formulate the problem and obtain the relevant inputs for the department, several meetings were conducted with the hospital staff.

2. **Analysis of historical records and medical protocols**: The PAI (Processo Assistencial Integrado) of the Oesophageal and Stomach department and record data from the hospital.
3. **Public platforms and studies**: Some other relevant data that is not available in the hospital is obtain from legislations (ex: patient priorities) and relevant studies from the literature in order to complete the data inputs

In the further section the values that the model receives as inputs are defined as described.

5.3 Input Data

In the present section the data that is provided as input to the model (sets and parameters) are explained and described. It is also presented the data transformation for some inputs in order to obtain results for the case study.

5.3.1 Planning Period (T)

In line with the current practice, and to support the formulation of IPO's yearly patient scheduling plan, a 12-month planning horizon is analysed, representing 365 days (T={T1,…,T365}). It is important to notice that, as stated before, if the patients are not scheduled for the present time horizon, they are re-scheduled for the next one.

5.3.2 Patient Priorities (P)

The principal differentiator that the model proposed to address in the department is priority levels for different category of patients. In the meetings provided with the hospital it was stated that although the oesophageal and stomach cancer department does not use priorities for patient admission this kind of priorities are used in some other pathologies. Regarding that, there are 4 types of priorities for patient scheduling being the level 4 the most severe and the level 1 the less (Diário da República, Maio 2017).

- Priority of level 4 - considers patients with known or suspected cancer where there is risk of life with progressive change in the state of consciousness.
- Priority of level 3 - considers aggressive neoplasms, situations with rapid progression, without immediate risk of life.
- Priority of level 2 - considers neoplasms without characteristics that fall into any of the other categories, corresponding to most neoplasms.
- Priority of level 1 – considers indolent neoplasms (causing little or no pain).

Regarding that the model is going acquire these 4 types of priorities with the purpose of addressing them to the patients that enter in the oesophageal and stomach department and analyse how categorising the patient by them affect the department scheduling performance (P= {P1,..., P4}).

5.3.3 Demand of Patients with Priority (d_{pt})

The demand of patients in the IPOLFG is majorly irregular and due to confidentiality and data protection policy that kind of information is difficult to estimate and obtain. Although it is stated in the PAI that the IPOLFG receives 120 new patients/year with oesophagus and 100 new patients/year of stomach cancer diagnosis. It is important to consider also that the department already has patients in the system. Considering that statement a sample of 300 patients/year is going to be under analysis in the present model. The implementation of the present model works with that sample of demand and is static. The distribution of the patients per priority is going to be random as stated in the table 23 in the appendix B.

5.3.4 Total Available Time for Service (c_t)

The total available time for service is a parameter from the model that intends to restrict the hours that a patient must receive treatment. It is stated by the department that the available time for consultation is 2 shifts per day with 4 hours each. Regarding that information, the total available time for service that is going to be considered in the model is 8h per day.

5.3.5. Service Time for Patient Priority (s_p)

In the current department environment, there is no distinction in the service time between patients, however when considering patient priorities, it is feasible to assume that patient with higher priority require a longer service time than patient with lower priority and as stated before that kind of reality is being used in other departments of the hospital. In light of this assumption, the model is going to consider that patients with higher priority (level 4) have higher service time than patients with lower priority (level 3, level 2 and level 1). The service time for patient priority considered are specified in the table 8.

Table 8 Service Time for Patient Priority

Patient Priority	*Service Time for Patient Priority (hours)*
Level 1	2h
Level 2	4h
Level 3	6h
Level 4	8h

5.3.6 Wait time targets (w_p)

Considering the severity of the cancer disease an important parameter to be under evaluation is the wait time target for patient scheduling. This parameter is important because allow the model to include patient expectations in the process, but it should be also realistic in terms of the hospital capacity and resources to attend the patients. Since the IPOLFG is a public hospital, the maximum number of days that a patient should be waiting to receive treatment are standardized in the legislation Diário da República, 1.ª Série N. º 86 4 de Maio de 2017 and described in the table 9. However, this parameter is going to be analysed in the further section when presenting the results of the model in order to understand how the wait time targets affect the efficiency of the patient scheduling.

Table 9 Patient Priorities for Surgery (Diário da República, Maio 2017)

Patient Priority	*Maximum nº of days to receive treatment*
Level 1	60 days
Level 2	45 days
Level 3	15 days
Level 4	3 days

5.3.7 Service Level (α_p)

The service level is stated as the fraction of patients that are served within their wait time target. When allocating patients for treatment and with the purpose of obtaining a balanced patient scheduling without a strict policy of allocating first the patients with higher priority and compromising lower priorities the service level can address this problematic and allow flexibility to the model. For a certain priority, the service level (α_p) is going to restrict the number of patients that must be scheduled within their wait time targets. When defining the problem, the indicator of performance under analysis *"Time between therapeutic decision by the GMCEE and beginning of treatment"* when confronted the patients, 90% said that they expect to receive treatment within 5 weeks (35 days) of waiting time. It is feasible to consider that high priority of patients must have a higher service level when comparing with lower priorities of patients. The service level is going to be another parameter to be analysed to understand the model performance in the further section. The distribution of the service level per priority is presented in the table 10.

Table 10 Service Level per Patient Priority

Patient Priority	*Service Level*
Level 1	60%
Level 2	70%
Level 3	80%
Level 4	90%

5.3.8 Penalty Cost for Delaying Patients (h(p,n))

In order to regulate the time that a patient is waiting to receive treatment, the present model allows a penalty cost h(p,n) in the objective function. A penalty cost h(p,n) is the cost the model incurs if a patient of priority p waits for n days in the system. If the penalty cost is 1 per day for all priorities, the objective would be the average waiting time for all patients. Intuitively, it would be reasonable to consider a higher penalty cost for patients of a higher priority. The objective function compromises to minimize this penalty cost. For that purpose, for each priority, the penalty cost is going to be considered as (1) until reached the patient wait time target, after achieving that time the penalty cost increases one unit until the end of the horizon, for example the penalty cost for priority level 4 is going to be 1 until n=3, after that it increases 1 unit until n=365.

5.4 Scenarios

After addressing the purposed data that are going to serve as inputs to the model, the performance of the model is going to be under analysis to achieve the results that minimize the patient overall waiting time considering patient priorities.

For that purpose, firstly the model is going to be addressed with the data determined in this chapter since is the one that simulates most reliably the hospital environment when considering patient priorities. Additionally, and with the purpose of examine the efficiency of the model, an alternative scenario is going to be tested depreciating the patient priorities, and the same priority for all the group of patients is addressed. This scenario is relevant since it is the present patient scheduling method of the department, and trough comparing these two scenarios it is possible to identify the pertinence of the present work for the oesophageal and stomach cancer departments of the IPOLFG hospital.

Additionally, the service time for patient priorities (s_p), the wait time targets (w_p) and the service level (α_p) are under analysis in order to verify the weight that the variability of these parameters have in the system performance when considering patient scheduling. The flexibility of these parameters is important to test with the ultimate goal of providing to the oesophageal and stomach department incisive recommendations for their patient scheduling methods.

5.5 Chapter Conclusions

The present chapter describes the data collection and treatment procedures required to estimate model parameters and sets from the purposed data. Different sources of information include meetings with IPOLFG oesophageal and stomach department, historical records, and public data. Since there is no similar practice in the department some assumptions regarding the data need to be considered. It Is possible to conclude that accurately collecting and treating the real data is challenging given the innovative character of the model and for the reason that some may not be readily available. The next chapter describes the results of model application to the case-study.

6. CASE STUDY RESULTS

This chapter presents the application of the proposed model to IPOLFG Oesophageal and Stomach department case study. Besides presenting computational results, the chapter focuses on discussing recommendations for the hospital. It is divided in four sections. Section 6.1 introduces the computational experiments to be conducted in the base scenario that reflects the hospital environment when addressed patient priorities. Section 6.2 presents an analysis of the system for the alternative scenario under consideration, considering the input data (section 6.2.1) and the principal results (section 6.2.2). Furthermore, the section 6.3 highlights the principal asymmetries of the 2 scenarios under analysis. Section 6.3 presents a sensitivity analysis to several model parameters, including in the service time for patient priorities (s_p) in the section 6.3.1, the wait time targets (w_p) in the section 6.3.2 and the service level (α_p) in the section 6.3.3. Finally, the section 6.4 presents the general recommendations for the hospital department. Conclusions are postponed to Chapter 7.

The proposed model was implemented in GAMS language, in a computer equipped with an Intel® CoreTM i5-8250U with 1.80 GHz and 12 GB of RAM.

6.1 Base Model Scenario (Hospital Environment)

The base model was addressed as stated before with the input data presented in the chapter 5. In the table 11 the principal statistics from the model solved with the software GAMS are represented.

Table 11 Computacional Results (Base Model Scenario)

Nº of equations	Nº of Variables	Total time for data generation (s)	Execution time (s)	Nº of iterations	Optimal margin (%)	Objective function value (days)
532.179	1.066.166	4.515	0.48	2316	0	3081

In the purposed model the demand that is being considered is 300 patients, and the results were able to schedule 299 patients with the parameters considered, the distribution of the patients scheduled per priority level is represented in the figure 12.

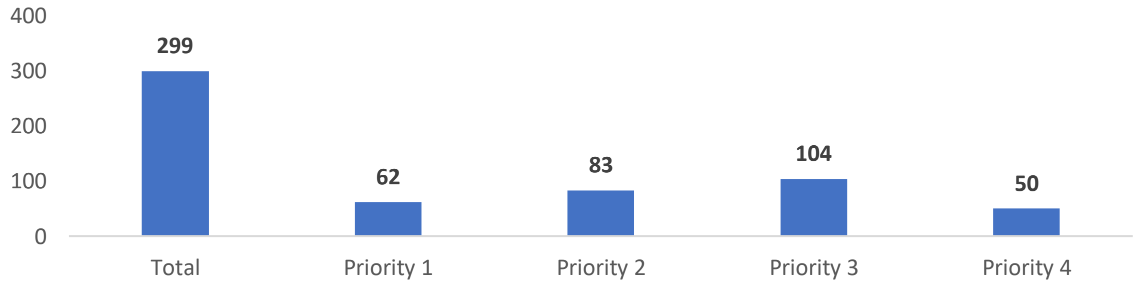


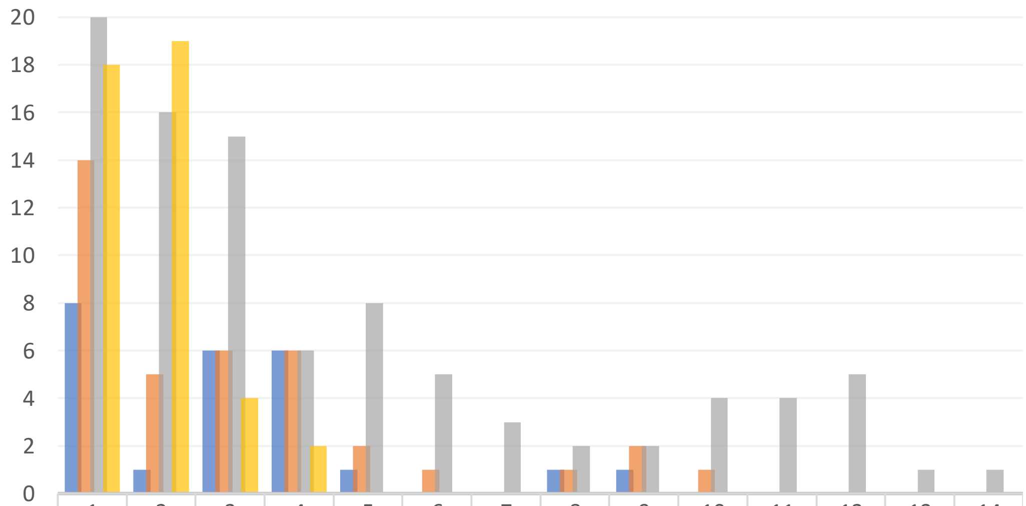
Figure 12 Number of patients attended (Base Model Scenario)

Although the principal objective of the model is to obtain a balanced patient scheduling attending to the patient wait target levels and with that add patient preferences to the model. The current results were effective since from the demand sample 102 patients were attended with 0 days of waiting time. The distribution of patients attended with 0 waiting time per priority is described in the table 12. When considering the results, the solution provided were able to decrease the wait time to 0 for 14% of the patient demand for level 4 of priority, 11% for priority level 3, 54% for priority level 2 and lastly 61% for priority level 1.

Table 12 Number of patients with 0 waiting time (Base Model Scenario)

Patient Priority	*Nº of patients with 0 waiting time*
Level 1	38
Level 2	45
Level 3	12
Level 4	7

Another relevant data is the number of days that the patients is waiting to receive treatment per priority. In the present solution the maximum number of days of wait time achieves is 14 days (n=14). The distribution of the wait time per priority level is described in the figure 13. In the data provided it is relevant to state that for priority level 4 98% of the patients were attended within the wait time target of 3 days, with only 2 patients with 4 days of waiting time. Despite that conclusion, the acuity level was 90% so that restriction was achieved. For the rest of the priority levels the wait time target was achieved (100%) for all the patients.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Priority 1	8	1	6	6	1	0	0	1	1	0	0	0	0	0
Priority 2	14	5	6	6	2	1	0	1	2	1	0	0	0	0
Priority 3	20	16	15	6	8	5	3	2	2	4	4	5	1	1
Priority 4	18	19	4	2	0	0	0	0	0	0	0	0	0	0

Figure 13 Number of patients waiting to be scheduled per priority (Base Model Scenario)

After addressing the results in the current model, it is relevant to simulate the current practice of the hospital (absence of priorities). The following chapter presents the results of this solution.

6.2 Alternative Scenario (Absence of Priorities)

In this section, it is presented the alternative scenario with the absence of patient priorities with the purpose of analysing the performance of the base case scenario. Through the following sections the necessary data for the model is explained and the principal results are presented.

6.2.1 Data input

As stated in the chapter 5, the present scenario is considered with the purpose of simulating the hospital current practice and with that testing the results of the base model scenario. In order to formulate this scenario, the data presented in the chapter 5 was reformulated. The planning period is similar (T=365) as the demand of patients (300 patients) and the total available time for service (8h). Although, with the purpose of achieving response in the model the weight of the patient's priorities was modified through the parameters service time for patient's priority (s_p), wait time targets (w_p), service level (α_p) and penalty cost for delaying patients (h(p,n)).

- The service time for patient priority (sp) was considered the same through de 4 levels of priority, that is 4h for all the patients, since is the normal consultation time used in the hospital for all patients.
- As defined in the PAI, the wait time target considered in the department is 35 days for 90% of the patients.
- The penalty cost for delaying patients with priority (h(n,p)) as stated in the chapter 5 was considered 1 until the desired service level (35 for all the patients) and increase 1 decimal case until the end of the horizon.

The principal assumptions of the alternative scenario are presented in the Table 13.

Table 13 Alternative Scenario Data Input

Parameter	*Value*
Planning Period (T)	365 days
Patient Priorities (P)	P1=P2=P3=P4
Demand of Patients with Priority (d_{pt})	300 patients
Total Available Time for Service (c_t)	8h
Service Time for Patient Priority (s_p)	4h
Wait time targets (w_p)	35 days
Service Level (α_p)	90%
Penalty Cost for Delaying Patients (h(p,n))	1 until n=35, increasing 1 unit until n=365

Ensuring the data that is going to serve as input for the present scenario, the following section focuses on the principal results for the present assumptions.

6.2.2 Results

In the table 14 the principal statistics from the model solved with the software GAMS are represented.

Table 14 Computational Results (Alternative Scenario)

Nº of equations	Nº of variables	Total time for data generation (s)	Execution time (s)	Nº of iterations	Optimal margin (%)	Objective function value (days)
532.179	1.066.166	4.454	0.47	1376	0	24295

In the purposed model the demand that is being considered is 300 patients, and the results were able to schedule 295 patients with the parameters considered, the distribution of the patients scheduled per priority level is represented in the figure 14.

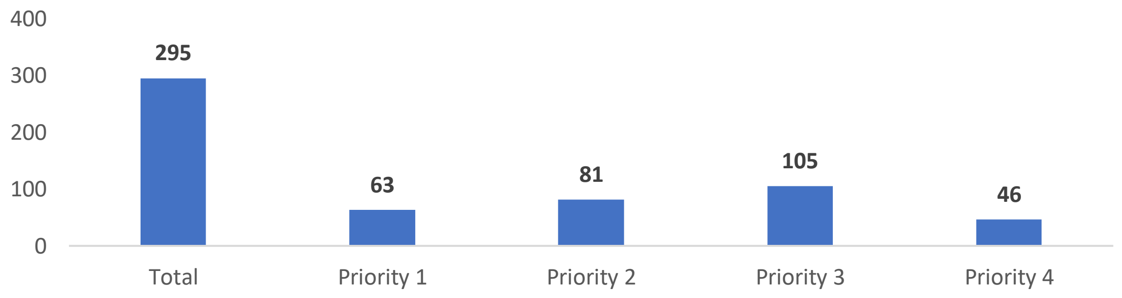


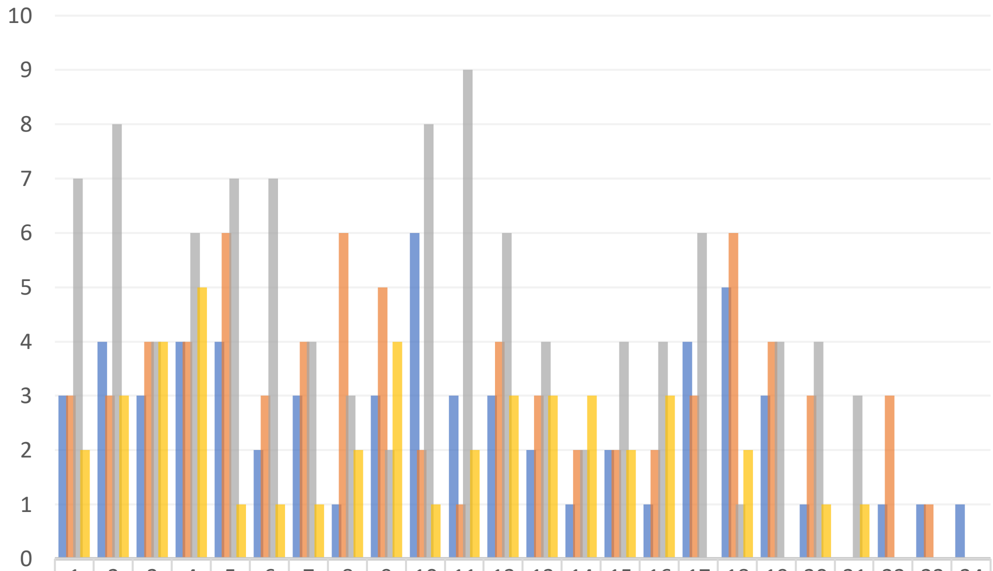
Figure 14 Number of patients attended (Alternative Scenario)

The distribution of patients attended with 0 waiting time per priority is described in the table 15. When considering the results, the solution provided were able to decrease the wait time to 0 for 2% of the patient demand for level 4 of priority, 2% for priority level 3, 8% for priority level 2 and 3% for priority level 1.

Table 15 Number of patients with 0 waiting time (Alternative Scenario)

Patient Priority	*Nº of patients with 0 waiting time*
Level 1	2
Level 2	7
Level 3	2
Level 4	2

As stated before, another relevant data under study is the number of days that the patients are waiting to receive treatment per priority. In the present solution the maximum number of days of wait time achieves was 24 days (n=24). In the data provided it is relevant to state that for the current's scenario the wait time target for all the patients were increased to 35 days, and it is visible that the model is able to schedule all the patients within this time for the required service level (90%). Although and as is going to be analysed in the next chapter and due to the severity of the cancer disease depreciation the patient priorities could have negative effects in the condition of the patients, and it is visible that for higher priority level of patients the waiting time is larger than the expected and this could be a high conditioner for the timely treatment of the patient and his health status. The distribution of the wait time per priority level is described in the figure 15.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Priority 1	3	4	3	4	4	2	3	1	3	6	3	3	2	1	2	1	4	5	3	1	0	1	1	1
Priority 2	3	3	4	4	6	3	4	6	5	2	1	4	3	2	2	2	3	6	4	3	0	3	1	0
Priority 3	7	8	4	6	7	7	4	3	2	8	9	6	4	2	4	4	6	1	4	4	3	0	0	0
Priority 4	2	3	4	5	1	1	1	2	4	1	2	3	3	3	2	3	0	2	0	1	1	0	0	0

Figure 15 Number of patients waiting to be scheduled per priority (Alternative Scenario)

The principal trade-offs for both scenarios under analysis is presented in the next section.

6.3 Scenarios Trade-off

In this section, it is presented the principal comparisons of both scenarios under analysis. The purpose is to be able to compare the effect that introducing patient priorities has in oesophageal and cancer department scheduling performance. To simplify the analysis the base model scenario is going to be addressed as scenario A and the alternative scenario (absence of priorities) is going to be addressed as scenario B.

The first consideration is that in the scenario A, we were able to schedule more patients than in the scenario B. This states that the scenario A is more effective when minimizing the objective function and balance the number of patients that receive treatment according to the different priority levels as stated previously, in order to obtain a balanced schedule for patient admission.

Furthermore, another relevant consideration is the number of patients with 0 wait time per priority. For all the priority levels it is visible that the number of patients that are scheduled without wait time are superior in the scenario A than in the scenario B (as shown at the figure 16). With that consideration is feasible to say that addressing priorities within the different patients could help the department to decrease the wait time for all the demand of patients.

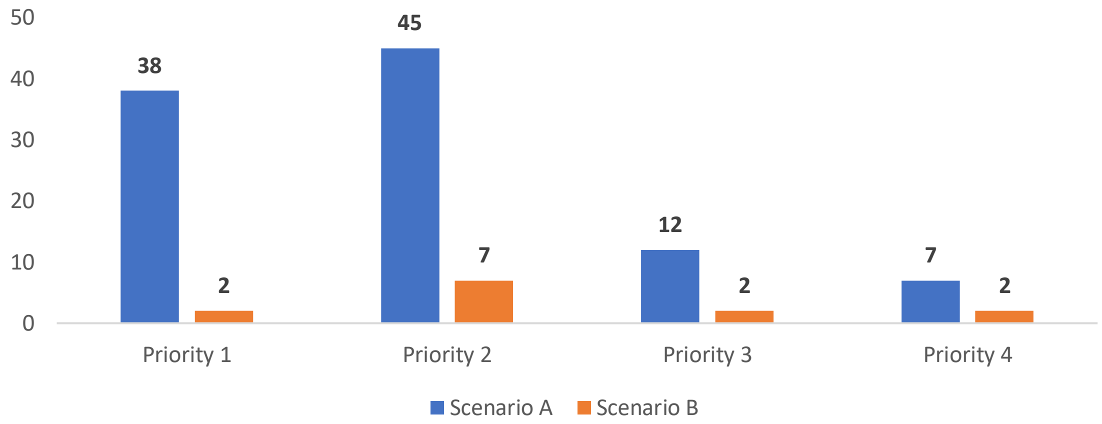


Figure 16 Nº of patients with 0 wait time per priority (Scenario A vs Scenario B)

When analysing the maximum number of days that a patient is waiting to receive treatment, once again in the scenario A we were able to decrease in 10 days the overall waiting time for the overall patient demand. The figure 17 shows the evolution of the number of patients per waiting day. This indicator is especially important to consider, because when considering patients with higher priority for the scenario B we could observe that (figure 22) for example for the priority of level 4 there are 35 patients waiting for more than 3 days for treatment, representing 76% of the patients of this priority and for level 3 there are 9 patients waiting for more than 15 days for treatment representing 8% of the patients of this priority. This scenario provides a solution that could be threatening for the patient health status.

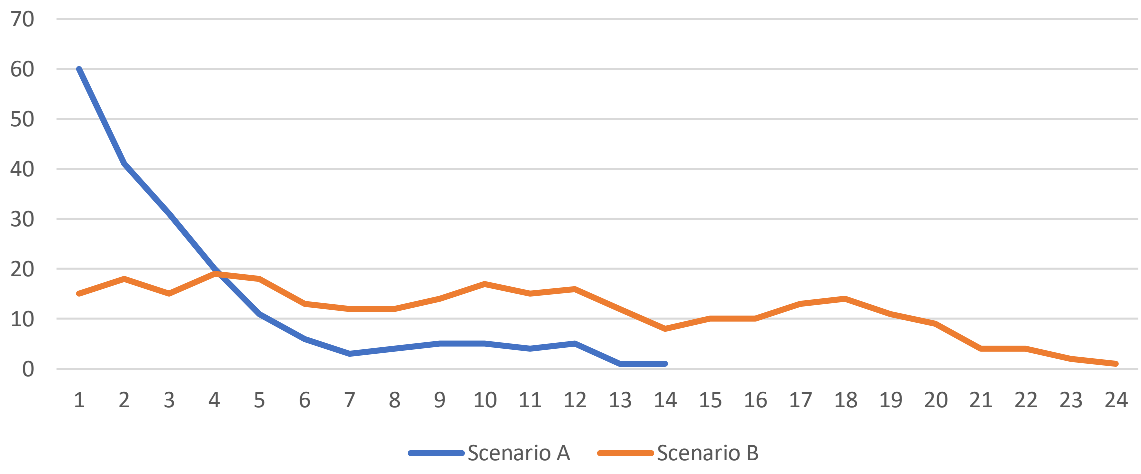


Figure 17 Nº of patients waiting for n days per scenario

The evidence the present chapter provide valid conclusions to say that the performance of the scenario A is better than the scenario B. Furthermore, in the next chapter some parameters are analysed with the purpose of understanding the weight that their variation has in the model performance.

6.4 Sensitivity Analysis

After considering the results for both scenarios, it is relevant to test the effect that the variation of the different parameters has in the model performance. For that purpose, through the following sections the service time for patient priorities, wait time targets and service level for the base model scenario are analysed with the purpose of evaluate the model performance. In the case of the service time and the wait time target for patient priorities the values were variated 20% and in the case of the service level it was variated 1 percentual point.

6.4.1 Service Time for Patient Priorities (s_p)

The principal results for the variation of the service time for patient's priority is presented in the table 15. When analysing the results, we can conclude that when decreasing the service time for patient priorities could be an additional improvement in the model. When decreasing 20% of the service time for each priority we were able to decrease 2 days the wait time target and increase the number of patients with 0 wait time for almost the priority levels. Although this could be an improvement in the model, needs to be articulated with the oesophageal and stomach cancer department, because reducing the service time may not be feasible in the real context.

Table 16 Sensitivity Analysis Service Time for Patient Priorities (sp)

Variation	-20%		Base model scenario		+20%	
	Nº of patients with 0 wait time	Max. nº days waiting	Nº of patients with 0 wait time	Max. nº days waiting	Nº of patients with 0 wait time	Max. nº days waiting
Priority level 4	8	4	7	4	8	4
Priority level 3	26	12	12	14	9	15
Priority level 2	41	9	45	8	24	17
Priority level 1	57	2	38	5	20	13
	SUM (132)	MAX (12)	SUM (102)	MAX (14)	SUM (61)	MAX (17)

6.4.2 Wait Time Targets (w_p)

The principal results for the variation of the wait time target are presented in the table 16. Therefore, it is important to state that it is infeasible to decrease 20% of this parameter for the patients with priority level 4, since it's impossible to attend the demand of this patients with less than 3 days. For the case of this parameter, we can state that for the variation considered, the wait time target doesn't have much effect in the model solution.

Table 17 Sensitivity Analysis Wait Time Targets

Variation	-20%		Base model scenario		+20%	
	Nº of patients with 0 wait time	Max. nº days waiting	Nº of patients with 0 wait time	Max. nº days waiting	Nº of patients with 0 wait time	Max. nº days waiting
Priority level 4	6	4	7	4	4	4
Priority level 3	14	15	12	14	12	15
Priority level 2	44	9	45	8	49	10
Priority level 1	38	10	38	5	39	7
	SUM (102)	MAX (15)	SUM (102)	MAX (14)	SUM (104)	MAX (15)

6.4.3 Service Level (α_p)

The principal results for the variation of the wait time target are presented in the table 17. It is also stated that when variating in 1pp the wait time target the solution provided don't change much and neither increasing nor decreasing the service level provides a better solution than the base model scenario.

Table 18 Sensitivity Analysis Service Level

Variation	**-1 pp**		**Base model scenario**		**+1pp**	
	Nº of patients with 0 wait time	Max. nº days waiting	Nº of patients with 0 wait time	Max. nº days waiting	Nº of patients with 0 wait time	Max. nº days waiting
Priority level 4	4	4	7	4	9	3
Priority level 3	14	15	12	14	11	15
Priority level 2	47	9	45	8	42	11
Priority level 1	38	9	38	5	35	9
	SUM (103)	MAX (15)	SUM (102)	MAX (14)	SUM (97)	MAX (15)

After analysing the principal results of the model, the next chapter presents the general recommendations for the oesophageal and stomach department.

6.5 General Recommendation to IPOLFG Oesophageal and Stomach Department

In addition to the results obtained in the present chapter, this section purposed to present the general recommendations for the oesophageal and stomach department at IPOLFG considering the model results.

The first consideration, and the most relevant, is that considering patient priorities within the several patients of the department have effective results regarding the patient scheduling optimization. In the present study it is concluded that when prioritizing different group of patients, the department is able to decrease the overall patient wait time. This consideration is supported with the comparison of the result data analysed through the section 6.3

Another relevant recommendation to the department is that when prioritizing patients, it is possible to attend the patient wait targets for all the patients. With that assumption the oesophageal and cancer department is able to achieve the maximum patient satisfaction and expectation. This conclusion is important, since was stated in the meetings with the department that is necessary to justify near the hospital administration that the departments have sufficient capacity to attend the demand of oesophageal and stomach cancer disease. The present study presents sufficient results to support this necessity.

Furthermore, is important to clarify that the current practice of the department, consisting of depreciating patient priorities is a dangerous approach when taking into account the health status of the patient, because high priority level of patients that require more detailed attention from the department could fall into late treatment dates (as observed in the alternative scenario that represents the current practice of the department). That consideration could be reflected into severe consequences and contribute to the evolution of the disease.

However, the department coordinator presented a relevant limitation considering that prioritizing patients in the hospital department is not ethical in a medical perspective. Although, with the conclusions presented in this dissertation it is justified that the benefit of implementing this model could have a positive effect for the totality of the patients, providing relevant and satisfying results for a balanced patient scheduling method.

Despite that, and due to the lack of data available, a group of assumptions were made to obtain the present results. For that reason, it is important for the part of the department to analyse the feasibility of the assumptions in order to validate the positive effect of the addressed changes.

Finally, the principal recommendations for the oesophageal and stomach cancer department are resumed as:

- Addressing patient priorities within the scheduling methods decrease the waiting time for the overall demand of patients.
- It is possible the attend the overall yearly demand of patients with the present resources available
- In order to validate the assumption made, it is important to realize an analysis regarding the feasibility of the data provided to the model and possible implementation in the department.

In the following chapter the principal conclusions of the present dissertation are presented and also some considerations for future work.

7. CONCLUSIONS AND FUTURE WORK

The oncology department is a complex environment requiring multiple professionals and departments coordination, and the limited budget create a complex decision for administrators in the healthcare field to increase efficiency with the existent resources. The IPOLFG operations optimization are conditioned by the complex nature of the cancer disease. Thus, the cancer patient, since the diagnosis and treatment are individual, the path is majorly heterogeneous, and the specific comorbidities affect the process. The oncology departments work under a pressure environment of decision-making policies, and, within a lack of decision models, the hospital relies on the experience and quality of the institution and their professionals to make the best decisions possible.

In Portugal, the IPOLFG receives the highest volume of patients with oesophagus and stomach pathology, addressing the institution a higher responsibility in the efficiency and management of the operation. The performance indicators in the PAI and the hospital effort to modernize the resources available and the conditions for the staff and patients show that there is room for improvement in the institution, stating the importance of this research with the ultimate purpose of saving lives and addressing the patient needs and expectations in terms of quality of service.

One of the most important decisions in the process is to address the complexity of the operations balanced with the patient's expectations of the process. In the literature it is observed that the capacity and the availability of resources, as well as the multi-appointment nature of the decisions conditionate this process, but very few models incorporate the patient expectations and needs in their formulation.

In the present dissertation is developed a mathematical model to help the IPOLFG to optimize the patient flow and the process time of the operations in the RCOS providing an increased patient satisfaction and serving patient's wait time targets. With that in mind, a Multi-Priority Integer Programming model is developed in which patients are prioritized based on their acuity level, assuming that there is a wait time target for each acuity level to ensure that patients of lower acuity do not wait for an unreasonable amount of time while higher acuity patients are being served and through that achieving a balance scheduling for all patients. It was also stated that in the present hospital patient admission there are no rules in the appointment booking since the department receives a waiting list and the first patient that is contained in the waiting list is booked for consultation according to the multidisciplinary group consultation. As concluded in the present dissertation, that method is not the optimal way to increase the efficiency of the patient flow and neglecting patient priorities could lead to catastrophic results due to the condition of the disease in analysis.

Furthermore, the results obtained with the present study provide sufficient evidence that addressing priorities through the demand of patients in the department is more efficient than the patient scheduling method that is currently used in the department.

Considering the problem that is being under optimization in the department, it represents an innovation in the current processes of the hospital, since any type of prioritization isn’t being considered. Stating that, is predictable that the amount of data the hospital is able to provide is scarce and some assumptions need to be taken in order to analyse the case study. These assumptions restrict the feasibility of the results. Although, the amount of data collected was validated through several meetings with the hospital providing high credibility for the overall results.

Despite the dissertation present resolute solution for the hospital patient scheduling, some future work considerations that were not possible to be covered need to be addressed. The first consideration is that the integration of multiple healthcare providers with different levels of expertise must be addressed. It is feasible to consider that the demand of patients requires different type of resources, physical and human. This consideration could help the model to obtain more robust results.

Another future consideration is the condition of patient availability. As presented in the literature review, the demand of patients is not static, and several factor as the punctuality and assiduity of patients could affect the optimal patient scheduling. This uncertainty has not been addressed in the present research and such factor could be an important addition when simulating a model that strives to reflect the real context of the hospital patient flow.

In sum, this study reflects that there is space for increasing the efficiency in the oesophageal and stomach department of the IPOLFG. The principal conclusion is that addressing patient priorities within the scheduling methods decrease the waiting time for the overall demand of patients. Also, it is possible to attend the overall yearly demand of patients with the present resources available, and that consideration is important for the department. Finally, balancing the hospital service time capacity and the patient’s wait time expectation is able to bring benefits for both parts since the hospital is able to balance the resources in a more balanced way and with increased efficiency and for the patients it is able to increase the satisfaction without compromising their health status, and in a disease as cancer with the mortal condition that is well known, this could help to save lives.

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Appendix A: Access to IPOLFG

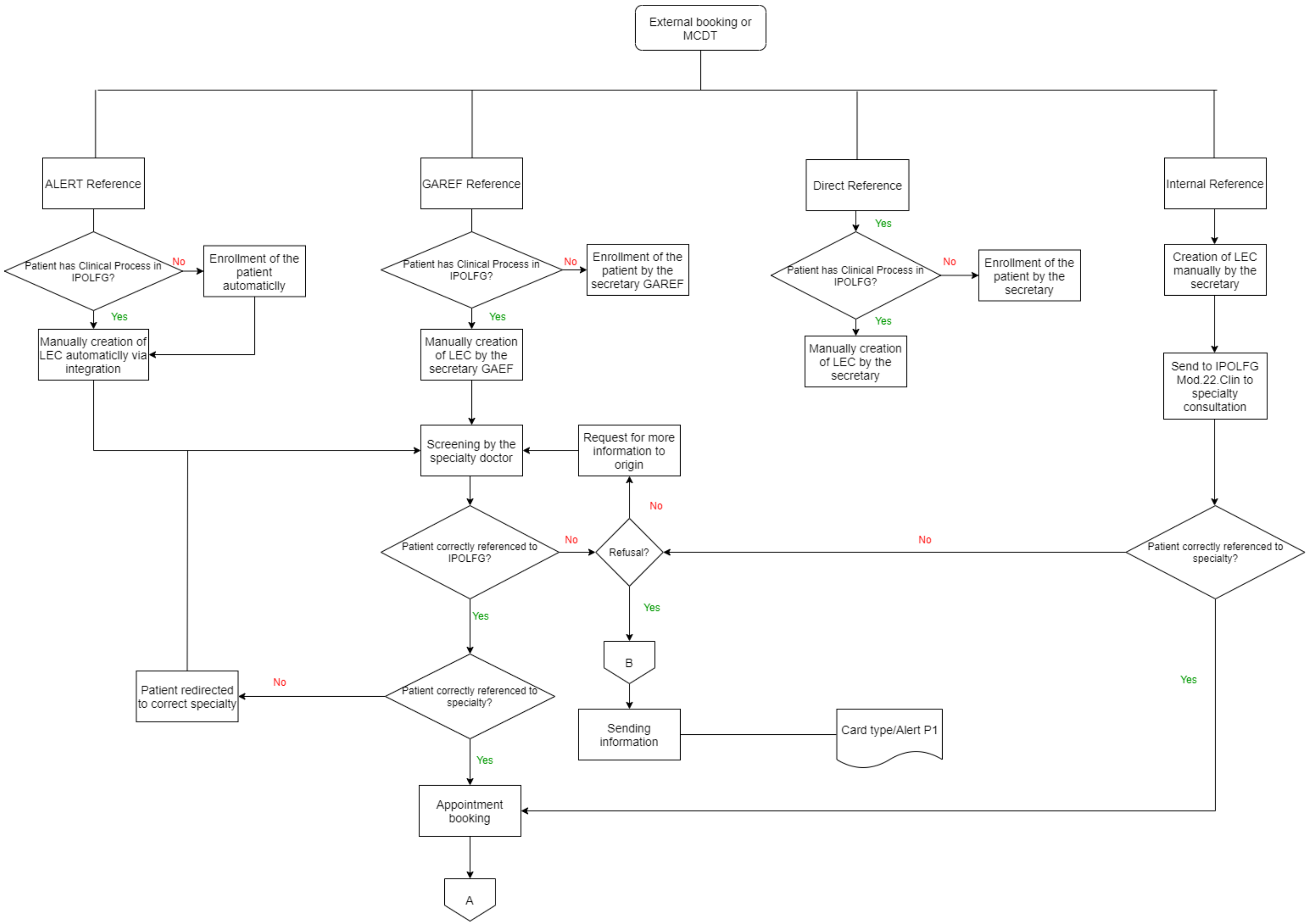

Figure 18 Flowchart of the different ways of access to IPOLFG

Appendix A: Access to IPOLFG

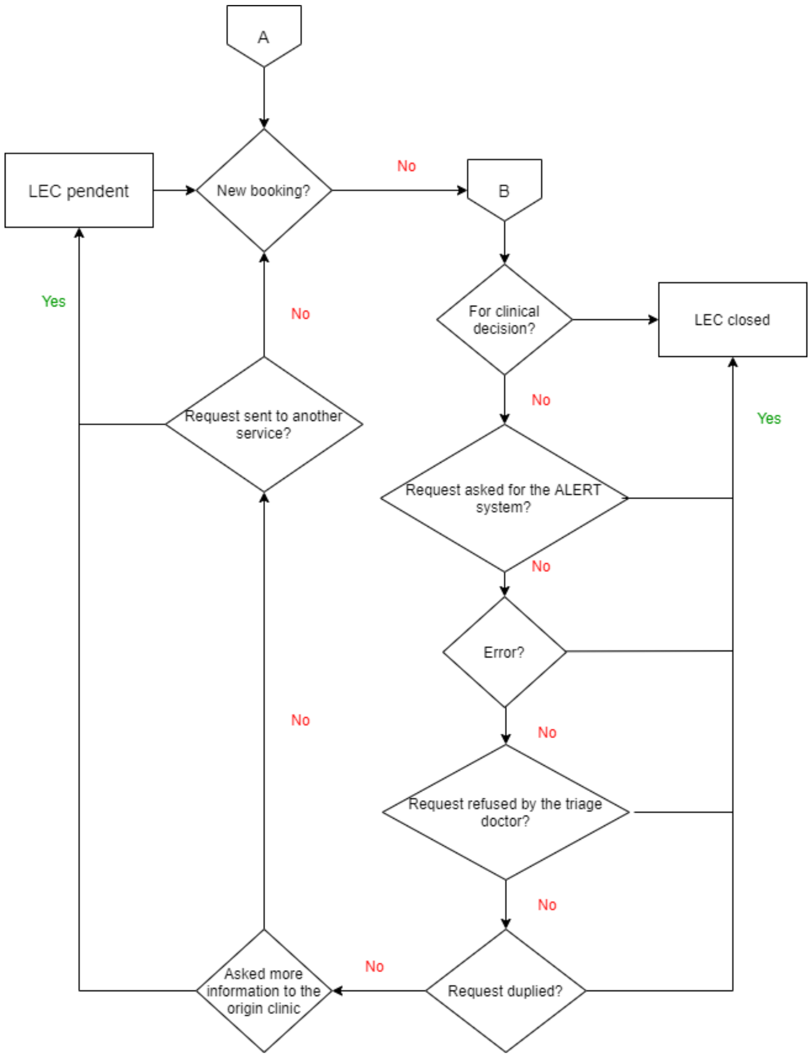

Figure 19 Flowchart of new booking assignment

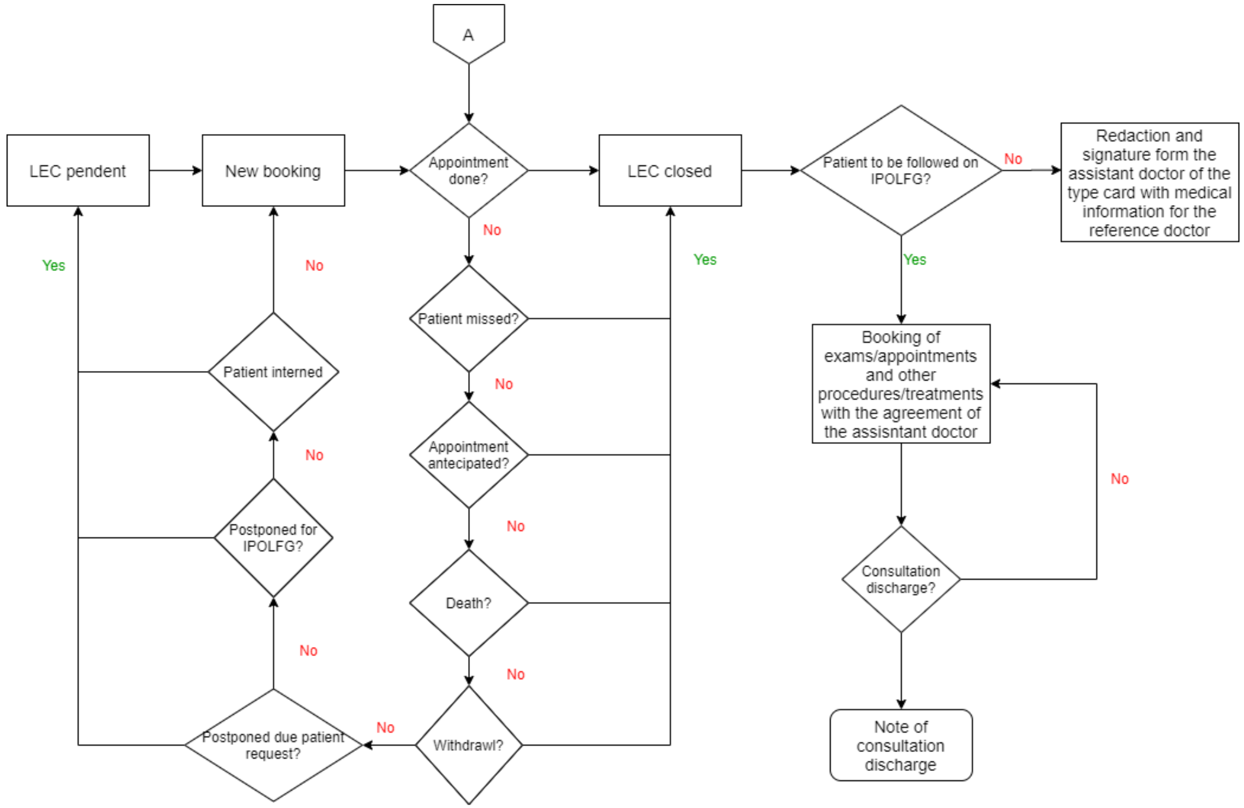

Figure 20 Flowchart to close process

Appendix A: Access to IPOLFG

Table 19 Description of the activities of ALERT Reference

Activity	Responsibility	Execution criteria	Indicator
External Booking or MCDT	Doctor of Health Center	Clinical information, copy of the exams results, collection of patient data	-
Verifying existence of clinical process	Secretary of GAREF	Analysis of physical or informatic process	0 days
Enrolment of patient	Secretary of GAREF	Evaluation of patient data and process	0 days
LEC creation	Secretary of GAREF	Automatically created	0 days
Screening by specialty doctor	Specialty doctor	Evaluation of the documents received about the patient information	< 2,5 days
Patient incorrectly referenced to IPOLFG	Specialty doctor	Refused (LEC closed) or request more information (LEC pendent)	< 1 day
Patient incorrectly referenced to specialty	Specialty doctor	Redirect to correct specialty. Evaluation of the information to requested specialty	<1,5 days
Appointment booking	Clinic secretary of specialty	Verify agenda, priority and information of the patient	<3 days
LEC closed	Clinic secretary	Depends on the patient presence	-

Table 20 Description of the activities of GAREF Reference

Activity	Responsibility	Execution criteria	Indicator
External Booking or MCDT	Hospital doctor, Private doctor, DGS, embassy request	Clinical information, copy of the exams results, collection of patient data	-
Verifying existence of clinical process	Secretary of GAREF	Analysis of physical or informatic process	0 days
Enrolment of patient	Secretary of GAREF	Registration of patient data	0 days
LEC creation	Secretary of GAREF	Manually creation of LEC and sending to service	0 days
Screening by GAREF doctor	GAREF Doctor	Evaluation of the documents received about the patient information by the assistant doctor	<1,5 days
Patient incorrectly referenced to IPO	GAREF Secretary	Refusal or request for more information	<1 day
	Clinic Secretary	Inform GAREF and evaluate necessity of patient returning to IPOLFG	<1 day
Patient incorrectly referenced to specialty	Specialty Doctor	Sending information and redirecting patient	<1,5 days
Appointment Booking	Clinic Secretary of specialty	Verify agenda, priority and information of the patient	<1 day
LEC closed	Clinic Secretary	Depends on the patient presence	-

Table 21 Description of the activities by Direct Reference

Activity	Responsibility	Execution criteria	Indicator
External Booking or MCDT	Doctor of Health Center, Hospital or Private	Clinical information, copy of the exams results, collection of patient data	-
Verifying existence of clinical process	Secretary	Analysis of physical or informatic process	0 days
Enrolment of patient	Secretary	Evaluation of patient data and process	0 days
LEC creation	Secretary	Manually creation of LEC	0 days
Medical Screening	Specialty screening doctor	Evaluation of the documents received about the patient information by the assistant doctor	< 1,5 days
Patient incorrectly referenced to IPOLFG	Clinic Secretary	Inform GAREF and evaluate necessity of patient returning to IPOLFG	< 1 day
Sending to correct specialty	Secretary of GAREF	Redirect to correct specialty patient information	<1,5 days
Appointment booking	Clinic secretary of specialty	Verify agenda, priority and information of the patient	<3 days
LEC closed	Clinic secretary	Depends on the patient presence	-

Table 22 Description of the activities by Internal Reference

Activity	Responsibility	Execution criteria	Indicator
External Booking or MCDT	Specialty doctor		-
LEC manually created	Secretary	Register of patient data	-
Sending to correct specialty	Specialty Doctor	Evaluation of the booking request	-
Patient incorrectly referenced to specialty	Specialty Doctor	Sending to origin specialty	-
Appointment booking	Clinic secretary of specialty	Verify agenda, priority and information of the patient	-
LEC closed	Clinic secretary	Depends on the patient presence	-

Appendix B: Patient Demand Distribution

Table 23 Distribution of patient demand

	P1	P2	P3	P4
t1	0	0	0	0
t2	0	0	0	0
t3	0	0	0	0
t4	0	0	0	0
t5	0	0	0	0
t6	0	0	0	0
t7	0	0	0	2
t8	0	0	0	0
t9	0	0	0	0
t10	0	0	0	0
t11	0	0	0	0
t12	0	0	0	0
t13	0	1	2	0
t14	1	2	3	3
t15	2	1	3	3
t16	0	0	0	0
t17	0	0	0	0
t18	0	0	0	0
t19	0	0	0	0
t20	0	0	0	0
t21	0	0	0	0
t22	0	0	0	0
t23	0	0	0	0
t24	0	0	0	0
t25	0	2	2	1
t26	0	0	0	0
t27	0	0	0	0
t28	0	1	2	0
t29	0	0	0	0
t30	0	0	0	0
t31	0	0	2	0
t32	0	0	0	0
t33	0	0	0	0
t34	0	0	0	0
t35	0	0	0	0
t36	0	0	0	0
t37	0	0	0	0
t38	0	0	0	0

	P1	P2	P3	P4
t39	0	0	0	0
t40	0	0	0	0
t41	0	0	0	0
t42	0	0	0	0
t43	0	0	0	0
t44	0	0	0	0
t45	0	0	0	0
t46	0	0	0	0
t47	0	0	0	0
t48	0	0	0	0
t49	0	0	0	0
t50	3	1	3	0
t51	0	0	0	0
t52	0	0	0	0
t53	0	0	0	0
t54	0	0	0	0
t55	0	0	0	3
t56	0	1	1	0
t57	3	0	3	3
t58	0	0	0	0
t59	0	0	0	0
t60	0	0	0	0
t61	1	1	1	3
t62	2	1	2	0
t63	0	0	0	0
t64	0	0	0	0
t65	0	0	0	0
t66	0	0	0	0
t67	0	0	0	0
t68	0	0	0	0
t69	0	0	0	0
t70	0	0	0	0
t71	0	0	0	0
t72	0	0	0	0
t73	0	0	0	0
t74	0	1	2	0
t75	0	0	0	0
t76	0	0	3	1
t77	0	0	0	0
t78	0	0	0	0
t79	0	0	0	0
t80	0	0	0	0

	P1	P2	P3	P4
t81	0	0	0	0
t82	0	0	0	0
t83	0	0	0	0
t84	0	0	0	0
t85	0	0	0	0
t86	0	0	0	0
t87	0	0	0	0
t88	2	3	2	0
t89	0	0	0	0
t90	0	0	0	0
t91	0	0	0	0
t92	3	3	1	0
t93	0	0	0	0
t94	0	0	0	0
t95	0	0	0	0
t96	1	2	3	3
t97	0	0	0	0
t98	0	0	0	0
t99	0	0	0	0
t100	0	0	0	0
t101	0	0	0	0
t102	0	0	0	0
t103	0	2	2	0
t104	0	0	0	0
t105	0	0	3	0
t106	0	0	0	0
t107	0	0	0	0
t108	0	0	0	0
t109	0	0	0	0
t110	0	0	0	0
t111	0	0	0	0
t112	0	0	0	0
t113	0	0	0	0
t114	0	0	0	0
t115	0	0	0	0
t116	1	2	2	3
t117	0	0	0	0
t118	0	0	0	0
t119	0	0	0	0
t120	0	0	0	0
t121	0	0	0	0
t122	0	0	0	0

	P1	P2	P3	P4
t123	0	0	0	0
t124	0	0	0	0
t125	0	0	0	0
t126	1	0	3	2
t127	0	0	0	0
t128	0	0	0	0
t129	0	0	0	0
t130	0	0	0	0
t131	0	2	2	0
t132	0	0	0	0
t133	0	0	0	0
t134	0	0	0	0
t135	0	0	0	0
t136	3	1	2	2
t137	0	1	1	0
t138	0	0	0	0
t139	0	0	0	0
t140	0	0	0	0
t141	0	0	0	0
t142	2	3	2	0
t143	0	0	0	0
t144	0	0	0	0
t145	0	0	0	0
t146	3	1	1	0
t147	3	2	2	0
t148	0	0	0	0
t149	0	0	0	0
t150	0	0	0	0
t151	0	0	0	0
t152	3	3	0	0
t153	0	1	1	0
t154	0	0	0	0
t155	0	0	0	0
t156	0	0	0	0
t157	0	3	1	0
t158	0	1	2	0
t159	0	0	0	0
t160	0	0	0	0
t161	0	0	0	0
t162	0	0	0	0
t163	0	3	2	0
t164	0	0	0	0

	P1	P2	P3	P4
t165	0	0	0	0
t166	0	0	0	0
t167	0	0	0	0
t168	0	0	0	0
t169	0	0	0	0
t170	1	2	2	0
t171	0	0	0	0
t172	0	0	0	0
t173	0	0	0	0
t174	0	0	0	0
t175	0	0	0	0
t176	0	0	0	0
t177	0	0	0	0
t178	0	0	0	0
t179	0	2	3	2
t180	0	0	0	0
t181	0	0	0	0
t182	0	2	3	3
t183	0	0	0	0
t184	0	0	0	0
t185	0	0	0	0
t186	0	0	0	0
t187	0	0	0	0
t188	3	0	3	1
t189	0	0	0	0
t190	0	0	0	0
t191	0	0	0	0
t192	0	0	0	0
t193	0	0	0	0
t194	0	0	0	0
t195	0	0	0	0
t196	0	0	0	0
t197	0	0	0	0
t198	3	1	1	0
t199	0	0	0	0
t200	0	0	0	0
t201	0	3	1	0
t202	0	0	0	0
t203	0	1	1	0
t204	0	0	0	0
t205	0	0	0	0
t206	0	0	0	0

	P1	P2	P3	P4
t207	0	0	0	0
t208	0	0	0	0
t209	0	0	0	0
t210	0	0	0	0
t211	0	0	0	0
t212	0	0	0	0
t213	0	0	0	0
t214	0	0	0	0
t215	0	0	0	0
t216	0	0	0	0
t217	3	1	0	1
t218	0	0	0	0
t219	2	1	2	0
t220	0	0	0	0
t221	0	0	0	0
t222	3	0	1	3
t223	0	0	0	0
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t225	0	0	0	0
t226	0	1	2	0
t227	0	0	1	1
t228	0	0	0	0
t229	0	0	0	0
t230	0	0	0	0
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t232	0	0	0	0
t233	0	0	0	0
t234	0	0	0	0
t235	0	0	0	0
t236	0	0	0	0
t237	0	0	0	0
t238	3	2	1	0
t239	0	0	0	0
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t242	0	0	0	0
t243	0	0	0	0
t244	0	0	0	0
t245	0	0	0	0
t246	0	0	0	0
t247	0	0	0	0
t248	0	0	0	0

	P1	P2	P3	P4
t249	0	0	0	0
t250	0	0	0	0
t251	0	0	0	0
t252	0	0	0	0
t253	0	0	0	0
t254	0	0	0	0
t255	0	2	0	0
t256	0	0	0	0
t257	0	0	0	0
t258	0	0	0	0
t259	2	3	1	2
t260	0	0	0	0
t261	0	0	0	0
t262	0	0	0	0
t263	0	0	0	0
t264	0	0	0	0
t265	0	0	0	0
t266	0	0	0	0
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t269	0	0	0	0
t270	0	0	3	0
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t272	0	0	0	0
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t279	0	0	3	0
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t284	0	0	0	0
t285	0	0	0	0
t286	0	0	0	0
t287	0	0	0	0
t288	0	0	0	0
t289	0	0	0	0
t290	0	0	0	0

	P1	P2	P3	P4
t291	0	0	0	0
t292	0	0	1	0
t293	0	0	0	0
t294	0	0	0	0
t295	0	0	0	0
t296	0	0	0	0
t297	0	0	0	0
t298	0	0	0	0
t299	0	0	0	0
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t325	0	1	2	0
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t327	0	0	0	0
t328	0	0	0	0
t329	0	0	0	0
t330	0	0	0	0
t331	0	0	0	0
t332	0	0	0	0

	P1	P2	P3	P4
t333	0	0	0	0
t334	0	0	0	0
t335	0	0	0	0
t336	0	0	0	0
t337	0	0	0	0
t338	0	0	0	0
t339	1	2	1	2
t340	0	0	0	0
t341	0	0	0	0
t342	0	0	0	0
t343	0	0	0	0
t344	0	0	0	0
t345	0	0	0	0
t346	0	2	1	0
t347	0	0	0	0
t348	0	0	0	0
t349	0	0	0	0
t350	0	0	0	0
t351	0	0	0	0
t352	0	0	0	0
t353	0	3	2	0
t354	0	1	3	0
t355	0	0	0	0
t356	0	0	0	0
t357	0	0	0	0
t358	0	0	0	0
t359	0	0	0	0
t360	0	3	3	2
t361	0	0	0	0
t362	0	0	0	0
t363	0	0	0	0
t364	0	0	0	0
t365	0	0	0	0