A simulation model for predicting palliative care needs and utilization of cancer patients

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Abstract

In European countries, the number of cancer patients and of deaths caused by cancer grows each year. This growth is influenced by the ageing of the population and by cancer’s rising incidence within each age group. The same problem affects the Portuguese population. Cancer patients, suffering from a high number of symptoms in their last months of life, may receive Palliative Care (PC), a service designed to alleviate pain and other distressing symptoms in patients suffering from life-threatening illnesses. PC is still in an incipient stage, with limited availability. An expansion of these services is necessary, requiring knowledge of the current and future number of patients benefiting from PC. However, no clear estimation of current needs exists, and while methodologies have been developed to predict future health care needs, they have not yet been applied to PC.

The goal of this study is then to determine the current and future number of cancer patients requiring PC, disaggregated by age and gender, through the use of a Markov cycle tree methodology, which also allows the separation of patients across the different service typologies (ambulatory care, home care and inpatient care) according to factors such as phase of disease and income level. Additionally, the costs associated with these services are calculated and compared to the costs of providing those services outside a specialized PC network.

The developed methodology is applied at the small-area level, to the Lisbon county and its municipalities, from the 2016 to 2021 period.

Keywords

Health Care, Palliative Care, Planning, Demand Prediction, Simulation, Markov Cycle Tree
Resumo

Nos países europeus, o número de pacientes oncológicos e de mortes causadas por cancro aumenta anualmente. Este aumento é influenciado pelo envelhecimento da população e pelo aumento da incidência de cancro em cada faixa etária. O mesmo problema afeta a população Portuguesa. Os pacientes oncológicos, que sofrem de um elevado número de sintomas nos seus últimos meses de vida, podem receber cuidados paliativos, um serviço destinado a aliviar a dor e outros sintomas angustiantes nos pacientes que sofrem de doenças fatais. Estes cuidados ainda estão numa fase inicial, com disponibilidade limitada. Uma expansão destes serviços é essencial, requerendo informação sobre o número atual e futuro de pacientes que necessitam de cuidados paliativos. No entanto, não existe qualquer estimativa clara das necessidades atuais, e apesar da existência de várias metodologias para prever as necessidades futuras de vários cuidados de saúde, estas ainda não foram aplicados aos cuidados paliativos.

O objetivo deste estudo é determinar o número atual e futuro de pacientes com cancro que necessitam de cuidados paliativos, desagregados por idade e género, através de uma metodologia de árvore de ciclo de Markov, permitindo a separação de pacientes nos diferentes tipologias de serviços (cuidados em ambulatório, domicílio e internamento), de acordo com fatores como a fase da doença e rendimento. Adicionalmente, os custos associados a estes serviços são calculados e comparados com os custos de fornecer esses serviços fora da rede de cuidados paliativos.

Esta metodologia é aplicada no distrito de Lisboa e nos seus concelhos, entre 2016 e 2021.

Palavras Chave

Cuidados de Saúde, Cuidados Paliativos, Planeamento, Previsão de Necessidades, Simulação, Árvore de Ciclo de Markov
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Abbreviations

AC  Ambulatory Care
BMI  Body Mass Index
EAPC  European Association for Palliative Care
EoL  End of Life
ER  Emergency Room
IC  Inpatient Care
INE  Instituto Nacional de Estatística
HC  Home-Based Care
LTC  Long Term Care
NHS  National Health Service
PC  Palliative Care
PPS  Palliative Performance Scale
QoL  Quality of Life
WHO  World Health Organization
1. Introduction

With the known ageing of the European population, diseases whose incidence rises with age are becoming an increasingly pressing concern to health care providers. One of those diseases is cancer, which is one of the main causes of death worldwide and whose age-specific incidence has been steadily rising over the years. Cancer patients, who usually suffer from a fast decline in health in their last months of life, experience a high number of distressing symptoms, which require alleviation, so the patients can have as much quality of life as possible. An answer to that lies in Palliative Care (PC), a holistic approach aimed at the prevention and relief of suffering, whose development only began in the 60s [1]. Its development has been slow worldwide, and even more so in Portugal, where it only began in the 90s [2]. Nowadays, there is a network of PC in place in Portugal, providing care in ambulatory or inpatient settings and in the patients’ homes. While the number of PC services available in Portugal has been increasing through the years, it is still not enough to meet all the demand, and further expansion of the PC network is necessary.

For that expansion, extensive information is required, both on the total number of patients that currently require PC and their characteristics, and the number of patients that will require it in the future. However, this information is often either unavailable, or extremely incomplete. This makes planning the expansion of the PC network a challenging endeavour.

Several methods exist to predict or forecast future health care needs of a given population, most of which are simulation models. However, these methods have focused on other areas of health care, and no studies on the estimation of future needs for PC could be found. In fact, the studies that are found in the literature are only focused on the current need of PC. These studies provided only rough estimates of need, not disaggregating results by age and gender, or taking a patient’s progression through the different phases of the disease into consideration. The estimates obtained were also annual values.

It is within this context that this study is developed. This study aims at developing a methodology that can estimate current and future demand for PC in a given population, disaggregated by age, gender and type of care required (Ambulatory Care (AC), Home-Based Care (HC) or Inpatient Care (IC)) each month. For that purpose, a Markov cycle tree methodology was developed, which separates patients by type of care according to phase of the disease, level of dependency, income level and presence or absence of an informal caretaker. The methodology also includes the calculation of the costs of providing care to dying cancer patients both within the PC network and outside. The work developed here allows a much more detailed view of the current level of need, by providing estimates disaggregated by factors such as age, gender, type of care and income level, for a smaller time period, and predicts future values.

With the knowledge of the number of patients requiring each type of care each month, several observations can be made of the results obtained. The changes in the number of patients requiring
each type of care over time can be studied, as well as the influence of factors not related to the disease (such as income level or presence of a caretaker) in the type of care required. The relation between age and gender and their effect on setting can be explored. A detailed cost analysis can be performed, enabling the determination of the potential savings from a PC network capable of providing care to all those that require it.

The methodology developed was applied to the Lisbon county and its municipalities, from 2016 to 2021, to individuals 18 years or older. We explored the evolution of need for PC for the Lisbon county and for each municipality separately. Afterwards, we took a closer look at the Lisbon municipality and studied the distribution of need across age group, gender, phase of the disease, and its relation to types of services. We studied the costs associated with this distribution and its evolution over time.

As expected due to the early stage in the development of PC in our country, it was found that the current offer of PC services is still far from meeting all the demand for this type of care. It was determined that the total number of patients requiring PC rises steadily over the time period in study, with a higher percentage of men requiring PC than woman. The majority of patients, both male and female, requiring PC are 65 years or older. Most patients, male and female and across age groups, require ambulatory care. Furthermore, it was determined that an extensive PC network, capable of meeting all the demand for this type of care, comes with considerable cost savings to the National Health Service (NHS).

This work is split across seven chapter. It begins with this chapter, where a broad overview of the thesis is given. It is followed by chapter 2, with the contextualization of PC, where its definition is presented, as well as its goals and its evolution over time, both in a broader sense in Europe, and in Portugal in particular, and its importance for cancer patients. In chapter 3, a review of the methods used to estimate health care needs in general is presented, along with the methods used to assess palliative care needs, both worldwide and in Portugal. In chapter 4, the methodology developed to estimate current and future PC needs is explained in-depth. In chapter 5, the data used is presented extensively, the model is validated and the methodology is applied to the Lisbon county and its municipalities, for the 2016 to 2021 period. In chapter 6, the results obtained are commented on and the contribution and limitations of the methodology are discussed. To finalize, in chapter 7 some final remarks on the work developed are presented and further work and methodology improvements are suggested.
2. Context

This chapter introduces the subject of PC. Initially, PC is defined, and its evolution worldwide and in Portugal is summarized. Afterwards, a closer look is taken at the organization of these services in Portugal and the type of patients they are destined for. To contextualize this thesis, the importance of PC services for cancer patients is explained, and these patients’ characteristics and the importance of providing them are explored in more detail. To finalize, the goal of this thesis is presented.

2.1 Definition of Palliative Care

The changes in medicine in the past century have led to an increase in the average life expectancy of the human population. However, this increase has also been accompanied by an increase in the incidence of chronic diseases, such as cancer, both in the total population and in each individual age group. Both these factors have led to an increase in the total number of individuals suffering from life-threatening diseases. For example, in 2003 it was estimated that in the following 10 to 15 years, there would be a 20% increase in the need for PC both for cancer and for non-cancer patients.

This increase necessarily translates into a higher number of people requiring care for relief from the symptoms of which they suffer. One of the answers to that problem can be found in PC, a modern movement which began internationally in the 60s, but only started to make an appearance in Portugal during the 90s.

Though the definition of PC has varied through the years, it is currently defined by the World Health Organization (WHO) as "an approach that improves the quality of life of patients and their families facing the problems associated with life-threatening illness, through the prevention and relief of suffering by means of early identification and impeccable assessment and treatment of pain and other problems, physical, psychosocial and spiritual".

In Portugal, the definition of PC differs slightly, with PC being considered the active, coordinated and comprehensive care, provided by special units and teams, in a hospital or at home, to patients suffering from an incurable or serious illness, in an advanced and progressive phase, as well as to their families, with the main objective of promoting their well-being and their quality of life, through the prevention and relief of physical, psychological, social and spiritual suffering, based on early identification and rigorous treatment of pain and other physical problems, but also psychosocial and spiritual problems.

PC is based on a set of principles and goals, which are as follows:

- The provision of relief from pain and other symptoms.
- The affirmation of life and the treatment of death as a natural process.
- To neither hasten nor postpone death.
• The integration of psychological and spiritual aspects of care.

• The offer of a support system to help patients live as actively as possible until death, and to help the patient’s family cope during the course of the patient’s illness and in their own bereavement after the patient’s death.

• Enhancing the patients’ Quality of Life (QoL) and potentially improving the course of illness.

• Seeing the disease as a cause of suffering to alleviate.

• Respecting and accepting each patient's values and priorities.

• The treatment of the patient’s physical, psychological, social and spiritual suffering in a holistic way.

• It is only provided when the patient and the patient's family accept it.

In Figure 2.1, it is possible to observe the distribution of PC needs by pathology worldwide, with cancer being one of the leading drivers of need.

![Figure 2.1: Distribution of adults worldwide in need of palliative care at the end of life by pathology](image)

Though initially PC was only destined for cancer patients, nowadays the patients receiving PC suffer from cancer, AIDS, advanced organ failure, or degenerative neurological diseases [5, 7]. However, these services can also be provided to patients suffering from cardiovascular diseases,
Palliative care provision is associated with several benefits. On the one hand, it has been shown that palliative care (PC) improves the End of Life (EoL) experience [8]. In fact, patients receiving PC report better QoL than those not receiving it, as well as a lower incidence of depression, longer median survival, along with better pain and symptom control [9]. PC has also been reported to decrease the effects of cancer symptoms. Additionally, several studies show a marked decrease in costs for PC providers when PC is provided to patients requiring it, as the number of visits to the Emergency Room (ER) these patients need decreases significantly, as well as the number of times the patient has to receive inpatient care and the length of stay when said services are required [10].

The potential for cost savings when there is an extensive PC network in place is of remarkable importance in several European countries, such as in the case of Portugal, given the recent cuts to the health budget, due to the economic crisis the country has been experiencing. It must also be noted that it is estimated that around 27.9% of all medical expenditure comes from patients in the last year of life [11].

Nowadays, it is estimated that there are approximately sixteen thousand hospice or palliative care service units worldwide [6].

2.2 Palliative Care in Europe

Throughout History, society has always tried to care for and support dying people. In Europe, the most notable efforts before the twentieth century are those of Mary Aikenhead and Jeanne Garnier [3]. Mary Aikenhead was the founder of Congregation of the Religious Sisters of Charity in Dublin in 1815. This religious order would then go on to found St Vicent’s Hospital in 1834, which Our Lady’s Hospice for the Dying would become part of in 1878. In 1842 Jeanne Garnier formed L’Association des Dames du Calvaire, which opened a house for the dying the following year.

Both these institutions tried to care for patients suffering from terminal and incurable diseases, though due to the lack of understanding of medicine and symptom control, these efforts weren’t as useful as they might otherwise have been.

In the twentieth century, however, things began to change. Modern medicine considers incurability and the inevitability of death as a failure and with its development people started being hidden away to die. There was also a repression of death-related emotions. Additionally, the focus of Medicine turned to finding the cure for diseases, which led to symptom control and relief of pain becoming less of a priority [12].

What is considered to be the modern PC movement—a holistic approach combining clinical care, research and education—began only in 1967, when Lady Cicely Saunders opened St Christopher’s Hospice in London [1]. This hospice had as a goal the provision of patients with proper care to ensure a good QoL in the last days before their deaths. Two years later, in 1969, the first home-care team was established, also as a part of St Christopher’s Hospice [1].

From that point on, PC services spread all over Europe, developing at different speeds. The
following years also saw the creation of several international organizations, such as the International Association for the Study of Pain and the International Hospice Institute and the European Association of Palliative Care. In the 80s, the WHO included PC into its medical concepts as an indelible part of cancer treatment. Since then, scientific journals have been started, professional and non-professional organizations have been set up, and national policy recommendations have been published.

A literature search on PC shows that there isn’t a single model of provision that is considered to be ideal, and indeed the way these services are organized varies greatly across Europe. Instead of recommending a strict set of guidelines for the implementation of PC services, the European Association for Palliative Care (EAPC) suggests each country should adapt the organization of its services, taking into consideration the needs of the patients and its own sociocultural characteristics [7]. For example, 5 of 52 European countries have well-developed hospices, while others have more home-care teams [7]. Traditionally, hospices are more widespread in Northern countries, while in Southern Mediterranean countries home care is more popular, both for religious and cultural reasons.

Observing the PC situation in Europe, it becomes clear there is a clear lack of consensus between experts regarding the right way to provide care, or even the total number of people requiring care, with a study showing a very low percentage (29%) of agreement between European experts on PC when it comes to the proportion of patients in need of PC in the community [13].

Since there is no model considered to be ideal when it comes to providing these services, they are organized in a multitude of ways throughout all of Europe. Some services are more common than others, however, such as specialist in-patient units, hospital PC teams, home care teams, day care facilities, hospitalization at home services and outpatient clinics [3].

The most important types of service are summarized below, according the European Association of Palliative Care [7].

- **PC units** provide specialist inpatient care and can usually be found inside a hospital or adjacent to it, though they can also exist as a stand-alone service. Their organization differs from country to country. In some countries, they are regular units of hospitals, providing care for the patients that require it. In other countries, they are standalone institutions, providing end of life care for patients for who cannot receive the care they require at home.
  - Complex procedures can be performed in this type of services and they allow the transmission of knowledge between healthcare practitioners.
  - Conversely, PC units are the services with the higher costs for the PC provider [10].

- **Inpatient hospices** provide care to patients in the last phase of their lives. Patients are admitted to a hospice when treatment in a hospital isn’t required but care at the patient’s home or in a nursing home isn’t possible. In many countries, inpatient hospices function as a PC unit, whereas, in other countries, a distinction between the way these services are organized can be observed. In Germany, for example, patients will be admitted to an inpatient hospice for EoL care, while in other countries, it is the PC units that provide EoL care.
• Hospital palliative care support teams provide specialist advise and support other health professionals, as well as patients and their families.

• Home palliative care teams provide PC in the patient's home, and support their families and carers. They might also advise other health care professionals.

  – Home care teams are the PC delivery model with the most reported benefits. This type of PC has the highest cost savings, as it reduces hospital stays [10], has a significant effect in the improvement of pain control [14], has a better reported QoL than the other types of services [15], and the QoL of caregivers remains constant over time, instead of decreasing [9].

  – Nevertheless, they provide limited access to the full PC teams and resources that are more easily accessed within a hospital setting, and require the presence of a caretaker.

• 'Hospital at home' services provide intensive care for patients, in their homes, that resembles the care the patients would receive in a hospital. This way, patients who would otherwise spend their last days in a hospital can be at home.

• Volunteer hospice team offers support and friendship to PC patients and their families, collaborating closely with other professional services in palliative care.

• Day hospices or day-care centers can be found in hospitals, hospices, palliative care units or in the community itself. They promote recreational and therapeutic activities among palliative care patients.

• Palliative outpatient clinics offer consultation services for patients.

  – Outpatient clinics decrease hospital admissions and improve QoL [9]. They might also potentially seem less threatening to patients and their families, while presenting lower costs to the PC provider.

  – As drawbacks, these services might not be able to handle patients with a heavier symptom burden, and patients in an advanced phase of their disease might not be able to visit this type of clinic.

PC can be provided by specialists or by non-specialists but it has been shown that specialists provide better results over time in control of pain and other symptoms, increased satisfaction, and reduction in the number of days of hospital stay [16].

Currently, there is no country member of the European Union without PC [17]. The current distribution of PC services across Europe can be observed in Figure 2.2. As can be seen, there is a higher number of PC services available in Northern European countries (such as Iceland, Ireland and Sweden), while in Southern regions there is a much more limited number of services. Eastern European countries present the smallest number of services available.
2.3 Palliative Care in Portugal

In this section, the history and organization of PC services in Portugal is presented.

2.3.1 Evolution of PC provision in Portugal

The modern PC movement is fairly recent in Portugal, having only started in the 90s, due to grassroots actions rather than because of government initiatives. In 1992, the Pain Unit of the Fundão Hospital was created, which would later go on to become the hospital’s palliative medicine service [2]. Two years later, in 1994, the first Portuguese PC unit opened at Porto IPO [2]. The following year, in 1995, the first Portuguese PC organization was founded: Associação Nacional de Cuidados Paliativos, which would later become Associação Portuguesa de Cuidados Paliativos [18].

In 1996 the first homecare team was formed, in Odivelas [2]. In 2001 the National Cancer Plan was released, mentioning PC for the first time [19]. In 2004 the National Program of Palliative Care was approved by the Ministry of Health, later reviewed in 2010 [20]. In 2006 the National Network of Integrated Continued Care was created, including in its services the provision of PC which was a major factor in the development of PC in Portugal [21]. This network operates under the tutelage of the Ministry of Health (Ministério da Saúde) and the Ministry of Labour, Solidarity and Social Security (Ministério do Trabalho, Solidariedade e Segurança Social), and it is provided under the NHS. The NHS is a group of health care providers and services operating under the tutelage of the Ministry of...
Health, with the goal of protecting individual and collective health [22]. In 2012 the National Network of Palliative Care was created, assuming responsibility for the provision of PC in Portugal [23] and two years later, in 2014, hospital palliative care support teams became mandatory for every hospital in Portugal [24]. This network also operates as part of the NHS. It was only four years later, in 2016, that paediatric PC began to be implemented in Portugal, with the first service opening in June of that year.

2.3.2 PC organization in Portugal

In Portugal, PC can be provided in palliative care units, to inpatients, by hospital palliative care support teams, in a hospital environment, and finally by community support teams in palliative care at home, which can provide PC in patients’ homes.

When it comes to payments, while the main costs are supported by the NHS, partial payment is required from patients for palliative care consultation and medication. There is, however, no costs for patients for hospitalizations to receive PC [17].

Currently, the offer of PC services is well below the demand for these services [25]. As of 2016, there are 31 palliative care units, only 12 of which were managed by the NHS. Four more units are being built. There are hospital support teams present in 54 hospitals, 52 of which are managed by the NHS. There were 22 community care teams in operation, though only 15 of those were managed by the NHS [26].

Despite the importance given to home-care teams in the literature, it was found that they were only present in 9 of the 30 NUTS III regions that make up Portugal. This absence is more noted in the central, inland region of Portugal. This can be seen in Figure 2.3.
Palliative care units, meanwhile, can be found only in 17 NUTS III regions [26].

In an editorial written for a magazine curated by the Portuguese Association of Palliative Care [27], it is mentioned that it was complicated to gather all the scientific papers required for the magazine, which might be interpreted as a sign of both the phase of development of PC in Portugal, and the state of research and publication in the area in Portugal.

The same article also mentions the difficulties in the hirings of specialized PC professionals, due to the country’s current social, economic and political situation.

Additionally, an European study found that while the number of PC resources has increased, there hasn’t been a uniform development in the quality of care, which can vary across the country, as the priority of the government has been to increase the quantity of available services, rather than the quality of those services [17].

Looking at the numbers of teams available and at the other indicators of PC development, it becomes clear that PC in Portugal is still in an incipient stage, needing further development and investment in order to expand and provide care to all those who require it. That development must be guided and adapted towards each country’s needs, which might depend on type of pathology, existing resources, complexity of disease, etc [5].

For that purpose, in the following section a closer look is taken at the type of patients requiring PC in Portugal, essential information to have in order to properly plan the expansion and implementation.
2.3.3 Patients in need of PC in Portugal

Not a lot of information could be found regarding the utilization of and requirements for PC services in Portugal, which severely hinders a balanced and well thought-out expansion of the PC network. According to the National Programme for PC in Portugal is destined to patients and families with a limited life prognosis, intense suffering, and problems and needs which are difficult to solve, requiring specific, organized and interdisciplinary support [5]. This encompasses not only patients suffering from cancer, but also from HIV, severe organ failure, degenerative neurological diseases, amongst others [5].

PC was initially developed to answer to the needs of terminal cancer patients. Additionally, although this type of care has been developed so as to provide care for patients suffering from other diseases (i.e., non-cancer diseases), most terminal patients receiving care are still cancer patients. For this reason, the capability of a health system to respond to this need and provide the care required to this type of patients is one of the tools currently used to rate the efficacy of any PC network [28]. In Portugal, one of the goals of the National Programme for Palliative Care is to ensure that, until 2016, 40% of all patients dying from cancer can receive specialized PC [28], a number that, even if reached, does not cover all the currently estimated needs.

When it comes to patients suffering from other pathologies, an European study found that despite efforts to the contrary there has been no expansion of the network to encompass treatment of non-cancer patients, with approximately 95% of all patients receiving PC in Portugal being cancer patients [17]. However, it is still estimated that half of Portuguese cancer patients die before they receive the care they need [29].

Given the current utilization of PC services and the growing cancer incidence, it is the total PC needs of cancer patients that are studied in-depth. For that purpose, the following section focuses solely on the unique characteristics of these patients.

2.4 Cancer Patients and Palliative Care

As noted in the previous section, cancer patients are one of the key groups of patients requiring PC. For that reason, it is important to take a closer look at their characteristics.

Cancer has been a serious problem for the Portuguese population for several years. Since 1990, the mortality of cancer patients has been steadily increasing, while mortality by other causes has mostly either remained constant or decreased considerably. This can be observed in Figure 2.4.
As can be observed, apart from cancer mortality, only mortality by diabetes has increased, though this increase has been significantly less pronounced.

This increase in cancer mortality, coupled with the increase in cancer incidence, leads to a constant increase in the number of patients in terminal phases of cancer disease, which require relief from the increasingly high number of cancer symptoms they suffer from (it is estimated that each terminal cancer patients suffers an average of 11 symptoms \[31\]).

Unlike other chronic diseases, cancer is characterized by a long period of relatively good health followed by a fast decline over a period of weeks or months, as opposed to a long, steady decline over time, as shown in Figure 2.5.

It is when the phase of decline begins that PC is most often required. However, this point isn’t always easy to identify, as evidenced by the lack of consensus between experts as to when patients should begin receiving PC \[13\]. Therefore, it becomes necessary to develop methods to classify these patients according to their needs and symptoms. One of these methods will be further described in the following section.
2.5 Palliative Performance Scale

The Palliative Performance Scale (PPS) is a standardized tool used by health care providers to assess the health status of a patient [33]. In this scale, patients are classified in an 11-point scale ranging from 0% to 100%, with a 10% interval between each level (0%, 10%,..., 100%). A higher PPS score means a higher performance status, which translates into a higher degree of health and quality of life for the patient.

Patients are classified according to five different parameters: degree of ambulation (from full to bed bound), activity level (from normal activity to unable to do any activity) and evidence of disease (from no evidence of disease to extensive disease), ability to perform self-care (from full ability to total care required), level of intake (from normal to mouth care only) and conscious level (from full to drowsy or coma, with a varying degree of confusion. This can be seen in Table 2.1.

Table 2.1: Palliative Performance Scale [33]

<table>
<thead>
<tr>
<th>PPS Level</th>
<th>Ambulation</th>
<th>Activity and evidence of disease</th>
<th>Self-care</th>
<th>Intake</th>
<th>Conscious level</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>Full</td>
<td>Normal activity</td>
<td>Full</td>
<td>Normal</td>
<td>Full</td>
</tr>
<tr>
<td>90%</td>
<td>Full</td>
<td>No evidence of disease</td>
<td>Full</td>
<td>Normal</td>
<td>Full</td>
</tr>
<tr>
<td>80%</td>
<td>Full</td>
<td>Normal activity with effort</td>
<td>Full</td>
<td>Normal or reduced</td>
<td>Full</td>
</tr>
<tr>
<td>70%</td>
<td>Reduced</td>
<td>Unable to do normal job/work</td>
<td>Full</td>
<td>Normal or reduced</td>
<td>Full or confusion</td>
</tr>
<tr>
<td>60%</td>
<td>Reduced</td>
<td>Unable to do hobby/house work</td>
<td>Occasional assistance necessary</td>
<td>Normal or reduced</td>
<td>Full or confusion</td>
</tr>
<tr>
<td>50%</td>
<td>Mainly sit / lie</td>
<td>Significant disease</td>
<td>Considerable assistance required</td>
<td>Normal or reduced</td>
<td>Full or confusion</td>
</tr>
<tr>
<td>40%</td>
<td>Mainly in bed</td>
<td>Unable to do any work</td>
<td>Mostly assistance</td>
<td>Normal or reduced</td>
<td>Full or drowsy or confusion</td>
</tr>
<tr>
<td>30%</td>
<td>Totally bed bound</td>
<td>Unable to do any work</td>
<td>Total Care</td>
<td>Reduced</td>
<td>Full or drowsy or confusion</td>
</tr>
<tr>
<td>20%</td>
<td>Totally bed bound</td>
<td>Extensive disease</td>
<td>Total Care</td>
<td>Minimal sips</td>
<td>Full or drowsy or confusion</td>
</tr>
<tr>
<td>10%</td>
<td>Totally bed bound</td>
<td>Unable to do any work</td>
<td>Total Care</td>
<td>Mouth care only</td>
<td>Drowsy or coma</td>
</tr>
<tr>
<td>0%</td>
<td>Death</td>
<td>Extensive disease</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To characterize a patient according to the PPS, the health care provider starts at the ambulation column and reads downwards until finding the patient’s ambulation level. The health provider then moves to the next column, the activity and evidence of disease column in this case, starting not at the top but at the line corresponding with the ambulation level found in the previous step. The provider then reads downwards until finding the one that better fits the patient. These steps are repeated for all columns in the table.

This way, the further left a column is, the more important it is in determining a patient’s health status and the more precedence it takes over the other columns. For example, a patient that is bed bound must have a performance score of 30% or less, regardless of his performance in the other four parameters. The PPS has been used in many countries and translated into different languages, with experts agreeing that it is a valuable clinical assessment tool. Furthermore, when PPS classifications done by different doctors for the same patient are compared, consistent scores are achieved, indicating that the PPS is a good communication tool between healthcare professionals [34].

Using this scale, it is possible to separate cancer patients into different phases of the disease,
each with different symptoms and health care requirements.

Using the PPS, it is possible to divide cancer patients into four separate groups according to symptom burden and functional status: stable patients (for patients with PPS scores from 100% to 70%), transitional patients (for patients with PPS scores from 60% to 40%), EoL patients (for patients with PPS scores from 30% to 10%) and finally dead patients (for patients with a performance status of 0%). This separation is possible as studies have shown that patients in the 70-100% score band have different survival curves to those in the 40-60% score band and to those in the 30%, 20% and 10% scores) [35]. This separation has also already been used in other palliative care studies [36].

It is advised that patients begin receiving PC when they enter the transitional state, as the average sojourn period in the EoL state is too short (around two weeks) to fully answer the patient’s needs [35].

2.6 Thesis Motivation and Objectives

Given the previous chapter, it becomes clear that the ageing of the population, along with the increase in the incidence of chronic diseases, leads to an increase in the number of patients requiring PC each year. Patients with cancer, historically the main recipients of PC and those for whom PC services were initially created, now live much longer with the disease than they did in the past, which means higher cancer prevalence that might in turn mean a higher number of PC needs [37].

Unfortunately, the PC services available in Portugal are still not enough to provide care to everyone who requires it. This problem is only worsened by the recent budget cuts to the NHS which complicates the expansion of the PC network and the establishment of more PC services. In order to effectively expand the PC network, knowledge of the number of patients requiring PC and the type of care each patient requires, is required [38].

There is no accurate information of these needs, and, as will be shown in the following chapter, there is no accurate method to predict these values. Accordingly, the motivation of this thesis is therefore to give an answer to this problem. For that, a methodology that can be used to predict the number of cancer patients requiring PC each month, and study how these numbers evolve over time, is developed. Furthermore, these patients are also separated into different phases of the disease, each with different characteristics, and assigned to each type of PC service available in Portugal. The costs associated with these assignments, as well as the potential savings from implementing a PC network that can provide as much care as required, are also determined.

This is achieved using a simulation methodology, which allows the prediction of PC needs at the small area level, which in turn allows a more detailed planning of the PC network, at a local level.

The Portuguese reality—namely in the Lisbon county—will be analyzed as a case study, with the methodology developed being applied there.
3. Literature Review

This chapter presents an overview of the methods used to estimate and predict health care needs in general, and PC needs in particular. This begins with one section devoted to regression techniques and another to grey theory methodologies, both non-simulation techniques, followed by a section where an overview of the simulation methodologies used is presented. According to the literature review performed, those are the most widely used methods to estimate health care needs. After these sections, the methodologies used to predict PC needs are presented, first internationally and then in Portugal.

The databases searched were Pubmed, Science Direct, Google Scholar, B-ON and Helioblast. The keywords used in the search were primarily "health care needs", "health care needs AND (projection OR forecast OR estimation OR prediction)", "palliative care needs", "palliative care needs assessment", "palliative care needs AND (projection OR forecast OR estimation OR prediction)".

3.1 Regression methods

While regression methods are common in studies to predict future health care needs, namely for the purposes of estimating incidence of a given disease over time, they are usually only a part of the methodology used. In fact, the values obtained through regression models are typically applied to future population projections, in a technique further discussed below. Regression models have been used to forecast the number of hip replacement surgeries [39], changes in Body Mass Index (BMI) [40], cancer incidence [41], renal disease projections [42] amongst others.

As an example, one of the papers published with regression as a main methodology had as a focus the calculation of future cancer incidence [43]. For that, researchers estimated the number of new cancer cases each year, using a simple linear regression model with the year of diagnosis as the only explanatory variable.

The lack of studies using regression as a main methodology can easily be explained. These methods are more commonly used when there is a noticeable trend in the data, and allow researchers to study the relationship between a dependent variable and one or more independent variables. In fact, most of the studies found using this methodology estimated future incidence rates of a given disease based on calendar year. However, that is a rough approximation when it comes to diseases whose incidence varies with age, given all the expected changes in population demographics. The expected ageing of a given population, for example, is not accounted for in this type of methodology, and the results thus obtained—especially in areas where considerable changes in the age structure of the population are expected, such as the European continent—have several limitations.

Overall, regression models are a possible, though coarse, alternative to project health care needs.
3.2 Grey theory

Grey theory is a scientific methodology developed to deal with systems with several unknown parameters and thus to study the relationship between variables when there is little information available [44]. It allows the prediction of the future values of a time series (a group of data points typically sampled in equal time intervals) based on a set of the most recent data. It is typically represented in the form of GM(n,m), where n represents the order of the difference equation used and m is the number of variables [45]. All grey theory methodologies found were of the form GM(1,1).

One of its uses has been to forecast the all-cause and disease-specific rates of disability adjusted life years for the Chinese population, in order to study the effect of population aging [46].

It has also been used to project the disability rate and demand for Long Term Care (LTC) services, testing different scenarios about the growth of disability in the population [47]. These values were obtained for the total population, with no degree of disaggregation, and were then extrapolated to population projections and used to determine the number of people in need of LTC in the future.

While efficient at determining incidence rates over time, these methods have the same limitations as regression models, since when disease incidence rate is determined based on calendar year, changes in the age structure of the population are not accounted for.

3.3 Simulation methodologies

Simulation methodologies can be of two types: macrosimulations or microsimulations. The majority of simulation methodologies used in healthcare are macrosimulations. These methods analyse cohorts of individuals grouped together by their characteristics (such as age, gender or income), while microsimulation methodologies analyse individual people, families or households [48].

While microsimulation methods yield more detailed information, they also require a higher number of inputs and data, which might explain the much higher number of macrosimulation studies found.

In this section, an overview of the simulation methodologies used to predict health care needs is presented, focusing only on some health care areas, rather than an extensive survey, due to the high number of articles published on the field of healthcare forecasts and projection.

3.3.1 Macrosimulation

Several macrosimulations techniques to estimate future health care needs have been found. These will be explained below.

3.3.1.1 Extrapolation-based methodologies

There is conflicting information as to how to classify extrapolation-based models, where future prevalence or incidence of a disease and associated burden is determined by extrapolating current values to future population projections. Some authors consider it to not be a simulation methodology
While others do [48]. For the purpose of this thesis, the classification developed by Comas-Herrera et. al [48] is followed, who include it in the group of macrosimulation techniques.

These are the simplest macrosimulation techniques and have been used for several diseases and types of care.

One of the most commonly used applications of this type of methodology is to estimate future prevalence of diabetes and the burden it is expected to place upon health care providers. One of the first studies found dates back to 1992 [50]. Assuming diabetes incidence remains constant within each age group, current values of incidence were directly applied to population projections in each age group. The same procedure was done to estimate future prevalence based on current prevalence values, thus calculating the total number of diabetes patients per year, and the number of new diabetes patients. This study disaggregated patients only into four large age groups. Another article, written in 1998, predicts the total global diabetes prevalence up to 2025 disaggregated by age and gender [51], applying current prevalence rates.

In 2014 a regression framework was used to calculate the future number of total hip replacements in Sweden from 2013 to 2030 [39], assuming the existence of an upper limit to this value. Annual incidence values were calculated per 10^5 residents aged 40 or older to account for future differences in age distribution. From these values, a regression model was developed with the calendar year as input and the incidence of hip replacement surgeries as output. Two scenarios were analyzed: the first, using a Poisson regression model and assuming no upper limit to the number of surgeries performed, and then a framework which assumed an upper limit was used.

This sort of approach has also been used to project the future workforce requirements for care of the critically ill and of patients with pulmonary disease [52]. Using population, patient, hospital and clinical data, researchers initially determined the use of critical care and of pulmonary services, the proportion of these services provided by specialists and the number of current working specialists. The age and disease-specific use of intensive care units was also determined, as was the age-specific prevalence of pulmonary disease, which was associated with patients’ use of hospital resources.

Future disability and associated insurance costs in the United States has also been estimated [53]. Initially, age-specific disability profiles are constructed as a function of age and calendar year from past data and individuals are separated into three groups: institutionalized individuals, individuals with some limitations in their activities of daily living, and individuals with no limitations in their activities of daily living. The number of disabled people in each group is then found by multiplying total population by prevalence values. A similar approach is taken to estimate future costs.

An area in which this methodology has been widely used is that of LTC. In 1998, the widely used and adapted PSSRU methodology to project demand for LTC and associated expenditure was developed [54]. Like previously mentioned methodologies, this worked by extrapolating future needs from current usage and applying it for future population projections. Separating individuals by age, dependency, household type, housing tenure, and receipt of informal help with domestic tasks, and determining need for LTC within each age group, this methodology estimated the number of elderly people with different levels of dependency along with the levels of LTC demanded and its associated
expenditure. Another study built a similar model, aiming at calculating LTC need for four different countries and projecting future expenditure in order to determine the sensitive of LTC expenditure to alternative scenarios regarding the numbers of older people, the prevalence of dependency, the number of informal carers and macroeconomic conditions [55].

A study aimed at determining the effect of demographic changes on health expenditure created an economic model of hospital costs based on patient age and time remaining to death [56]. Using population projections, individuals of each age and sex were divided according to time to death (ranging from 1 to 15+ years) using age- and sex-specific mortality rates. The number of people in each group was then multiplied by their expected per capita costs and total costs were determined.

This methodology has been further used to forecast asthma incidence and prevalence [57], cardiovascular disease [58] prevalence, the number of incontinence and prolapse surgeries [59], etc.

Extrapolation-based methodologies have their limitations, however. In order to properly determine future needs, they require information of current needs, which might not exist, such as in the case of PC where information is still very limited. Furthermore, when there are a lot of factors influencing a disease, modelling it through an extrapolation based-methodology can be either too simplistic if all those factors are assumed to remain constant or too cumbersome to implement, if all those factors are assumed to evolve over time.

3.3.1.2 Markov models

By definition, Markov models can be considered to be both macrosimulation or microsimulation methodologies, depending on how they are implemented.

These methods allow the separation of a population into discrete states of health and the study of the transition between these states over a certain period of time, according to transition probabilities defined by the health care planner [60]. These transitions typically happen at discrete points in time, and the separation between them might be as long or as short as required. As will be shown, they allow a more in-depth study of a disease's progression and of the influence external factors might have on it, though they typically require more data than the macrosimulation models mentioned above and thus might be more cumbersome to implement.

Like the previous methods, Markov models have also been used to predict future diabetes needs. A simple model, developed in 2003, and aimed at estimating the future prevalence of diabetes in the United States, forecasts the number of individuals in the population within each of three states: diagnosed with diabetes, not diagnosed with diabetes and death [61]. Another model integrates population, obesity and smoking trends (two important factors that directly affect diabetes incidence in individuals) in order to estimate the future prevalence of Type 2 diabetes [62]. The population is initially divided into three starting states: healthy (non-obese, non-smoker, non-diabetes patient), obese and smoker. Using a Markov chains methodology, individuals are then allowed to move between these, a diabetes state and two death states (one for diabetes related deaths and one for non-diabetes related deaths), according to different transition probabilities. This allows researchers to determine the evolution of the number of people with diabetes over time and the number of deaths caused
by diabetes, by applying transition probabilities between these states. The results obtained were
disaggregated by age and gender.

Markov chains have also been used to predict the need for LTC, namely the need for home and
community care [63]. Considering the changes in age demographics in the population to be studied
and in the relationship between age and health status, researchers divided this type of care into ten
different client groups (states), between which individuals can transition. The number of patients
per age group in each state is then determined. Another approach to project the demand of LTC
has been the use of a Markov cycle tree structure to predict the total number of patients in need of
each type of service each year, the resources and services required to provide that care, and the
costs associated with that provision, by considering individuals’ age, gender, type of chronic disease,
level of dependency, household composition and level of income in order to separate them between
discrete states [64].

Renal disease projections have also been made using this type of methodology [42]. The model
combined the use of a Poisson regression methodology to project incidence rates, and a Markov
model to study patient follow-up of both new patients and prevalent patients. Patients in the Markov
model were split into four different states: haemodialysis, peritoneal dialysis, functioning kidney
transplant and death, between which they could transition.

A more general Markov model to project prevalence of chronic diseases and the impact of public
health interventions has been developed. This model considers the existence of three states: healthy,
ill and dead. The transitions between these states depend on calendar time and birth date. This was
then applied to estimate future dementia prevalence in France [65].

Markov chains have also been used, for example, to project tuberculosis incidence, in cohorts
disaggregated by age, race, ethnicity and geography [66], and the future prevalence of Alzheimer’s
disease [67] and the effect intervention policies might have.

It must be noted that the majority of these studies are focused only on the projection of future
values, even though Markov chains can easily be adapted to determine both current and future values.
This might be explained by the fact that these methods are being applied to diseases such as diabetes,
where the current incidence and prevalence levels are already known and therefore don’t need to be
determined. Nevertheless, there are areas such as LTC where it is assumed that, at least in some
countries, the current offer of services is not enough to meet all the demand and studies such as that
developed by Cardoso et al [64] determine both current and future values of need for LTC.

As seen, this type of method allows researchers to take a closer look at the progression of a
disease and all the factors that influence it. Markov methodologies might be especially useful in the
case of chronic diseases, which are characterized by a steady decline in health and whose patients
might be characterized as belonging in different disease stages, as shown in this section. They allow
the study of the progression of a disease over time, in discrete time intervals, with a high degree of
disaggregation regarding individuals’ characteristics. Furthermore, they allow the health care planner
to account for changes in the population’s age structure and don’t project future need based on current
need (which is not an appropriate method when the current offer of services is not enough to meet all
3.3.1.3 System Dynamics

Although less used than the previously mentioned methods, system dynamics are also a relevant tool to predict future demand for health care. System dynamics considers the system to be studied as a series of stocks and flows, with individuals flowing continuously between stocks. The equations underlying the model are difference equations, typically solved by numerical integration [69].

This has been applied to study the growth of diabetes and to project possible future values of prevalence [70]. Researchers modelled the movement of the population through several disease stages: normal blood glucose, prediabetes, uncomplicated diabetes and complicated diabetes, with the diabetes stages being further divided into undiagnosed or diagnosed diabetes. The flow of individuals between these stages was influenced by a long list of factors, such as the adoption of a healthy lifestyle and the prevalence of obesity. A scenario analysis was then performed, in order to observe what effect decreasing trends in obesity or better clinical management of diabetes would have on the total population.

This methodology has also been used to forecast future supply and demand of physical therapists [71]. Using publicly available data, researches developed a model that took into consideration the ever-changing number of practising physical therapists (influenced by new graduates, retirements, migration, etc) and the rate of future demand (assumed to be the same as the rate at the time of writing). This way, the difference between the projected supply and the projected demand was used to determine the shortage or surplus of physical therapists.

Future smoking prevalence has also been forecast using this methodology [72], by estimating the future population, divided by age and smoking status. This is done through the use of rates of birth, mortality, smoking initiation and cessation. Researchers also tested the effect of changing trends in smoking initiation or cessation rates.

System dynamics has also been used to forecast the future supply and demand of ophthalmologists [73]. This model calculates the prevalence of eye diseases, the number of patient visits, and the workforce requirements for public health care providers under different scenarios. Results for prevalence of eye disease are disaggregated by age, ethnicity and education attainment.

3.3.2 Microsimulation

As has already been mentioned, these methods require more data than macrosimulation methods. As they are more extensive methodologies, they tend to be more time-consuming and harder to implement [48]. As there has been limited use of microsimulation methodologies to forecast health care needs, perhaps due to the higher amount of data required for their implementation when compared to macro-simulation models, the number of studies found was significantly smaller than for macrosimulation methods.

Using a microsimulation framework developed to predict future prevalence of obesity, researches have projected the future health and economic burden from the continued rise in obesity, testing
various scenarios for obesity prevalence. The model developed consisted of two modules. In the first module, BMI distributions are projected for the planning horizons. In the microsimulation module, virtual individuals are created on the basis of this projections and their progression through various BMI values are projected. To estimate health burden, each individual had a probability of getting a specific disease each year, which was a function of age, sex and BMI. The prevalence of each disease was then used to calculate the economic burden of obesity. The effects of a rising or falling diabetes prevalence were studied [40].

Another study, based on a Markov model methodology, aimed at determining the size of a diabetes population and its associated economic burden [74], using age- and sex-specific prevalence and the incidence of diagnosed and undiagnosed diabetes, along with the mean annual direct and indirect costs of diabetes patients. Simulating individual lives, the model was comprised of six health states: healthy, undiagnosed diabetes, diagnosed diabetes, net migration, diabetes-related death and death from other causes. The authors performed a sensitivity analysis so they could explore how uncertainty affected the model and the results obtained, by changing the values of diabetes incidence.

No simulation methodologies (either macro or microsimulations) were found to predict the future needs of cancer patients or the total number of cancer patients requiring PC. Of all the methodologies studied, macrosimulation Markov chains appear to be the most appropriate method to predict future PC needs. While a microsimulation methodology could also be useful, these are too cumbersome and time-consuming to implement, besides requiring a considerable amount of (non-available) data. System dynamics methods have the same limitations. Non-simulation methodologies do not account for changes in the age-structure of the population, becoming very limited in the prediction of values related to diseases whose incidence changes with age. Extrapolation-based methodologies require the knowledge of current service utilization/need, which is not available in the case of PC and not easy to estimate, given the scarcity of data. Markov chains, on the other hand, allow the disaggregation on individuals according to as many characteristics as desired, predict future values not based on current service usage or demand and are relatively easy to implement.

In the following section, a closer look will be taken at the methods used to estimate current PC needs.

3.4 Predicting palliative care needs

In this section, the methods used to predict PC needs worldwide and in Portugal are presented.

3.4.1 Predicting palliative care needs worldwide

To the best of our knowledge, no simulation methodology has been developed to estimate current or future PC needs, which might be explained in part by the pronounced lack of accurate data regarding current need and utilization of PC services. Methods to predict future need of PC based on current usage could not be found either, potentially due to the widely held belief that the current offer of PC services is not enough to efficiently meet all of the demand and the total level of need for PC consequently being difficult to determine.
Perhaps for this reason, all studies regarding the estimation of PC needs focus only on estimating how many people need PC at the time of writing, rather than estimating future needs. For this purpose, several different approaches are taken, which will be described below.

There have been plenty of attempts at determining qualitative PC needs, mainly through the use of questionnaires to assess current needs of patients with serious, life-threatening illnesses who could benefit from PC, with a high number of questionnaires aimed at cancer patients [75–79]. However, the number of studies aimed at quantifying the total need for PC has been limited.

In 1997, one of the first studies trying to estimate PC needs was published [80]. The methodology used consisted of determining the diseases requiring PC and the number of deaths they were responsible for in the general population, and multiplying it by the symptom prevalence, which was used as a proxy for the need of PC. The author considered there were three disease categories that might require PC: cancer, nonmalignant progressive diseases (such as circulatory or cardiovascular illnesses) and children’s terminal illnesses (like muscular dystrophy and cystic fibrosis).

Most of the studies found are mortality-based studies, building on this approach. In 2006, another group of researchers identified, through a literature review and a focus group, ten conditions which were widely accepted to have patients in need of PC in their later phases [81]. These diseases were cancer, heart, renal and liver failure, chronic obstructive pulmonary disease, motor neuron disease/amyotrophic lateral sclerosis, Parkinson’s disease, Huntington’s disease, Alzheimer’s disease, and HIV/AIDS. Researchers then developed three estimates of need, through the analysis of mortality data. One estimate was based on the ten identified conditions. The mid-range estimation included all these along with deaths where the patient was admitted to the hospital in the last twelve months of life for the same condition as that recorded as the cause of death. The maximum range condition included all but sudden deaths (derived from poisoning, injury, maternal death, perinatal and neonatal deaths). The minimal estimate consisted of 50.0% of all deaths, the mid-range estimate consisted of 55.5% of all deaths and, finally, the maximal estimate consisted of 89.4% of all deaths. These numbers, however, provide only the size of a potential PC population, as not everyone who dies will require PC.

Researchers responsible for the Global Atlas of Palliative Care [8] sought to calculate the total global need for PC. For that purpose, the authors assumed that only patients suffering from pain in their last year of life require PC. First, two Delphi studies were conducted, in order to determine which diseases require PC (Alzheimer’s disease and other dementias, cancer, cardiovascular diseases, cirrhosis, chronic obstructive pulmonary diseases, diabetes, HIV and AIDS, kidney failure, multiple sclerosis, Parkinson’s disease, rheumatoid arthritis and drug-resistant tuberculosis). Once consensus was reached between the experts and the diseases were established, the pain prevalence (percentage of patients with pain) for each disease was found. The total need for PC was obtained by multiplying the number of people dying from each disease each year by its pain prevalence.

In the same year, another mortality-based approach was applied to England by Murtagh et. al [82]. Initially, mortality data was analyzed to identify conditions (malignant or nonmalignant) whose
patients may benefit from PC and afterwards four estimates of need were calculated. The first estimate was based on the number of deaths from a given set of diseases accepted to have PC needs (malignant neoplasm, heart disease, renal disease, liver disease, respiratory disease, neurodegenerative disease, Alzheimer, dementia, senility and AIDS). The second included all previous deaths along with deaths where Alzheimer’s disease, dementia, senility or renal disease were considered to be contributory causes of death. The third estimate includes all previous deaths and any deaths in which any of the ten diseases accepted to have PC needs were contributory causes to the patient’s death. Finally, the fourth and maximal estimate included all deaths except those resulting from sudden causes. The percentage of people requiring PC ranged from 63.03% to 81.87% of all deaths.

Mortality-based studies such as these, while useful, have their limitations. By using mortality data and symptom prevalence, only patients in the last year of life are accounted for, and disaggregation between types of service required is not possible.

Another approach was used in 2004, and applied to the Australian population [83]. Researchers conducted a completely random selection of 3027 participants from the general population, and conducted a survey on the need for, uptake rate of, and satisfaction with specialized PC services from family members of PC patients or people to whom they were close. While providing important results, this study has its limitations as it only provided a rough overview of the total need for PC with no distinction between age or gender or type of service each patient required. Furthermore, PC needs were assessed by someone other than the patients, who might have a different view of the patients’ illness and their need for care. Moreover, population survey studies are time and resource consuming, especially in areas with more inhabitants, where a higher number of surveys is required in order to have a sample large enough to represent the population.

Gomez et al [84] developed a different method to determine need for PC in 2014, by directly measuring the prevalence of patients with advanced chronic diseases and with a limited life prognosis in a general population at the small area level, in the county of Osonia in Catalonia, Spain. A list of patients suffering from advanced chronic conditions was generated using patient lists and national registries. From these lists, health care professionals were instructed to choose all possible advanced chronically ill patients, who might benefit from PC. In total, researches determined that 1.5% of the total population could benefit from PC. This sort of method is not practical on a national level as individual patients’ information needs to be analysed by health care professionals. There was also a reported lack of consensus between health care providers, evidence of the lack of consensus between experts worldwide as to when patients should initiate PC. Furthermore, only the health care providers’ perspective is included in this sort of study, and patients’ opinion regarding their own needs might vary.

### 3.4.2 Predicting palliative care needs in Portugal

Only two studies could be found which estimate PC needs in Portugal. As in the studies mentioned in the previous section, these studies only determine current need for PC services in Portugal, with
no projection or forecast of these values being performed for the future.

The first article was published in 2010 [85], with the goal of estimating the number of home-care teams required in Portugal. It simply uses international standard ratios of the number of teams per number of inhabitants and applies it to the population of each Portuguese county, achieving low, high and mid-range estimation of needs of each team across Portugal. Applying international ratios for healthcare professionals, the number of professionals required to provide these services is also determined. These are values determined for total need, with no separation by pathology. The author estimates that, in total, between 106 and 160 HC teams are required in Portugal, with the Lisbon county needing between 22 and 34 teams, being supported by 44 to 68 doctors and 66 to 136 nurses.

A study published three years later, by the same author, presents a different methodology [86]. In it, using annual mortality data and assuming that 60% of all dying patients require PC, a value taken from the literature, the author calculates the total number of people requiring PC each year in Portugal. As in previous studies, mortality data is very limited in predicting total needs as it provides only annual need with no distinction between phases of disease and type of care required for each patient. The author concludes that 62,000 patients could've benefited from PC countrywide.

Using a different methodology, the authors looks directly at cancer mortality. It is seen that 21,700 people died of cancer in Portugal in 2007, all of which the author assumes could've benefited from PC. Using international rates for the need of PC for non-cancer patients (from 350 to 1,400 patients per million inhabitants), the author determines the number of non-cancer patients requiring PC to be between 3,716 and 14,865. Using international standards for the number of teams, the author considers for a PC network that meets all the demand from 106 to 159 HC teams are required, along with 103 hospital support teams and between 850 and 1062 beds in PC units.

Neither method disaggregates the results by age, gender, or other demographic characteristics of the patients. No cost analysis has been performed, to the best of our knowledge.

As can be concluded by the literature review performed here, there is a very limited number of studies predicting PC needs, and even fewer studies predicting the PC needs of cancer patients. The few studies that do exist to predict these needs present several limitations. First, they estimate need only for the present moment, based on questionnaires, which provide information only on the qualitative need for care, and mortality studies, which give only the total number of patients in a given region who might benefit from PC in a certain time period, not disaggregating patients based on their characteristics or the evolution of their disease, and not assigning them to different types of care.

Nevertheless, that is important information to have, so as to allow the proper implementation and expansion of a PC network capable of providing care to all the individuals that require it. Based on the literature review on techniques to predict future health care needs, it becomes clear that Markov models are a methodology that might help find more detailed values on the need for PC even more important when considering how cancer's incidence varies across age groups and gender. This methodology thus allows predictions for a longer time period, and with a much higher level of disaggregation than other methodologies found, both required for the thorough, detailed planning of a PC network.
4. Proposed Methodology

In this chapter, the methodology developed to predict the PC needs of oncological patients and the costs associated with those needs is presented. The chapter begins with a list of all the notation used (indices, sets, parameters and variables), for easier comprehension. In the following section, a broad overview of the entire methodology is given, explaining the goals of this thesis, the choice of methodology and its implementation, followed by a comprehensive description of the methods used, first with a subsection relative to the short-term decision tree (used for the first month of the model) and then a subsection relative to the long-term Markov model (used in all subsequent months). The last section gives a detailed explanation of the mathematical formulation underlying these models, first for the decision tree and then for the Markov model.

4.1 Notation

The list of notation used can be seen in Table 4.1, Table 4.2, Table 4.3, Table 4.4 and Table 4.5. Table 4.1 lists all the indices and sets used, while Table 4.2 and Table 4.3 list all the parameters. Table 4.4 and Table 4.5 give a list of all the variables used.

<table>
<thead>
<tr>
<th>Table 4.1: Indices and Sets</th>
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</thead>
<tbody>
<tr>
<td>Indices and Sets</td>
</tr>
<tr>
<td>$i \in I$</td>
</tr>
<tr>
<td>$j \in J$</td>
</tr>
<tr>
<td>$k \in K$</td>
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<tr>
<td>$m \in M$</td>
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<td>$t \in T$</td>
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<table>
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<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>$P_{i,j,k}^{0}$</td>
</tr>
<tr>
<td>$PC_{i,j,k,m,t}$</td>
</tr>
<tr>
<td>$PS_{i,j,k,m,t}^{0}$</td>
</tr>
<tr>
<td>$PS_{i,j,k,m,t}^{1}$</td>
</tr>
<tr>
<td>$PS_{i,j,k,m,t}^{2}$</td>
</tr>
<tr>
<td>$PS_{i,j,k,m,t}^{3}$</td>
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<tr>
<td>$PS_{i,j,k,m,t}^{4}$</td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>( PT_{i,j,k,m,t} )</td>
</tr>
<tr>
<td>( P_{LD_{i,j}} )</td>
</tr>
<tr>
<td>( PHD_{i,j} )</td>
</tr>
<tr>
<td>( PNCT_{i,j} )</td>
</tr>
<tr>
<td>( PCT_{i,j} )</td>
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<tr>
<td>( PBPL_{i,j} )</td>
</tr>
<tr>
<td>( PAPL_{i,j} )</td>
</tr>
<tr>
<td>( PEOL_{i,j,k,m,t} )</td>
</tr>
<tr>
<td>( m_{i,j,k,m,t}^A )</td>
</tr>
<tr>
<td>( m_{i,j,k,m,t} )</td>
</tr>
<tr>
<td>( I_{i,j,k,m}^A )</td>
</tr>
<tr>
<td>( I_{i,j,k,m,t}^m )</td>
</tr>
<tr>
<td>( PS_j \rightarrow S )</td>
</tr>
<tr>
<td>( PT_j \rightarrow S )</td>
</tr>
<tr>
<td>( PS_j \rightarrow S )</td>
</tr>
<tr>
<td>( PS_j \rightarrow T )</td>
</tr>
<tr>
<td>( PT_j \rightarrow T )</td>
</tr>
<tr>
<td>( PS_j \rightarrow EOL )</td>
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<tr>
<td>( PT_j \rightarrow EOL )</td>
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<tr>
<td>( PS_j \rightarrow CD )</td>
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<tr>
<td>( PT_j \rightarrow CD )</td>
</tr>
<tr>
<td>( C_{AC} )</td>
</tr>
<tr>
<td>( C_{IC} )</td>
</tr>
<tr>
<td>( C_{HC} )</td>
</tr>
<tr>
<td>( C_{NPC} )</td>
</tr>
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</table>
Table 4.4: Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$NC_{i,j,k,m,t}$</td>
<td>Total non-cancer population of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$C_{i,j,k,m,t}$</td>
<td>Total cancer population of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$S^0_{i,j,k,m,t}$</td>
<td>Number of cancer patients in the stable state 0 of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$S^1_{i,j,k,m,t}$</td>
<td>Number of cancer patients in the stable state 1 of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$S^2_{i,j,k,m,t}$</td>
<td>Number of cancer patients in the stable state 2 of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$S^3_{i,j,k,m,t}$</td>
<td>Number of cancer patients in the stable state 3 of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$S^4_{i,j,k,m,t}$</td>
<td>Number of cancer patients in the stable state 4 of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$T_{i,j,k,m,t}$</td>
<td>Number of cancer patients in the transitional state of age $i \in I$ and gender $j \in J$ in the transitional state with low dependency in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$TLD_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the transitional state with high dependency in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$THDNCT_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the transitional state with high dependency and without a caretaker in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$THDCT_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the transitional state with high dependency and with a caretaker in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$THDCTBPL_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the transitional state with high dependency and with a caretaker who live below the poverty line in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$THDCTAPL_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the transitional state with high dependency and with a caretaker who live above the poverty line in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$EOL_{i,j,k,m,t}$</td>
<td>Number of cancer patients in the end of life state of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$EOLCT_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the end of life state with a caretaker in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$EOLNCT_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the end of life state without a caretaker in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$EOLCTAPL_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the end of life state with a caretaker who live above the poverty line in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$EOLCTBPL_{i,j,k,m,t}$</td>
<td>Number of individuals of age $i \in I$ and gender $j \in J$ in the end of life state with a caretaker who live below the poverty line in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$sr_{i,j,k,m,t}$</td>
<td>Probability of an individual of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, month $m \in M$ and year $t \in T$, not dying from non-cancer causes</td>
</tr>
<tr>
<td>$cm_{i,j,k,m,t}$</td>
<td>Cancer mortality rate for individuals of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
<tr>
<td>$CD_{i,j,k,m,t}$</td>
<td>Number of cancer deaths of individuals of age $i \in I$ and gender $j \in J$ in municipality $k \in K$, at month $m \in M$ and year $t \in T$</td>
</tr>
</tbody>
</table>
### Table 4.5: Variables (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( NCD_{i,j,k,m,t} )</td>
<td>Number of non-cancer deaths of individuals of age ( i \in I ) and gender ( j \in J ) in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T )</td>
</tr>
<tr>
<td>( AC_{i,j,k,m,t} )</td>
<td>Total number of cancer patients of age ( i \in I ) and gender ( j \in J ) requiring ambulatory care in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T )</td>
</tr>
<tr>
<td>( HC_{i,j,k,m,t} )</td>
<td>Total number of cancer patients of age ( i \in I ) and gender ( j \in J ) requiring home care in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T )</td>
</tr>
<tr>
<td>( IC_{i,j,k,m,t} )</td>
<td>Total number of cancer patients of age ( i \in I ) and gender ( j \in J ) requiring inpatient care in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T )</td>
</tr>
<tr>
<td>( Ct_{AC}^{i,j,k,m,t} )</td>
<td>Total monthly cost of providing ( AC ) for all patients of age ( i \in I ) and gender ( j \in J ) in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T ) requiring it</td>
</tr>
<tr>
<td>( Ct_{HC}^{i,j,k,m,t} )</td>
<td>Total monthly cost of providing ( HC ) for all patients of age ( i \in I ) and gender ( j \in J ) in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T ) requiring it</td>
</tr>
<tr>
<td>( Ct_{IC}^{i,j,k,m,t} )</td>
<td>Total monthly cost of providing ( IC ) for all patients of age ( i \in I ) and gender ( j \in J ) in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T ) requiring it</td>
</tr>
<tr>
<td>( Ct_{NPC}^{i,j,k,m,t} )</td>
<td>Total monthly cost of providing care in a acute care for all patients of age ( i \in I ) and gender ( j \in J ) in municipality ( k \in K ), at month ( m \in M ) and year ( t \in T ) requiring ( PC )</td>
</tr>
</tbody>
</table>

#### 4.2 Model Description

The aim of the developed methodology is to predict the number of cancer patients requiring \( PC \) in a given region for a certain time period, the type of services those patients require (which might be \( AC \), \( HC \) or \( IC \) services), and all the costs associated with those services. To determine these needs, it is necessary to study the epidemiological patterns of cancer over time in a population and to observe how patients progress through different phases of the disease, requiring different PC services in the different points of the disease’s trajectory.

As shown in Chapter 3, Markov chains are a method commonly used to study epidemiological factors and disease trajectories. A Markov chain is a stochastic simulation methodology, which allows the division of a given population into a set of states [60]. The population is divided in these different states according to a set of parameters to be studied. Individuals in each state can move to other states according to different transition probabilities. All transitions in the system are calculated for equal time intervals. Markov chains are considered to be a “memoryless” process, as the distribution of an entire population across different states in any given moment, depends only on the distribution of that population in the previous moment, and not on all the moments that precede it [60].

Studies have shown that cancer progression can be simplified and more easily studied by separating the disease into different phases [35], i.e., into stable, transitional and EoL (as described in Chapter 2.5). Patients can move repeatedly through these disease phases (or states) over time. These states are all-inclusive and mutually exclusive, as a patient can only be part of one state at any given time. Markov chains are thus an adequate method to study the evolution of cancer populations over time as cancer patients move through different phases of the disease according to different probability values, showing different symptoms and having different needs at different time periods in their disease trajectory.
For this purpose, both a decision tree and a Markov chain model are implemented. The decision tree is used only for the first month of the model, dividing the patients into separate groups. In the following months, a Markov model is used instead.

Initially, the patients are divided according to age and gender. This division is done as cancer affects different age groups and both genders differently. It has been shown that incidence typically rises with age, with older men showing higher incidence values than older women [87–90]. This isn’t true for all age groups, however, and there are groups—such as the 25 to 49 age group—in which incidence is higher in women than in men.

After that, they are separated according to phase of disease. Figure 4.1 gives a general overview of the model, showing the separation of the individuals according to phase of disease and establishing the connection between each tree branch and each Markov state. Both the decision tree and the Markov model will be expanded further in the following sections.

![Figure 4.1: Model Overview. a) Short Term Decision Tree, b) Long-term Markov Model. NC–Non Cancer, S–Stable, T–Transitional, EOL–End of Life, NCD–Non-Cancer Death, CD–Cancer death](image)

In the first month, the total number of individuals in each branch of the tree depends only on cancer prevalence and demographic characteristics (i.e., age and gender). Cancer prevalence is the number of individuals in a population with cancer at a given time period. A higher cancer prevalence means a higher number of people with cancer, which necessarily means a higher number of patients requiring PC [91].

In the Markov model, used for the following months, these values depend on cancer incidence and mortality rates, as well as the dynamic transition between states. Cancer incidence is the number of new cases of cancer per population in a given time period. The higher the cancer incidence, the higher the number of people with cancer and the higher the number of patients later requiring PC [92].

A possible transition in the Markov model is, for example, a patient that is considered to be in the S (stable) state in the first month remaining in the stable state, or transitioning to another state, such as the transitional or end of life states, or one of the death states. Another patient, initially in the NC (non-cancer) state, may remain in that state, become an S state cancer patient, or die from...
Once the patients are separated according to phase of the disease, it becomes necessary to separate them according to other characteristics. These characteristics determine which type of care each patient requires, and are as follows:

- Dependency level: Patients with cancer and, primarily, cancer patients needing PC have a high level of needs and the higher their level of dependency, the higher those needs are. A high dependency level is connected to a low ambulation level, which severely hinders the patient’s ability to visit an AC service and makes other types of care (HC or IC) necessary [93].

- Presence/Absence of a caretaker: Given the high symptom burden of cancer patients in the terminal stages of the disease, a caretaker is usually required, and the absence of one is one of the criteria used for referral to an inpatient unit [5].

- Income level: Receiving PC at home comes with the highest expenditure for the patient or the caretaker, out of all PC services. These costs must be supported either by the patient or the caregiver, if there is one [94].

Both the decision tree and the Markov model divide the total population into separate cohorts, according to each individual’s characteristics. Once this separation has been done, the type of care each patient requires is determined.

Given the usual short length of life of terminal cancer patients, a time step of one month between each transition was adopted. Studies show, for example, that when patients are in the EoL state, a state characterized by a high symptom burden and a high level of need, they usually stay there for less than a month before their deaths [36]. Adopting a time step of this length allows for a more accurate prediction of needs over time, and more thorough results.

The methodology has been developed in a generic way, and can be applied in most countries or regions where socioeconomic and demographic data is publicly available, though some adaptation of the methodology might be required.

In the following subsections, a comprehensive description of the two key components of the model (the short-term decision tree and the long-term Markov model) is presented.

### 4.2.1 Decision Tree

In this section, a comprehensive description of the short-term decision tree implemented for the first month of the planning period is given.

After being separated into cohorts according to age, gender and geographic region, all individuals in a given population are divided into different groups. These groups can be seen in Figure 4.2.
Figure 4.2: Short-term decision tree. NC—Non Cancer, $S^0$—Stable 0; $S^1$—Stable 1; $S^2$—Stable 2; $S^3$—Stable 3; $S^4$—Stable 4; TLD—Transitional with low dependency; THDCTAPL—Transitional with high dependency, a caretaker and above the poverty line; THDCTBPL—Transitional with high dependency, a caretaker, and below the poverty line; THDNCT—Transitional with high dependency and without a caretaker; EOLCTAPL—End of life with a caretaker and above the poverty line; EOLCTBPL—End of life with a caretaker and below the poverty line; EOLNCT—End of life without a caretaker.
Initially, individuals are separated into two different groups: the non-cancer group (for individuals who are not cancer patients at the time, making up the NC branch) and the cancer group (for individuals who are cancer patients at the time, the C branch).

Using the classification explained in Chapter 2.5, the group of cancer patients is further divided into three different groups: stable, transitional and EoL.

- The stable group of patients is further divided into five different branches: stable 0 (for patients who have been stable for zero years, the $S^0$ branch), stable 1 (for patients who have been stable one year, the $S^1$ branch), stable 2 (for patients who have been stable two years, the $S^2$ branch), stable 3 (patients who have been stable three years, the $S^3$ branch), and stable four (patients who have been stable between four years, the $S^4$ branch). Knowing how long a patient has been stable is important since it is assumed that a cancer patient can become a non-cancer patient only after five years spent in the stable state.

- Patients in the transition group are divided into low dependency patients (corresponding to a PPS score of 60%) and high dependency patients (corresponding to a PPS score of 40 or 50%). Transitional patients with low dependency make up the TLD group. The group of patients with high dependency is then divided into patients with or without a caretaker. Patients with high dependency and without a caretaker are part of the THDNCT group. Patients with high dependency and a caretaker are further divided into patients with high dependency and a caretaker who live above the poverty line (THDCTAPL) and patients with high dependency and a caretaker who live below the poverty line (THDCTBPL).

- For patients in the EoL group, similar separations into smaller groups are performed. Here the level of dependency isn’t considered as all patients in this group have a high symptom burden, with high needs and a high level of dependency. Like in the transitional group, EoL patients are separated according to the presence or absence of a caretaker. Patients without a caretaker make up the EOLNCT branch. Like in the transitional branch, patients in the EoL branch with a caretaker are further divided into EoL patients with a caretaker who live above the poverty line (EOLCTAPL) and EoL patients with a caretaker who live below the poverty line (EOLCTBPL).

Once all patients have been divided into all the different tree branches, they must be assigned to an appropriate type of PC service. Since calculating the PC needs of non-cancer patients is outside the scope of this work, it is assumed that non-cancer individuals (NC individuals) do not require a PC service. According to the PPS stable patients ($S^0, S^1, S^2, S^3$ and $S^4$) don’t have a high symptom burden, so it is also assumed they do not need PC services [36].

PC provided in an ambulatory setting comes with lower costs to the NHS than care provided in the patient’s home or in an inpatient unit, and the separation of patients into groups who can receive care in an ambulatory setting and those that cannot, allows for a more efficient utilization of the available resources and a reduction of costs. Thus, it is assumed that patients in the transitional state with low dependency (TLD) receive care in an ambulatory setting, as their level of ambulation isn’t severely hindered by their disease.
According to the PPS, transitional patients with high dependency are patients with a high symptom burden, unable to do any work, who mostly lie and/or sit in bed all day. Without a caretaker present, it is assumed that they cannot receive the care they need as they are not capable of caring for themselves. Since the absence of an informal caretaker is a criterion for admission into an inpatient unit [5], these patients, who belong in the THDNCT group, receive PC in an inpatient unit.

Patients in the transitional state with high dependency and with a caretaker, are assigned to a PC service depending on their income level. Studies show that caretakers of PC patients incur the highest costs when they provide care for patients at home [94]. These costs can be financial, physical and emotional. Additionally, providing informal PC can also signify the loss of opportunities and loss and/or restriction of employment, since carers spend most of their time taking care of the patient [94]. Given that, it is assumed that patients who live below the poverty line (those in the THDCTBPL branch), must receive care in an inpatient unit, while those who live above the poverty line, belonging to the THDCTBPL branch, can receive care at home, as that is where most patients desire to receive care and eventually die [95].

For the group of patients in the EoL group, a similar separation between services is performed. Here the level of dependency isn’t considered as all patients in this group have a high symptom burden, with high needs and a high level of dependency. Patients without a caretaker, who make up the EOLNCT group, are immediately assigned to an inpatient unit, whereas patients with a caretaker and who live above the poverty line receive care at home and those with a caretaker who live below the poverty line receive care in an inpatient unit.

The choice of PC setting for each state is summarized in Table 4.6.
Table 4.6: PC services according to tree branch

<table>
<thead>
<tr>
<th>Tree Branch</th>
<th>PC Setting</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC, $S^0$, $S^1$, $S^2$, $S^3$, $S^4$</td>
<td>No PC</td>
<td>Individuals in the non-cancer state don’t need to receive palliative care, as they don’t show active cancer symptoms. Individuals in the stable state also don’t need palliative care, as their symptom burden is considered too low to require it and they are not in the terminal stages of the disease [36].</td>
</tr>
<tr>
<td>TLD</td>
<td>Ambulatory Care</td>
<td>Individuals in the transitional state with low dependency are individuals that, despite having a higher symptom burden than those in the stable state, show only partially reduced ambulation, and thus can frequent an AC service [33].</td>
</tr>
<tr>
<td>THDCTAPL, EOLCTAPL</td>
<td>Home Care</td>
<td>Most individuals prefer to receive care and die at home [95]. If there is a caretaker present and the patient has the economic conditions required to receive care at home, then that patient is assigned to a HC service.</td>
</tr>
<tr>
<td>THDCTBPL, THDNCT, EOLCTBPL, EOLNCT</td>
<td>Inpatient Care</td>
<td>Absence of a primary caretaker is one of the criteria used for admission to an inpatient unit [5]. Since patients in the transitional and the EoL stages are patients with high symptom burdens, in the cases where there are no caretakers present, care is given in an inpatient unit. Additionally, PC patients’ caretakers incur significant expenditures caring for the patients [94] and it can be onerous for patients who live below the poverty line to be able to accommodate such costs, so it is assumed these patients receive care in an inpatient unit.</td>
</tr>
</tbody>
</table>

4.2.2 Markov Model

Once individuals are organized into different groups with different characteristics and different needs for the first month of the planning period, it is possible to evaluate how they will progress over time. This evolution is studied with the Markov model summarized in Figure 4.3.
Figure 4.3: Long-term Markov Model. NC—Non Cancer; \( S^0 \)—Stable 0; \( S^1 \)—Stable 1; \( S^2 \)—Stable 2; \( S^3 \)—Stable 3; \( S^4 \)—Stable 4; THDCTAPL—Transitional with high dependency, a caretaker and above the poverty line; THDCTBPL—Transitional with high dependency, a caretaker, and below the poverty line; THDNCT—Transitional with high dependency and without a caretaker; TLD—Transitional with low dependency; EOLNCT—End of life without a caretaker; EOLCTAPL—Transitional with a caretaker and above the poverty line; EOLCTBPL—End of life with a caretaker and below the poverty line; NCD—Non-Cancer Death, CD—Cancer death

This model considers the transitions of individuals between 15 different states. 13 of the states are the same as the branches of the decision tree, while the other two correspond to the death by cancer causes state and the death by non-cancer causes state.

Given the similarities between some of the states, all patients in one of the stable states are considered to be part of the stable group (S group), all patients in a transitional state are considered to be part of the transitional group (T group), and all patients in the EOL states are considered to be part of the EOL group (EOL group). These groups are represented with squares in the model diagram. This way, the image becomes more readable and all possible transitions can be represented in a clearer way.

If individuals in all the states that make up a group can transition to another certain state, these transitions are represented with an arrow pointing from the square that contains those states towards the state to which they can all transition to. For example, patients in all four transitional states can transition to the \( S^0 \) state. Rather than representing this transition with four different arrows, one from each transition state, it is represented simply with one arrow pointing from the transitional square. For the same reason, when patients in a state can transition to all the states that make up another group
(for example, patients in the $S_0$ state can transition to all the transitional states), these transitions are represented only with one arrow, with the tip pointed at the group they can transition to (in this case, the tip would point towards the transitional square).

**NCD and CD absorbing states**

The NCD and CD states are absorbing states (i.e., states from which individuals can’t transition out of), which correspond, respectively, to deaths not caused by cancer, and deaths caused by cancer. All cancer patients can transition to either the NCD or the CD state as they can die both because of cancer and because of other causes. Non-cancer patients can only die from non-cancer causes, thus transitioning only to the NCD state.

**NC state**

Individuals in the NC state can only remain in that state, enter the cancer state, or evolve to the NCD state (i.e., die from non-cancer causes). It is a model assumption that all patients are in the stable state when they become cancer patients, and that they have been in that state for less than one year, so when a new patient enters the cancer state, he or she necessarily has to enter the $S_0$ state.

**Stable states**

For cancer patients, transitions between stable, transitional and EoL states are always possible and a cancer patient can, at any moment, transition to the CD or NCD state from one of these states.

While patients in any of the stable states can transition freely to the transitional and EoL states, only some transitions between stable states are possible. It must be noted that since each stable state separates the patients according to length of time spent in the stable state, transitions between them can only happen from stable state $n$ to stable state $n + 1$ (for example, a patient can transition from stable state 2 to stable state 3, but never to stable state 4, or stable state 1).

It is a model assumption that a patient can only reenter the NC state from the $S_4$ state, as it is assumed that a patient must spend five consecutive years in the stable state to be considered to be in a non-cancer state once more.

While it is assumed that the transition probabilities from any state in the stable group ($S_0, S_1, S_2, S_3, S_4$) to the transitional or the EoL groups are similar between themselves, transition probabilities into the stable group are not the same. Since it is a model assumption that the patient must spend five consecutive years in the stable state before being considered a non-cancer patient again, if an individual transitions to the transitional or to the EoL states and then reenters the stable state, he or she enters state $S_0$, regardless of the original stable state.

Thus, the only possible transition to the stable state from the transitional state or the EoL state is to the $S_0$ state.

**Transitional states**

Since it is a model assumption that patients leaving the NC state to enter a cancer state do so evolving to the $S_0$ state, only individuals who are already cancer patients can transition into the transitional state. For this reason, only transitions from the stable states, the transitional states or the
EoL states are considered possible.

For the same reason as the transitional states, only transitions from the stable states, the transitional states and the EoL states are considered possible.

The distribution of the patients in each of these states between cancer services is the same as the one described in Table 4.6.

4.3 Mathematical Formulation

To divide all individuals in a population into different groups and to study the transition between these groups, a set of equations is used. In the first section in this chapter, the equations underlying the short-term decision tree are given. In the next section, the equations underlying the long-term Markov model are studied.

4.3.1 Decision Tree

Non Cancer Branch

The first thing that must be calculated for the decision tree is the total non-cancer population, $NC_{i,j,k,m,t}$, in the first month of the planning period ($m = 1, t = 1$). This value is found by multiplying the total population of age $i \in I$ and gender $j \in J$, in municipality $k \in K$, in the first month of the planning period, $P_{i,j,k}^0$, by the probability of an individual not having cancer ($1 - PC_{i,j,k,m,t}$), where $PC_{i,j,k,m,t}$ is the probability of an individual having cancer). This is seen in Equation 4.1.

$$NC_{i,j,k,m,t} = P_{i,j,k}^0 \times (1 - PC_{i,j,k,m,t}), \forall i \in I, j \in J, k \in K, m = 1, t = 1$$ (4.1)

Cancer Branch

The total population with cancer, meanwhile, is given by Equation 4.2, where the total population in the first month of the planning period is multiplied by the probability of each individual having cancer.

$$C_{i,j,k,m,t} = P_{i,j,k}^0 \times PC_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1$$ (4.2)

Stable Branch

The number of patients in each of the stable branches is found by multiplying the number of cancer patients by the probability of a cancer patient being in that state. The number of patients in stable state $n$ is thus found using Equation 4.3.

$$S_{i,j,k,m,t}^n = C_{i,j,k,m,t} \times PS_{i,j,k,m,t}^n, \forall i \in I, j \in J, k \in K, m = 1, t = 1, n = 0, 1, 2, 3, 4$$ (4.3)

Transitional Branch

The number of patients in the transitional branch is calculated in the same manner, multiplying the total number of cancer patients by the probability of a cancer patient being in the transitional state, as shown in Equation 4.4.

37
\[ T_{i,j,k,m,t} = C_{i,j,k,m,t} \times PT_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1 \] (4.4)

Patients in this state are then divided into two groups, according to their dependency level. The number of individuals in the transitional state having a 60 PPS score (patients who still have a high ambulation level and don’t need to sit or lie in bed most of the time, thus considered to be low dependency patients) is given by Equation 4.5, where the total number of patients in the transitional branch is multiplied by the probability of a patient having a low dependency level.

\[ TLD_{i,j,k,m,t} = T_{i,j,k,m,t} \times PLD_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1 \] (4.5)

The number of individuals having a 40 or 50 PPS score (patients who lie or sit in bed all day, with a high symptom burden, considered to be high dependency patients) is given by Equation 4.6. The number of patients with high dependency in the transitional state is given by the product between the total number of patients in the transitional branch and the probability of a patient having a high dependency level.

\[ THD_{i,j,k,m,t} = T_{i,j,k,m,t} \times PHD_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1 \] (4.6)

The group of patients with high dependency is further divided according to the presence or absence of a primary informal caretaker. Thus, to find the number of patients without a caretaker, the total number of patients in the transitional state with high dependency is multiplied by the probability of a patient not having a caretaker, as shown in Equation 4.7.

\[ THDNCT_{i,j,k,m,t} = THD_{i,j,k,m,t} \times PNCT_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1 \] (4.7)

To find the total number of patients with a caretaker, we multiply the total number of patients in the transitional state with high dependency by the probability of a patient having a caretaker. This can be seen in Equation 4.8.

\[ THDCT_{i,j,k,m,t} = THD_{i,j,k,m,t} \times PCT_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1 \] (4.8)

The group of individuals with high dependency and with a caretaker is further divided into two subgroups, according to each individual’s income level. The total number of patients in the transitional state with high dependency and with a caretaker is multiplied by the probability of an individual living below the poverty line, which yields the total number of patients in the transitional state with high dependency and with a caretaker who live below the poverty line, as presented in Equation 4.9.

\[ THDCTBPL_{i,j,k,m,t} = THDCT_{i,j,k,m,t} \times PBPL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1 \] (4.9)

When the number of patients in the transitional state with high dependency and with a caretaker is multiplied by the probability of an individual living above the poverty line, the total number of individuals
in the transitional state with high dependency and with a caretaker who live above the poverty line is
obtained, which is shown in Equation 4.10.

\[
THDCTAPL_{i,j,k,m,t} = THDCT_{i,j,k,m,t} \times PAPL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1
\] (4.10)

**EoL Branch**

Applying the same logic, the number of cancer patients in the EoL branch is given Equation 4.11, where
the number of cancer patients in multiplied by the probability of a cancer patient being in the EoL state.

\[
EOL_{i,j,k,m,t} = C_{i,j,k,m,t} \times PEOL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1
\] (4.11)

To divide the individuals in the EoL state, calculations similar to the transitional state calculations can be performed.

First, patients in the EoL state are divided into individuals with a caretaker, using Equation 4.12, and
individuals without a caretaker, using Equation 4.13, both obtained by multiplying the total number of patients in the EoL state by the probability of an individual having a caretaker and by the probability of an individual not having a caretaker, respectively.

\[
EOLCT_{i,j,k,m,t} = EOL_{i,j,k,m,t} \times PCT_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1
\] (4.12)

\[
EOLNCT_{i,j,k,m,t} = EOL_{i,j,k,m,t} \times PNCT_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1
\] (4.13)

The patients with caretakers are further divided according to income level. Equation 4.14 yields the number of patients in the end of life state, with a caretaker, that live above the poverty line. This value is obtained multiplying the number of patients in the EoL state with a caretaker by the probability of an individual living above the poverty line.

\[
EOLCTAPL_{i,j,k,m,t} = EOLCT_{i,j,k,m,t} \times PAPL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1
\] (4.14)

Equation 4.15 returns the number of patients in the end of life state with a caretaker, who live below the poverty line, which can be obtained by multiplying the total number of patients in the EoL state with a caretaker by the probability of an individual living below the poverty line.

\[
EOLCTBPL_{i,j,k,m,t} = EOLCT_{i,j,k,m,t} \times PBPL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m = 1, t = 1
\] (4.15)

The connection between these equations and the branches in the Decision Tree is summarized in Table 4.7.
### Table 4.7: Decision Tree branches and equation association

<table>
<thead>
<tr>
<th>Decision Tree Branch</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>4.1</td>
</tr>
<tr>
<td>$S^0$</td>
<td>4.3</td>
</tr>
<tr>
<td>$S^1$</td>
<td>??</td>
</tr>
<tr>
<td>$S^2$</td>
<td>??</td>
</tr>
<tr>
<td>$S^3$</td>
<td>??</td>
</tr>
<tr>
<td>$S^4$</td>
<td>??</td>
</tr>
<tr>
<td>TLD</td>
<td>4.5</td>
</tr>
<tr>
<td>THDNCT</td>
<td>4.7</td>
</tr>
<tr>
<td>THDCTBPL</td>
<td>4.9</td>
</tr>
<tr>
<td>THDCTAPL</td>
<td>4.10</td>
</tr>
<tr>
<td>EOLNCT</td>
<td>4.13</td>
</tr>
<tr>
<td>EOLCTAPL</td>
<td>4.14</td>
</tr>
<tr>
<td>EOLCTBPL</td>
<td>4.15</td>
</tr>
</tbody>
</table>

### 4.3.2 Markov Model

#### Non Cancer State

In the Markov model, the number of individuals in the non-cancer state each month is given by the surviving non-cancer population in the previous month (a value obtained by multiplying the previous month’s surviving population by that month’s survival rate) which was not diagnosed with cancer. Hence, this value is then multiplied by the probability of an individual not becoming a cancer patient \((1 - I_{m_{i,j,k,m,t}})\).

Transitions into the NC state are also considered, by the addition of all the surviving patients in the \(S^4\) state who have been in the stable state for five years. This value is obtained by multiplying the total surviving number of \(S^4\) patients in the previous month by \(\frac{1}{12}\), as it is assumed that patients are evenly distributed throughout the different months of year (\(\frac{1}{12}\) of patients entered state \(S^4\) in January, \(\frac{1}{12}\) of patients entered the \(S^4\) state in February, etc). Therefore, each month, \(\frac{1}{12}\) of the patients in that state have been there for five full years, therefore transitioning back to a NC state.

Population ageing is taken into consideration every time \(t\) increases (i.e. the model advances to a new year). Therefore, every new year the number of individuals of age \(i\) is calculated based on the number of individuals of age \(i - 1\) in the last month of the previous year, as population ageing is only considered in the last month of the year. This can be seen in Equation 4.16, branch 2.

This method is used to calculate the ageing of the population across all states.

\[
NC_{i,j,k,m,t} = \begin{cases} 
\begin{aligned}
& s_{r_{i,j,k,m-1,t}} \times [NC_{i,j,k,m-1,t} \times (1 - I_{m_{i,j,k,m-1,t}}) + \\
& \frac{1}{12} \times S_{i,j,k,m-1,t} \times P_{S^4+S}^T] \\
& s_{r_{i-1,j,k,12,t-1}} \times [NC_{i-1,j,k,12,t-1} \times (1 - I_{m_{i-1,j,k,12,t-1}}) + \\
& \frac{1}{12} \times S_{i-1,j,k,12,t-1} \times P_{S^4+S}^T]
\end{aligned}
\end{cases} \\
\forall i \in I, j \in J, k \in K, m > 1, t \geq 1
\]

\[(4.16)\]

It is assumed that the mortality rates available are total mortality rates (i.e., mortality rates calculated for all causes of death, including cancer). However, since a distinction is made between
cancer deaths and non-cancer deaths in the model, values for both the cancer mortality rate and the non-cancer mortality rate need to be calculated.

Since the total mortality rate \((m_{i,j,k,m,t})\), a model parameter, is the sum of both the cancer and the non-cancer mortality rates, the non-cancer mortality rate can be calculated by subtracting the cancer mortality rate from the total mortality rate. With this value it is possible to calculate the survival rate \((sr_{i,j,k,m,t})\), which in this case represents the probability of an individual surviving a non-cancer related death, as the probability of suffering a cancer-related death is already accounted for in the transition probabilities used \((P_{S\rightarrow CD}^j, P_{T\rightarrow CD}^j, P_{EOL\rightarrow CD}^j)\). This value is given by Equation 4.17.

\[
sr_{i,j,k,m,t} = 1 - (m_{i,j,k,m,t} - cm_{i,j,k,m,t}), \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.17}
\]

**Death States**

As the transition probabilities from the cancer states to the cancer death state are known, the total number of cancer deaths is easily calculated through the total transitions of all patients in these states (stable, transitional and \(EoL\)) to the death state, according to Equation 4.18.

\[
CD_{i,j,k,m,t} = \sum_{n=0}^{4} S_{i,j,k,m,t} \times P_{S\rightarrow CD}^j + T_{i,j,k,m,t} \times P_{T\rightarrow CD}^j + EOL_{i,j,k,m,t} \times P_{EOL\rightarrow CD}^j \\
\forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.18}
\]

Dividing the total number of cancer deaths by the total population (the entire population in the cancer state and in the non-cancer state), the total cancer death rate for the entire population is obtained, as seen in Equation 4.19.

\[
cm_{i,j,k,m,t} = \frac{CD_{i,j,k,m,t}}{NC_{i,j,k,m,t} + \sum_{n=0}^{4} S_{i,j,k,m,t} + T_{i,j,k,m,t} + EOL_{i,j,k,m,t}} \\
\forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.19}
\]

To calculate the total number of non-cancer deaths, the non-cancer mortality rate is applied to every state (be it non-cancer or cancer) in the model, according to Equation 4.20.

\[
NCD_{i,j,k,m,t} = (m_{i,j} - cm_{i,j,m,k,t}) \\
\times (NC_{i,j,k,m,t} + \sum_{n=0}^{4} S_{i,j,k,m,t} + T_{i,j,k,m-1,t} + EOL_{i,j,k,m,t}) \\
\forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.20}
\]

**Stable states**

The number of patients in the \(S^0\) state is given by the number of surviving patients from the non-cancer state that transitions into the cancer state, the surviving patients that remain in the \(S^0\) state, and all the surviving patients from the transitional and \(EoL\) states who re-enter the stable state, as it is a model assumption that these patients join in the \(S^0\) state.
It is assumed that the total number of individuals in the $S^0$ state is divided equally between all months of the year. This means that each month $\frac{1}{12}$ of the total number of patients in that state has been there for a full year, transitioning to the $S^1$ state. Thus, the number of $S^0$ patients remaining in that state is always $\frac{11}{12}$ of the total each time new transitions are calculated.

This is summarized in Equation (4.21).

$$S_{i,j,k,m,t}^0 = \begin{cases} \frac{n}{12} \times (P_{i,j,k,m-1,t}^m + NC_{i,j,k,m-1,t} \times P^{S\rightarrow S}) + EOL_{i,j,k,m-1,t} \times P^{EOL\rightarrow S} & \forall i, j, k, m > 1, t \geq 1 \\ + \frac{11}{12} \times S_{i,j,k,m-1,t}^0 \times P^{S\rightarrow S} + T_{i,j,k,m-1,t} \times P^{T\rightarrow S} & \forall i, j, k, m > 1, t \geq 1 \end{cases}$$

(4.21)

For the remaining stable states ($S^1$, $S^2$, $S^3$ and $S^4$), the total number of patients in each of them becomes much easier to calculate, as state $S^n$, for $n > 0$, can only be entered by patients in state $S^{n-1}$, and thus only transitions between consecutive stable states need to be considered.

Therefore, the number of patients in $S^1$ is given by the number of surviving patients from $S^0$ who have been in that state for over a year and transition into the $S^1$ state, and by the number of patients in the $S^1$ state that have been stable for less than two years and remain in the $S^1$ state. The total number of individuals in the $S^1$ state is given by Equation (4.22).

$$S_{i,j,k,m,t}^1 = \begin{cases} \frac{n}{12} \times (\frac{1}{12} \times S_{i,j,k,m-1,t}^0 + \frac{11}{12} \times S_{i,j,k,m-1,t}^1) \times P^{S\rightarrow S} & \forall i, j, k, m > 1, t \geq 1 \\ + \frac{11}{12} \times S_{i,j,k,m-1,t}^0 \times P^{S\rightarrow S} + T_{i,j,k,m-1,t} \times P^{T\rightarrow S} & \forall i, j, k, m > 1, t \geq 1 \end{cases}$$

(4.22)

Similar logic is applied to $S^2$, where only transitions from $S^1$ and $S^2$ into $S^2$ are considered, and so the total number of patients in the $S^2$ state is given by Equation (4.23).

$$S_{i,j,k,m,t}^2 = \begin{cases} \frac{n}{12} \times (\frac{1}{12} \times S_{i,j,k,m-1,t}^1 + \frac{11}{12} \times S_{i,j,k,m-1,t}^2) \times P^{S\rightarrow S} & \forall i, j, k, m > 1, t \geq 1 \\ + \frac{11}{12} \times S_{i,j,k,m-1,t}^1 \times P^{S\rightarrow S} + T_{i,j,k,m-1,t} \times P^{T\rightarrow S} & \forall i, j, k, m > 1, t \geq 1 \end{cases}$$

(4.23)

Transitions into the $S^3$ state can only come from the surviving patients in the $S^2$ and the $S^3$ states and thus the total number of individuals in the $S^3$ state is given by Equation (4.24).
\[ S_{i,j,k,m,t}^4 = \begin{cases} s_{i,j,k,m-1,t} \times \left( \frac{1}{12} \times S_{i,j,k,m-1,t}^2 + \frac{11}{12} \times S_{i,j,k,m-1,t}^3 \right) \\
\times P_j^{S\rightarrow S} \\
s_{i-1,j,k,12,t-1} \times \left( \frac{1}{12} \times S_{i-1,j,k,12,t-1}^2 + \frac{11}{12} \times S_{i-1,j,k,12,t-1}^3 \right) \\
\times P_j^{S\rightarrow S} \end{cases} \]

\[ \forall i, j, k, m > 1, t \geq 1 \]

\[ \forall i, j, k, m = 1, t > 1 \]

(4.24)

For the aforementioned reasons, the number of individuals in the \( S^4 \) state is given by Equation 4.25. As before, only transitions from the \( S^4 \) state and the \( S^4 \) state are considered.

\[ S_{i,j,k,m,t}^4 = \begin{cases} s_{i,j,k,m-1,t} \times \left( \frac{1}{12} \times S_{i,j,k,m-1,t}^2 + \frac{11}{12} \times S_{i,j,k,m-1,t}^3 \right) \\
\times P_j^{S\rightarrow S} \\
s_{i-1,j,k,12,t-1} \times \left( \frac{1}{12} \times S_{i-1,j,k,12,t-1}^2 + \frac{11}{12} \times S_{i-1,j,k,12,t-1}^3 \right) \\
\times P_j^{S\rightarrow S} \end{cases} \]

\[ \forall i, j, k, m > 1, t \geq 1 \]

\[ \forall i, j, k, m = 1, t > 1 \]

(4.25)

**Transitional states**

The total number of patients in the transition states is given by Equation 4.26. All surviving patients in the stable states, the transitional states and the EoL states can transition to this state, according to different transition probabilities.

\[ T_{i,j,k,m,t} = \begin{cases} s_{i,j,k,m-1,t} \times \\
\left( \sum_{n=0}^{4} S_{i,j,k,m-1,t}^n \times P_j^{S\rightarrow T} + T_{i,j,k,m-1,t} \times P_j^{T\rightarrow T} + EOL_{i,j,k,m-1,t} \times P_j^{EOL\rightarrow T} \right) \end{cases} \]

\[ \forall i, j, k, m > 1, t \geq 1 \]

\[ s_{i-1,j,k,12,t-1} \times \left( \sum_{n=0}^{4} S_{i-1,j,k,12,t-1}^n \times P_j^{S\rightarrow T} + T_{i-1,j,k,12,t-1} \times P_j^{T\rightarrow T} + EOL_{i-1,j,k,12,t-1} \times P_j^{EOL\rightarrow T} \right) \]

\[ \forall i, j, k, m = 1, t > 1 \]

(4.26)

The transition groups are further divided into separate states using adaptations of the equations developed for the decision tree. Initially this separation is done according to dependency level, using Equation 4.27 for patients with low dependency and Equation 4.28 for patients with high dependency.

\[ TLD_{i,j,k,m,t} = T_{i,j,k,m,t} \times PLD_{i,j,k,m,t}, \forall i, j, k, m \in M, t \in T \]

(4.27)

\[ THD_{i,j,k,m,t} = T_{i,j,k,m,t} \times PHD_{i,j,k,m,t}, \forall i, j, k, m \in M, t \in T \]

(4.28)

The group of patients with low dependency makes up the TLD state. The group of patients with high dependency is then divided according to the presence of a caretaker, using Equation 4.30 or absence of a caretaker, with Equation 4.29.
\[ \text{THDNCT}_{i,j,k,m,t} = \text{THD}_{i,j,k,m,t} \times \text{PNCT}_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \] (4.29)

\[ \text{THDC}_{i,j,k,m,t} = \text{THD}_{i,j,k,m,t} \times \text{PCT}_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \] (4.30)

The group of patients in the transitional state with high dependency and without a caretaker forms the THDNCT state. Finally, the group of patients with a caretaker is divided according to income level. For patients who live below the poverty line, Equation 4.31 is used, and they make up the THDCTBPL state. To calculate the number of patients who live below the poverty line, making up the THDCTAPL state, we apply Equation 4.32.

\[ \text{THDCT}_{i,j,k,m,t} = \text{THD}_{i,j,k,m,t} \times \text{PBPL}_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \] (4.31)

\[ \text{THDCT}_{i,j,k,m,t} = \text{THD}_{i,j,k,m,t} \times \text{PAPL}_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \] (4.32)

**EoL states**

To find the number of patients in the EoL state Equation 4.33 is used. All surviving patients in the stable state, the transitional state and the EoL state can transition into the EoL state, though with different transition probabilities. In the first month of the planning period, this value is given by the total prevalence of patients in the EoL state.

\[
\begin{cases}
S_{i,j,k,m,t}^{-1} - 1 \times \\
\sum_{n=0}^{4} S_{i,j,k,m,t-1}^{-1} \times P_{j}^{S \rightarrow EOL} + \\
T_{i,j,k,m,t-1}^{-1} \times P_{j}^{T \rightarrow EOL} + \\
E_{i,j,k,m,t-1}^{EOL} \times P_{j}^{EOL \rightarrow EOL} \\
E_{i,j,k,m-1,t} \times (\sum_{n=0}^{4} S_{i,j,k,m-1,t}^{-1} \times P_{j}^{S \rightarrow EOL} + \\
T_{i,j,k,m-1,t} \times P_{j}^{T \rightarrow EOL} + \\
E_{i,j,k,m-1,t} \times P_{j}^{EOL \rightarrow EOL}) \quad \forall i \in I, j \in J, k \in K, m = 1, t > 1
\end{cases}
\] (4.33)

EoL patients are further divided using the equations developed for the decision tree. Initially, they are separated according to the presence or absence of a caretaker, using Equation 4.34 and Equation 4.35 respectively.

\[ \text{EOLCT}_{i,j,k,m,t} = \text{EOL}_{i,j,k,m,t} \times \text{PCT}_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \] (4.34)

\[ \text{EOLNCT}_{i,j,k,m,t} = \text{EOL}_{i,j,k,m,t} \times \text{PNCT}_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \] (4.35)
The group of patients without a caretaker makes up the EOLNCT state. The group of patients with a caretaker is further divided according to income level. Patients who live below the poverty line make up the EOLCTBPL state and are calculated using Equation 4.37, while patients with live above the poverty line make up the EOLCTAPL state and are calculated according to Equation 4.36.

\[
EOLCTAPL_{i,j,k,m,t} = EOLCT_{i,j,k,m,t} \times PAPL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.36}
\]

\[
EOLCTBPL_{i,j,k,m,t} = EOLCT_{i,j,k,m,t} \times PBPL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.37}
\]

The association between the Markov Model states and each equation can be seen in Table 4.8.

<table>
<thead>
<tr>
<th>Markov State</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>4.16</td>
</tr>
<tr>
<td>(S^0)</td>
<td>4.21</td>
</tr>
<tr>
<td>(S^1)</td>
<td>4.22</td>
</tr>
<tr>
<td>(S^2)</td>
<td>4.23</td>
</tr>
<tr>
<td>(S^3)</td>
<td>4.24</td>
</tr>
<tr>
<td>(S^4)</td>
<td>4.25</td>
</tr>
<tr>
<td>TLD</td>
<td>4.27</td>
</tr>
<tr>
<td>THDCTAPL</td>
<td>4.32</td>
</tr>
<tr>
<td>THDCTBPL</td>
<td>4.31</td>
</tr>
<tr>
<td>THDNCT</td>
<td>4.29</td>
</tr>
<tr>
<td>EOLCTAPL</td>
<td>4.36</td>
</tr>
<tr>
<td>EOLCTBPL</td>
<td>4.37</td>
</tr>
<tr>
<td>EOLNCT</td>
<td>4.35</td>
</tr>
</tbody>
</table>

4.3.3 PC settings

When all the individuals in a given population are separated into the different possible states, the number of patients requiring each type of PC service is calculated.

The total number of patients requiring ambulatory care is equal to the total number of patients in the transitional state with low dependency, calculated using Equation 4.38.

\[
AC_{i,j,k,m,t} = TLD_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.38}
\]

The total number of patients requiring home care is given by the total number of patients in the transitional state with high dependency and with a caretaker who live above the poverty line, and by the total number of patients in the EoL state with a caretaker, also living above the poverty line, as summarized in Equation 4.39.

\[
HC_{i,j,k,m,t} = THDCTAPL_{i,j,k,m,t} + EOLCTAPL_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.39}
\]

Finally, to calculate the number of patients requiring inpatient care, Equation 4.40 is used. This number is given by the total number of patients in the transitional state with high dependency and
without a caretaker, the total number of patients in the transitional state with high dependency and with a caretaker who live below the poverty line, the total number of patients in the EoL state without a caretaker, and, finally, the total number of patients in the EoL state with a caretaker who live below the poverty line.

\[
IC_{i,j,k,m,t} = THDNCT_{i,j,k,m,t} + THDCTBPL_{i,j,k,m,t} + EOLNCT_{i,j,k,m,t} + EOLCTBPL_{i,j,k,m,t},
\forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.40}
\]

### 4.3.4 Costs

Once patients are assigned to a [PC] setting, the costs behind those assignments are studied.

The monthly cost of caring for all the [AC] patients, \( C_{i,j,k,m,t}^{AC} \), is given by the product between the total number of patients requiring [AC] and the monthly cost of providing that type of care to a patient, according to Equation 4.41. Similarly, the number of patients requiring [HC] is given by Equation 4.42 while the number of patients requiring [IC] is given by Equation 4.43.

\[
C_{i,j,k,m,t}^{AC} = C_{i,j,k,m,t}^{AC} \times AC_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.41}
\]

\[
C_{i,j,k,m,t}^{HC} = C_{i,j,k,m,t}^{HC} \times HC_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.42}
\]

\[
C_{i,j,k,m,t}^{IC} = C_{i,j,k,m,t}^{IC} \times IC_{i,j,k,m,t}, \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.43}
\]

Comparatively, the total cost of caring for these patients in an acute hospital setting can also be calculated. This is given by Equation 4.44, where the total number of patients requiring [PC] is multiplied by the cost of caring for each patient in an acute hospital. With this value, a comparison can be made between the costs of providing [PC] inside and outside a [PC] network, and the total possible savings associated with the provision of [PC] can be determined.

\[
C_{i,j,k,m,t}^{NPC} = C_{i,j,k,m,t}^{NPC} \times (AC_{i,j,k,m,t} + HC_{i,j,k,m,t} + IC_{i,j,k,m,t}), \forall i \in I, j \in J, k \in K, m \in M, t \in T \tag{4.44}
\]
5. Case Study

The model proposed in the previous chapter is applied to each municipality in the Lisbon county, in the 2016-2021 period. The following section presents the data set used as well as all the assumptions that had to be made in order to apply the model. In the next section the model is validated, using data from the 2001 period onwards, and in the third and last section the results obtained are presented.

5.1 Data Set

Table 5.1 gives a summary of the data sources used and its main characteristics, as well as limitations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>[96]</td>
<td>Data from 2011 disaggregated by gender, age, and municipality. These values are used to estimate prevalence.</td>
</tr>
<tr>
<td>Incidence</td>
<td>[87–90, 98]</td>
<td>Incidence data was found for the Lisbon county, from 2002 to 2009, disaggregated by gender and age groups with a five year-span. No disaggregation was found between new patients and patients in remission.</td>
</tr>
<tr>
<td>Prevalence</td>
<td>No data found</td>
<td></td>
</tr>
<tr>
<td>Dependency level</td>
<td>[99]</td>
<td>Estimated using total population dependency data. Countrywide data from 2015, disaggregated by gender and age group (45 – 64, 65, 74, 75+).</td>
</tr>
<tr>
<td>Caretaker</td>
<td>[100]</td>
<td>Estimated according to marriage status. Data from the 2011 Censos, disaggregated by municipality, gender, and age groups within a five-year span.</td>
</tr>
<tr>
<td>Income level</td>
<td>[101]</td>
<td>Estimated according to the probability of a given individual living in risk of poverty or social exclusion. Countrywide data from 2014, disaggregated by gender and age groups with a five year-span and gender.</td>
</tr>
<tr>
<td>Costs</td>
<td>[10][102]</td>
<td>Data from 2011 for ambulatory, home-care and acute care settings, and from 2011 for inpatient settings. No data disaggregation found.</td>
</tr>
<tr>
<td>Transitions probabilities</td>
<td>[36]</td>
<td>Data from a 2013 Canadian study. No data disaggregation found.</td>
</tr>
<tr>
<td>Number of beds available</td>
<td>[103]</td>
<td>Data from February 2016. Estimated from the total number of [PC] units.</td>
</tr>
</tbody>
</table>

In the implementation of the model, the following assumptions were made:

- The possibility of cancer patients reentering a non-cancer state before a five year period isn't considered. This assumption was made as no data on cancer remission was found, and 5-year
survival rates are regularly used to estimate the prognosis of cancer patients, as well as a way to evaluate cancer treatments and to compare different types of cancers [104,105].

- If incidence for a certain age group is $X$, then each individual age in that group has an incidence of $X$.

- Non-cancer mortality remains stable over time.

- The probability of a patient having a caretaker remains constant over time.

- The probability of a patient living above the poverty line remains constant over time.

- The probability of a patient having low or high dependency remains constant over time.

- Results from a Canadian study [36] used to obtain the transition rates between the stable, the transitional, the EoL and the death state, are assumed to be valid for Portugal.
  - These rates remain constant over time.
  - Some changes were made to the data: the probability of a transition from the stable state to the stable state is increased, while the probability of other transitions from the stable state are decreased. This was done because values found in the study produced mortality rates higher than those expected to the Portuguese case. The age and case-mix standardised five year-survival rate of cancer patients in Portugal has a value of 52.1% for men and 60.7% for women [105], whereas directly applying the values from the studied resulted in a five-year survival rate of roughly 10% for both genders. While the data used didn’t provide different transition rates for individuals from different genders, with the data processing done, transition rates were calculated for both men and women. The results thus obtained yielded a survival rate is of 52.1% for men and 60.1% for women.
  - The need for this adjustment in the transition rates may be due to the following reasons: deadlier cancers might have higher incidence in Canada; the study takes place only in a 26-month period rather than the 5-year period the model created is being used; the study assumes all patients are stable when diagnosed; stable patients don’t undergo as many consultations as non-stable patients.

- Patients are in the stable state when first diagnosed (same assumption in the previously mentioned study, as 80% of patients were stable during their first consultation)

- Results from a Spanish study [102] can be applied directly to estimate the costs of delivering IC to cancer patients in Portugal.

- The costs of providing palliative care remain constant over time and don’t vary between age groups, gender and phases of the disease.

In order to better understand the application of the model, some of the data presented in Table 5.1 need to be further explained. These additional explanations are presented in the following subsections.
5.1.1 Mortality Rates

Since the data used represents annual mortality rates, these values had to be converted into monthly mortality rate. This was done according to Equation 5.1 where \( m_{i,j,k,m,t} \) is the monthly mortality rate and \( m_{i,j,k,m,t}^A \) the annual mortality rate. The deduction of this formula can be found in Appendix A.

\[
m_{i,j,k,m,t} = 1 - (1 - m_{i,j,k,m,t}^A)^{\frac{1}{12}}, \forall i \in I, j \in J, k \in K, m \in M, t \in T
\]  \hspace{1cm} (5.1)

5.1.2 Incidence Rates

The only information available on cancer incidence on the Lisbon county is a yearly incidence rate, disaggregated by gender and age group. Each age group had a five-year range (i.e., from twenty to twenty four years, twenty five to twenty-nine years, etc). These rates are only available from the year 2002 to the year 2009, and no future incidence forecasts for Portugal or Portuguese regions were found.

It thus became necessary to forecast these values for the years in which the model is used. When the behaviour of the data is observed, it is made clear that there is no seasonality to the data as the values present are yearly incidence values, so methods where seasonality is considered are not relevant. Since there was no cyclic variation to the data, averaging techniques such as naive forecasts or moving average were also dismissed.

It was possible to observe, however, that the incidence values found had a tendency to rise each year, thus showing a rising trend. For that reason, linear regressions were performed on the data available to estimate incidence over the years for each gender and age group. The results in Table 5.4 were found for men, while the results in Table 5.5 were found for women.

**Table 5.2:** Cancer Incidence (out of 100000 people) for men in Lisbon. \( y \)–total annual incidence, \( x \)–year

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Equation</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>[15,19]</td>
<td>( y = 0.3205x - 620.67 )</td>
<td>0.0343</td>
</tr>
<tr>
<td>[20,24]</td>
<td>( y = 1.0545x - 2081.8 )</td>
<td>0.1767</td>
</tr>
<tr>
<td>[25,29]</td>
<td>( y = 0.4281x - 813.72 )</td>
<td>0.0295</td>
</tr>
<tr>
<td>[30,34]</td>
<td>( y = 1.8479x - 3641.6 )</td>
<td>0.2797</td>
</tr>
<tr>
<td>[35,39]</td>
<td>( y = 0.6325x - 1182.5 )</td>
<td>0.0103</td>
</tr>
<tr>
<td>[40,44]</td>
<td>( y = 4.92x - 9058.1 )</td>
<td>0.4431</td>
</tr>
<tr>
<td>[45,49]</td>
<td>( y = 7.9201x - 15594 )</td>
<td>0.6759</td>
</tr>
<tr>
<td>[50,54]</td>
<td>( y = 12.396x - 24369 )</td>
<td>0.4786</td>
</tr>
<tr>
<td>[55,59]</td>
<td>( y = 22.622x - 44571 )</td>
<td>0.6377</td>
</tr>
<tr>
<td>[60,64]</td>
<td>( y = 36.929x - 72898 )</td>
<td>0.6396</td>
</tr>
<tr>
<td>[65,69]</td>
<td>( y = 8.6135x - 15600 )</td>
<td>0.5661</td>
</tr>
<tr>
<td>[70,74]</td>
<td>( y = 43.834x - 85805 )</td>
<td>0.3364</td>
</tr>
<tr>
<td>[75,79]</td>
<td>( y = 24.679x - 47078 )</td>
<td>0.2599</td>
</tr>
<tr>
<td>[80,84]</td>
<td>( y = 43.133x - 84066 )</td>
<td>0.4209</td>
</tr>
<tr>
<td>[85+]</td>
<td>( y = 37.16x - 72419 )</td>
<td>0.4137</td>
</tr>
</tbody>
</table>
It is important to note that some of the equations found to calculate future incidence yield a very low $R^2$ value, even after outlier removal was attempted. In the lower age groups, this fact can be explained by the low number of new cancer cases each year. Given this low incidence, just a few new cases can change the results significantly each year. As a result, performing a linear regression is more difficult in such circumstances.

For the age groups showing a higher incidence, and, therefore, a higher number of cases each year, better values of $R^2$ were found, as small variations each year didn’t alter the incidence as much as they altered it for the low age groups.

Nevertheless, an unexpected result is found for the age group from 75 to 79, in both males and females. Despite the high number of cancer cases for individuals with that age, the $R^2$ value is much lower than what would be expected, which might be explained by the presence of multiple pathologies in that age group and the possibility of individuals with high risk factors for cancer, suffering and dying from other diseases.

With these equations, total incidence values for the 2016 to 2021 period were taken, for the Markov model, as well as the incidence rates from 2011 to 2015, which were use to estimate total prevalence, which will be discussed in the following section.

The results obtained for men are present in Table 5.4, whereas the results obtained for women are presented in Table 5.5.
These values are divided by 100000 (as they are the incidence rates out of 100000 people), so they are converted into the probability of any individual becoming a cancer patient, as shown in Equation (5.2)

$$ I^A_{i,j,k,t} = \frac{y_{i,j,k,t}}{100000} $$

Given the total annual incidence, monthly incidence can be calculated according to Equation 5.3 following the procedure explained in Appendix A.

$$ I^m_{i,j,k,m,t} = 1 - \left( 1 - I^A_{i,j,k,t} \right)^\frac{1}{12} $$

### 5.1.3 Prevalence rates

Each year, the total population with cancer is made up of new patients diagnosed in that year (captured by incidence rates) and patients diagnosed with cancer in past years. The total number of cancer patients, new and past, is captured by prevalence rates. Thus, any model intending to simulate cancer progression for a population and to study current and future PC needs of cancer patients must take both of these groups into consideration.
Since no information on cancer prevalence in Portugal could be found, or information on the probability of a patient being in any of the cancer states, those values had to be estimated so that the results found could be as accurate as possible.

It is a model assumption that only prevalence from the past five years is relevant, as it is considered that after a five-year period in the stable state, the patient reenters the non-cancer state. Therefore, to project prevalence rates, we will apply an adapted version of the Markov model described in the above chapter, five years before 2016 (the first year in which the Markov model will be applied) until January of 2016. The values calculated for January of 2016 will thus be the ones used to populate the non-cancer branch of the decision tree, as well as the cancer branch (along with the stable, transitional and \textit{EoL} branches). It is assumed that only data from the past five years is important to the Markov model, and so no incidence or prevalence data prior to that period is relevant to the Markov model’s starting year, due to the 5-year period to reenter the non-cancer state.

A simpler decision tree adapted from the decision tree in Figure 4.2 can be seen in Figure 5.1, to allow the easy visualization of all the different states considered here. This tree is used for the first month of 2011 only.

![Decision Tree](image)

\textbf{Figure 5.1: Decision Tree used to estimate prevalence}

It is important to note that when no data on prevalence is available, there is no information on how many patients, diagnosed in the past, live with cancer at any given time. Prevalence effectively allows us to know the number of patients living with a disease and, indirectly, the total non-cancer population of a given area. Since the goal of this approach is to calculate the total cancer prevalence, the total population is divided into two separate groups, one for cancer patients and one for non-cancer
patients.

The cancer group is divided into three different groups (stable, transitional and EoL), as in the former decision tree and Markov model. Stable patients are further divided into five groups (stable 0, stable 1, stable 2, stable 3 and stable 4), according to how long they’ve been in the stable state. This way, the Markov model can be populated in the first month for which it is run with information regarding the number of patients in each state.

Total incidence is calculated for each year and patients’ progression through the different cancer states (stable 0, stable 1, stable 2, stable 3, transitional, end of life and death) is studied, through patients’ transitions between states. These transitions are the same as in Figure 4.3, except transitional state patients and EoL state patients aren’t subdivided into other states, as that information isn’t relevant to calculate prevalence, since the focus is only the total number of patients in each cancer phase at the start of the Markov model in 2016.

The equations used for each state are adaptations of the equations used in the Markov model.

For the first month the method to calculate prevalence is applied, it is assumed that the non-cancer population equals the total population with the exception of new cancer cases. After that initial month, the non-cancer population is calculated in the same way as in Equation 4.16 except with no transitions from the $S^4$ state being considered until the end of 2015. Since there is no initial prevalence in the model, it is only after the model has run for five years, that a patient might reenter the NC state. Therefore, in the first month of 2016, $S^4$ patients might transition into the NC state.

This is summarized in Equation 5.4.

\[
NC_{i,j,k,m,t} = \\
\begin{cases} 
  P_{i,j,k,m,t}^0 \times (1 - I_{i,j,k,m,t}^m) & \forall i \in I, j \in J, k \in K, m = 1, t = 2011 \\
  sr_{i-1,j,k,12,t-1} \times NC_{i-1,j,k,12,t-1} \times (1 - I_{i-1,j,k,12,t-1}^m) & \forall i \in I, j \in J, k \in K, m = 1, 2011 < t < 2016 \\
  sr_{i,j,k,m-1,t} \times NC_{i,j,k,m-1,t} \times (1 - I_{i,j,k,m-1,t}^m) & \forall i \in I, j \in J, k \in K, m > 1, 2011 < t < 2015 \\
  sr_{i-1,j,k,12,t-1} \times NC_{i-1,j,k,12,t-1} \times (1 - I_{i-1,j,k,12,t-1}^m) + \\
  \frac{1}{12} \times S^4_{i-1,j,k,12,t-1} \times P_{j}^{S^4 \rightarrow S} & \forall i \in I, j \in J, k \in K, m = 1, t = 2016 
\end{cases} 
\]

(5.4)

Once the non-cancer population is known, it is necessary to divide the patients between cancer states and to calculate the transitions between them. However, it must be noted that not all transitions between the stable states are possible in the first years. In the first year the model is considered, patients have been diagnosed for less than one year, so they can only be in the $S^0$ state. In the second year, patients have been diagnosed for less than two years, so they can only be in and transition between $S^0$ and $S^1$. The same logic is applied to the third, fourth and fifth year.

These transitions are summarized in Table 5.6.
Table 5.6: Possible transitions between stable states when estimating prevalence rates

<table>
<thead>
<tr>
<th>Stable 0</th>
<th>Stable 1</th>
<th>Stable 2</th>
<th>Stable 3</th>
<th>Stable 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always possible</td>
<td>Possible after the second year</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Impossible</td>
</tr>
<tr>
<td>Stable 1</td>
<td>Impossible</td>
<td>Always possible</td>
<td>Possible after the third year</td>
<td>Impossible</td>
</tr>
<tr>
<td>Stable 2</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Always possible</td>
<td>Possible after the fourth year</td>
</tr>
<tr>
<td>Stable 3</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Always possible</td>
</tr>
<tr>
<td>Stable 4</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Impossible</td>
</tr>
</tbody>
</table>

Therefore, the equations used to calculate transitions between stable states vary according to the year the model is being run for, as these transition probabilities also vary.

In the first month of the model the total number of patients in the \( S_0 \) state is simply equal to the number of new cancer cases that month (given by the product between cancer incidence and the total population). Past incidence and prevalence from the previous years is not considered as that information is not available.

In the first year, all transitions to the stable state enter \( S_0 \), as these individuals have necessarily been in the stable state for less than one year. In the second year, it is assumed that the total number of individuals in the \( S_0 \) state is divided equally between all months of the year, so each month \( \frac{1}{12} \) of the total transitions to the \( S_1 \) state, while \( \frac{11}{12} \) remain in \( S_0 \).

The same logic is applied for the different stable states, considering only the transitions possible in Table 5.6. This equation is an adaptation of Equation 4.21.

\[
S_{i,j,k,m,t}^0 = \begin{cases} 
P_{i,j,k,m,t}^0 \times I_{i,j,k,m,t}^0 & \forall i \in I, j \in J, k \in K, m = 1, t = 2011 \\
S_{i,j,k,m-1,t}^0 \times (S_{i,j,k,m-1,t}^0 \times P_{j}^{S \rightarrow S} + T_{i,j,k,m-1,t}^0 \times P_{j}^{T \rightarrow S} + EOL_{i,j,k,m-1,t}^0 \times P_{j}^{EOL \rightarrow S} + I_{i,j,k,m-1,t}^0 \times NC_{i,j,k,m-1,t}^0) & \forall i \in I, j \in J, k \in K, m > 1, t = 2011 \\
\frac{1}{12} \times S_{i,j,k,12,t-1}^0 \times (P_{j}^{S \rightarrow S} + T_{i,j,k,12,t-1}^0 \times P_{j}^{T \rightarrow S} + EOL_{i,j,k,12,t-1}^0 \times P_{j}^{EOL \rightarrow S} + I_{i,j,k,12,t-1}^0 \times NC_{i,j,k,12,t-1}^0) & \forall i \in I, j \in J, k \in K, m = 1, t > 2011 \\
S_{i,j,k,m-1,t}^1 \times (P_{j}^{S \rightarrow S} + T_{i,j,k,m-1,t}^0 \times P_{j}^{T \rightarrow S} + EOL_{i,j,k,m-1,t}^0 \times P_{j}^{EOL \rightarrow S} + I_{i,j,k,m-1,t}^0 \times NC_{i,j,k,m-1,t}^0) & \forall i \in I, j \in J, k \in K, m > 1, t > 2011 \\
\end{cases}
\]

(5.5)

For \( S_1 \), the number of individuals is 0 in the first year, as there can be no transitions to that state. For the second year, patients from the \( S_0 \) state can transition into this state. There are no transitions to other stable states, as patients have not been in the model long enough. After the second year, 2012, patients can transition to the \( S_2 \) state, at a rate of \( \frac{1}{12} \), according to Equation 5.7, which is adapted from Equation 4.23.
\[ S_{i,j,k,m,t}^1 = \]
\[
\begin{cases}
0 & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m = 1, t = 2011 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^0 + \frac{1}{12} \times S_{i,j,k,m-1,t}^1 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m = 1, t = 2012 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^1 + \frac{1}{12} \times S_{i,j,k,m-1,t}^2 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m \leq 1, t = 2012 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^0 + \frac{1}{12} \times S_{i,j,k,m-1,t}^1 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m > 1, t = 2012 \\
\end{cases}
\]

(5.6)

Similar logic is applied to the \( S^2 \) state, where there are no patients for the first two years (2011 and 2012) as individuals have not been in the model long enough to transition into this state. After that, patients can transition into the \( S^2 \) state, and after another year they can transition from \( S^2 \) into \( S^3 \), as given by Equation \( 5.7 \) adapted from Equation \( 4.23 \).

\[ S_{i,j,k,m,t}^2 = \]
\[
\begin{cases}
0 & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m = 1, t < 2013 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^1 + S_{i,j,k,m-1,t}^2 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m = 1, t = 2013 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^1 + \frac{1}{12} \times S_{i,j,k,m-1,t}^2 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m \leq 1, t = 2013 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^0 + \frac{1}{12} \times S_{i,j,k,m-1,t}^1 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m > 1, t > 2013 \\
\end{cases}
\]

(5.7)

For \( S^3 \), the same logic is used, except now patients cannot transition into this state for the first three years of the model (Equation \( 5.8 \) adapted from Equation \( 4.24 \)).

\[ S_{i,j,k,m,t}^3 = \]
\[
\begin{cases}
0 & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m = 1, t < 2014 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^1 + S_{i,j,k,m-1,t}^2 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m = 1, t = 2014 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^1 + \frac{1}{12} \times S_{i,j,k,m-1,t}^2 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m \leq 1, t = 2014 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^0 + \frac{1}{12} \times S_{i,j,k,m-1,t}^1 \right) \times P_{j,t}^S & \text{if } i,j \leq 12, t \leq 12, i \leq j, k = j, m > 1, t > 2014 \\
\end{cases}
\]

(5.8)

Finally, for the \( S^4 \) state, transitions into the NC state need not to be accounted for until the first month of 2016, since it is only after five years in the model that patients can move back to a non-cancer state. For that reason, until the first month of 2016 \( (m = 1, t = 2016) \), there is no need to account for patients leaving \( S^4 \) for any state other than death (cancer or non-cancer) or the transitional or stable state. The equation relative to \( S^4 \) is Equation \( 5.9 \) adapted from Equation \( 4.25 \).
individuals are considered not to have one. Married people are considered to have a caretaker, whereas single, divorced or widowed individuals are considered not to have one.

5.1.4 Caretaker

The probability of a cancer patient having a caretaker or not is calculated using marriage status as a proxy. Married people are considered to have a caretaker, whereas single, divorced or widowed individuals are considered not to have one.

\[
S_{i,j,k,m,t}^1 = \begin{cases} 
0 & \forall i \in I, j \in J, k \in K, m = M, t < 2015 \\
\frac{1}{12} \times T_{i-1,j,k,12,t-1}^1 \times S_{i-1,j,k,12,t-1}^3 \times P_{j}^{S \rightarrow T} & \forall i \in I, j \in J, k \in K, m = 1, t = 2015 \\
\left( \frac{1}{12} \times S_{i,j,k,m-1,t}^3 + S_{i,j,k,m-1,t}^4 \right) \times P_{j}^{S \rightarrow T} & \forall i \in I, j \in J, k \in K, m > 1, t = 2015 \\
\left( \frac{1}{12} \times S_{i-1,j,k,12,t-1}^3 + \frac{11}{12} \times S_{i-1,j,k,12,t-1}^4 \right) \times P_{j}^{S \rightarrow T} & \forall i \in I, j \in J, k \in K, m = 1, t = 2016 
\end{cases} 
\]

(5.9)

Additionally, the total number of patients in the transitional and EoL states is also calculated, using Equation 5.10 and Equation 5.11 respectively. For the first month, it is assumed that this value is 0, due to lack of prevalence data. As stated above, it is also assumed all new cancer patients transition to the S0 state, so there are no transitions into the transitional or the EoL states for the first month.

After that period, the number of patients in the transitional and the EoL state is simply given by the sum of all the possible transitions into these state. These equations are the same as Equation 4.26 for the transitional state, and Equation 4.33 for the EoL state, with the only differences being the values in the first month of 2011.

\[
T_{i,j,k,m,t} = \begin{cases} 
0 & \forall i \in I, j \in J, k \in K, m = 1, t = 2011 \\
\sum_{n=0}^{4} T_{i-1,j,k,12,t-1}^n \times P_{j}^{S \rightarrow T} & \forall i \in I, j \in J, k \in K, m = 1, t > 2011 \\
\sum_{n=0}^{4} T_{i,j,k,m-1,t}^n \times P_{j}^{S \rightarrow T} & \forall i \in I, j \in J, k \in K, m > 1, t > 2011 
\end{cases} 
\]

(5.10)

\[
EOL_{i,j,k,m,t} = \begin{cases} 
0 & \forall i \in I, j \in J, k \in K, m = 1, t = 2011 \\
\sum_{n=0}^{4} T_{i-1,j,k,12,t-1}^n \times P_{j}^{S \rightarrow EOL} & \forall i \in I, j \in J, k \in K, m = 1, t > 2011 \\
\sum_{n=0}^{4} T_{i,j,k,m-1,t}^n \times P_{j}^{S \rightarrow EOL} & \forall i \in I, j \in J, k \in K, m > 1, t > 2011 
\end{cases} 
\]

(5.11)

As an example, the values obtained for the Lisbon municipality are presented in Appendix B.

5.1.4 Caretaker

The probability of a cancer patient having a caretaker or not is calculated using marriage status as a proxy. Married people are considered to have a caretaker, whereas single, divorced or widowed individuals are considered not to have one.
Given the values present in *Censos 2011* [100], the probability of a patient being married is calculated and used as the probability of a patient having a caretaker, while the probability of a patient not being married gives the probability of a patient not having a caretaker.

This data is disaggregated by age, gender and municipality. It was assumed that it remains constant over time.

### 5.1.5 Dependency

No information was found on performance status among cancer patients, so data concerning dependency levels for the total population was used [99]. People with dependency were divided into two groups (group 1—limited, though not severely; group 2—severely limited). The probability of a patient belonging to each group was calculated, and it was assumed that a patient belonging to group 1 would have a PPS of 60 (being then considered a low dependency patient in the model) and that a patient belonging to group 2 would have a PPS of 50/40 (thus a high dependency patient in the model).

This data was available for only three large age groups: 45-64, 65-74 and over 75, and disaggregated by gender. The values used were national values, as no regional division was found. It was assumed that distribution between these two groups for patients younger than 45 years old was similar to the 45-64 age group. These values were assumed to remain constant over time.

### 5.1.6 Income Level

Patients were divided into two socioeconomic groups: those who live above the poverty line make up one group, and those who live below the poverty line make up another. Public data was available indicating the probability of an individual being at risk of poverty or social exclusion, and this value was used as the probability that said individual lives below the poverty line. The probability of an individual living above the poverty line was calculated in the same way.

This data was available for each gender, for three age groups: 0-17, 18-64, over 65. No regional disaggregation was found. It was assumed that these values remain constant over time.

### 5.1.7 Costs

Limited data regarding costs was found. A study [10], conducted in Portugal, found values for the cost of caring for patients requiring PC in the last month of life. Patients receiving care strictly in an acute hospital setting, without receiving care from a PC team presented the highest costs for the NHS, a value of 6469.5265 € per month. These values were assumed to remain constant throughout all phases of the disease.

The same study found the cost of providing care in a community setting to be 3155.26 € per month, per patient. Again, it was assumed these values remain constant for non-terminal phases of a patient’s disease.

The same study found that patients followed strictly on the hospital received an outpatient consultation 0.86 times in their last month of life, with each trip costing the NHS 205.42 €. The
product between those two, 176.66 € was assumed to be the cost of providing AC to a patient per month.

Values for the costs of providing inpatient care were not found for Portugal. A Spanish study [102] found the daily cost of having a PC bed to be 132.5 € per day. On average, this value is of 4030 € per month.

A summary of the values used can be found in Table 5.7.

Table 5.7: Monthly costs of terminal care (in Euros)

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute</td>
<td>6,469.5265</td>
</tr>
<tr>
<td>AC</td>
<td>176.66</td>
</tr>
<tr>
<td>HC</td>
<td>3,155.26</td>
</tr>
<tr>
<td>IC</td>
<td>4,030</td>
</tr>
</tbody>
</table>

5.1.8 Available beds

There is a pronounced lack of information regarding the total number of beds available for PC in Portugal, and the information available often presents conflicting values. An article from February 2016, claims the total number of beds available in Portugal to be 252 [106]. Another article, written just two weeks later, mentions that value as 359 [107]. According to the Portuguese Association of Palliative Care, however, there are currently five PC units operating under the tutelage of the NHS in the Lisbon county [103], and another two units operating under a public/private partnership. The number of beds available in these units could not be found. However, according to the literature each unit should have between ten and fifteen beds available [38]. Assuming all seven PC units in the Lisbon county operate at the higher limit, with fifteen beds available, that makes up a total of 105 beds.

5.2 Model Validation

In order to ensure that the model developed can be used to efficiently predict future PC needs, a validation process is required. However, due to the dearth of information available regarding current PC needs, and the lack of detailed studies projecting future values, a direct comparison between the values obtained and the real or projected values cannot be made.

Another approach is taken, comparing instead the population predicted by the model for the Lisbon NUTS II region against the National Statistics Institute (Instituto Nacional de Estatística (INE)) projection of those values [108]. While ideally the model would be run retrospectively from 2001 to 2011 and compared against the real observed values in 2011, the detailed data necessary for the model could not be found, so this approach had to be taken.

The percent deviation between the predicted values can be seen in Table 5.8 separated by gender and age group. The age groups are separated according to a 5-year time span, so as to coincide with the time span of the incidence values.
Table 5.8: Percent deviation between prediction values for the total population of the NUTS II region of Lisbon in 2021

<table>
<thead>
<tr>
<th>Age group</th>
<th>Deviation Men (%)</th>
<th>Deviation Women (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-19</td>
<td>1.36</td>
<td>1.30</td>
</tr>
<tr>
<td>20-24</td>
<td>6.19</td>
<td>2.25</td>
</tr>
<tr>
<td>25-29</td>
<td>13.56</td>
<td>4.88</td>
</tr>
<tr>
<td>30-34</td>
<td>11.25</td>
<td>3.74</td>
</tr>
<tr>
<td>35-39</td>
<td>10.95</td>
<td>4.01</td>
</tr>
<tr>
<td>40-44</td>
<td>10.49</td>
<td>3.58</td>
</tr>
<tr>
<td>45-49</td>
<td>4.09</td>
<td>0.68</td>
</tr>
<tr>
<td>50-54</td>
<td>1.35</td>
<td>0.21</td>
</tr>
<tr>
<td>55-59</td>
<td>0.13</td>
<td>0.21</td>
</tr>
<tr>
<td>60-64</td>
<td>1.34</td>
<td>1.18</td>
</tr>
<tr>
<td>65-69</td>
<td>1.15</td>
<td>1.23</td>
</tr>
<tr>
<td>70-74</td>
<td>3.93</td>
<td>4.38</td>
</tr>
<tr>
<td>75-79</td>
<td>6.08</td>
<td>7.65</td>
</tr>
<tr>
<td>80-84</td>
<td>4.82</td>
<td>4.32</td>
</tr>
<tr>
<td>85+</td>
<td>17.72</td>
<td>19.60</td>
</tr>
</tbody>
</table>

It is clear that for men there are a few important deviations to consider. These happen mostly in the 25 to 44 age group, and can be due to several factors. First, the mortality rates used were from 2012 to 2014 and were assumed to remain constant over time, when in reality there might be changes. Additionally, net migration was also not considered, which might affect the results as this is the age group more likely to migrate. Furthermore, it is also the age group with the lowest cancer incidence and with the highest error in the calculation of future incidence. For women, when these calculations have a lower error, the deviation observed presents much lower values. Additionally, for older age groups, with higher incidence, the results obtained with the model fall in line with those projected by the INE.

The high deviation obtained for individuals 85 years or older, both for males and females, might also be explained by the mortality rates used, as they were assumed to remain static over time and to be equal throughout all of Portugal. Moreover, due to lack of data cancer mortality was assumed to be equal for all ages, even though these affect different age groups differently.

Given these results, it can be said that the model is able to accurately predict the number of individuals in need of PC.

5.3 Results

In this section, the results obtained when applying the model to each municipality in the Lisbon county in the 2016-2021 period for adult individuals are presented.

5.3.1 PC needs in the Lisbon county

In Figure 5.2, the evolution of the total monthly number of patients requiring PC over time is shown for entire Lisbon county from January 2016 to January 2021. It is possible to see that the total need is rising, as well as the need for each individual service, with the highest demand being of AC services, with the number of patients requiring IC being similar to those requiring HC.
5.3.2 PC needs per municipality in the Lisbon county

In Figure 5.3 the distribution of needs across municipalities is presented. Since it was observed that this distribution remains virtually constant over time, only results for 2021 were presented. The highest need for PC can be found in Lisbon, which represents 25.3% of all total need for PC services. Lisbon is followed by Sintra (15.5% of total needs), Loures (9.4%), Cascais (9.2%), Amadora (8.1%), Oeiras (7.9%) and Mafra (6.4%). These values are as expected, as they are in accordance with total population numbers for each of these municipalities, with the municipalities with a bigger population, showing a higher need for PC services.
When observing how the percentage of need for each service evolves over time, it can be seen that these values also remain constant, which is expected, as it was assumed that the parameters used to assign cancer patients to each type of service remains constant over time. These values are presented in Figure 5.4 for January 2021. While these values tend to be similar between municipalities, the Lisbon municipality presents a higher percentage of need for IC services than other municipalities, which can be explained by the higher percentage of non-married individuals in Lisbon, when compared to other municipalities.
5.3.3 PC needs per service and gender in the Lisbon municipality

Since there weren’t significant differences between municipalities in terms of the distribution of patients between services, only one municipality was chosen to take a closer look at the results. In this case, the Lisbon municipality was chosen, as it has the highest population numbers.

We begin by taking a closer look at how the results obtained differ between males and females. In Table 5.9, the total number of individuals requiring each type of service in the first month of every year from 2016 to 2021 can be observed.

Table 5.9: Monthly number of patients needing each palliative care service in the Lisbon municipality in the 2016-2021 period per gender

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC</td>
<td>HC</td>
<td>IC</td>
<td>Total</td>
</tr>
<tr>
<td>2016</td>
<td>96</td>
<td>47</td>
<td>35</td>
<td>177</td>
</tr>
<tr>
<td>2017</td>
<td>97</td>
<td>47</td>
<td>35</td>
<td>179</td>
</tr>
<tr>
<td>2018</td>
<td>98</td>
<td>48</td>
<td>35</td>
<td>181</td>
</tr>
<tr>
<td>2019</td>
<td>99</td>
<td>48</td>
<td>36</td>
<td>184</td>
</tr>
<tr>
<td>2020</td>
<td>101</td>
<td>49</td>
<td>37</td>
<td>187</td>
</tr>
<tr>
<td>2021</td>
<td>103</td>
<td>50</td>
<td>37</td>
<td>190</td>
</tr>
</tbody>
</table>

In Figure 5.5, the distribution of these individuals’ needs by setting is presented. Since there were no significant differences from the distribution in 2016 to the distribution in 2021, only results for 2021 are presented. This again can be explained by the parameters used to separate patients between settings of care being considered to remain constant over time.

![Figure 5.5: Distribution of palliative care needs per setting and per gender, in the Lisbon municipality in 2021](image)

As can be observed, there is a stark difference between men and women when it comes to HC with men requiring this type of service more than women. This can be explained by the fact that older men are more likely to be married than older women, which translates into a higher percentage of men having a caretaker. This influences the results obtained since it is a model assumption that...
individuals without a caretaker can’t receive care in their homes.

The opposite happens when it comes to AC with a higher percentage of women requiring this service when compared to men. This might be explained by the lower cancer mortality in women, with a smaller percentage of women in the late stages of the disease at a given point in time. Furthermore, for some younger age groups, characterized by lower dependency, cancer incidence is higher in women than in men, when for older age groups, with higher dependency, cancer incidence is higher for men. Therefore, there is a higher percentage of female cancer patients with low dependency than of male cancer patients with low dependency, which directly influences the number of patients needing AC.

In Figure 5.6 it can be seen that 43% of the individuals requiring PC are women, with the remaining 57% being men.

![Figure 5.6: Distribution of PC needs per gender in the Lisbon municipality in 2021](image)

The distribution of services required per gender is summarized in Figure 5.7. As shown, there is a much higher percentage of men requiring HC which falls in line with the expected results, due to the higher percentage of men with a caretaker.
5.3.4 PC needs per cancer state in the Lisbon municipality

When it comes to the distribution of patients per state, the results for men are shown in Figure 5.8a, and the results for women in Figure 5.8b. There is a slightly higher percentage of women in the stable state, which might be explained by the fact that cancer mortality is lower in women than in men, and so each month there are fewer women in terminal states of the disease.

The percentage of cancer patients of each gender can be seen in Figure 5.9. Despite the higher incidence in men, these results are very close to each other. This might be explained by higher mortality values for men, thus living less time with the disease, and by the higher incidence of cancer in women during their fertile years, in which mortality by non-cancer causes is lower than in older men, with women thus spending considerably more time as cancer patients.
Figure 5.9: Percentage of cancer patients of each gender in the Lisbon municipality in 2021

This is confirmed by the percentage of women in each state, which can be observed in Figure 5.10. While there is a much higher percentage of men in the EoL and transitional states, these values are split in the middle for the stable state, which corresponds to a longer expected length of life.

Figure 5.10: Percentage of patients of each gender in each cancer state in the Lisbon municipality in 2021
5.3.5 PC needs per age group in the Lisbon municipality

Next, a closer look is taken at the way the need for these services differ according to age group. For this purpose, the patients are split into two different groups: one for patients between 18 and 64 years old and patients who are 65 years old or older.

In Figure 5.11 the percentage of male patients requiring each type of service is presented. As shown, the lower age group has a higher percentage of patients receiving AC, which can be explained by the lower dependency in this age bracket. Conversely, the percentage of patients receiving HC is significantly higher for older age bracket, which is consistent with the expected results, as the probability of an individual having a caretaker is higher for the 65+ age bracket.

![Figure 5.11: Percentage of male patients requiring each type of service per age group in the Lisbon municipality in 2021](image)

In Figure 5.12 we present the percentage of female patients requiring each type of service. As with the male patients, the number of female patients requiring AC decreases with age, which is tied with an increase in the dependency level. Unlike with men, the probability of a woman having a caretaker is lower for the 65+ age group, which signifies an increase in the need for IC services.
Figure 5.12: Percentage of female patients requiring each type of service per age group the Lisbon municipality in 2021

The percentage of patients requiring PC in each age group can be seen in Figure 5.13a) for men, and Figure 5.13b) for women. As expected, for men there is a much higher percentage requiring PC who are 65 years old or older, as cancer incidence tends to increase steadily for men in line with an increase in age.

Figure 5.13: a) Percentage of male patients requiring palliative care per age group the Lisbon municipality in 2021. b) Percentage of female patients requiring palliative care per age group the Lisbon municipality in 2021

For women, while the percentage requiring PC is still higher in the older age group, the difference between the two age brackets isn’t as stark as it is for men. This is explained by the high incidence of cancer in women during their fertile years, at an age with a lower mortality, in which women are thus
expected to live longer with the disease.

The percentage of male patients requiring each type of service is shown in Figure 5.14. There is a higher need for all types of care in the older age bracket. This is more pronounced in the total need for HC services, potentially due to the increase in dependency level and in the probability of a patient having a caretaker.

![Figure 5.14: Percentage of male patients requiring each type of palliative care service per age group the Lisbon municipality in 2021](image)

For women, these values are presented in Figure 5.15. Like for men, the need for each type of service is higher in the older age bracket. However, unlike with men, the difference between age groups is more marked for IC services, due to the decrease in the number of women with a caretaker, who therefore need to receive care in an IC setting.
Figure 5.15: Percentage of female patients requiring each type of palliative care service per age group in the Lisbon municipality in 2021

5.3.6 PC provision costs

In Table 5.10, the costs associated with providing palliative care to all individuals that require it in the 2016-2021 period per year and per service for the Lisbon county are presented. The total costs of providing these services outside the PC network, in an acute-hospital setting, are also presented, as well as the potential savings from providing the services in a specialized PC service.

Table 5.10: Monthly costs of providing palliative care to all individuals that require it in the 2016-2021 period per year and per service for the Lisbon county (euros)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>116,971.42</td>
<td>119,961.24</td>
<td>122,288.32</td>
<td>125,252.53</td>
<td>128,405.55</td>
<td>131,587.96</td>
</tr>
<tr>
<td>HC</td>
<td>794,049.52</td>
<td>816,132.60</td>
<td>832,872.46</td>
<td>853,488.06</td>
<td>876,245.18</td>
<td>898,954.92</td>
</tr>
<tr>
<td>IC</td>
<td>988,876.80</td>
<td>1,015,329.03</td>
<td>1,035,324.39</td>
<td>1,061,456.47</td>
<td>1,089,259.22</td>
<td>1,117,428.67</td>
</tr>
<tr>
<td>Total</td>
<td>1,899,897.73</td>
<td>1,951,422.87</td>
<td>1,990,485.18</td>
<td>2,040,557.06</td>
<td>2,093,909.95</td>
<td>2,147,971.55</td>
</tr>
<tr>
<td>Acute</td>
<td>7,499,253.91</td>
<td>7,696,489.35</td>
<td>7,848,132.97</td>
<td>8,041,645.60</td>
<td>8,247,669.42</td>
<td>8,455,998.89</td>
</tr>
<tr>
<td>Savings</td>
<td>5,599,356.17</td>
<td>5,745,066.49</td>
<td>5,857,647.79</td>
<td>6,001,088.54</td>
<td>6,153,759.46</td>
<td>6,308,027.34</td>
</tr>
</tbody>
</table>

As expected, the costs associated with these services rise over time. They are found in Table 5.11 per service and in total, for the Lisbon municipality. The costs of caring for these patients in an acute hospital are also presented.
Table 5.11: Monthly costs of providing palliative care per service per gender in the Lisbon municipality in the 2016-2021 period (in Euros)

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC</td>
<td>HC</td>
</tr>
<tr>
<td>2016</td>
<td>16,883.88</td>
<td>147,096.50</td>
</tr>
<tr>
<td>2017</td>
<td>17,121.97</td>
<td>149,245.11</td>
</tr>
<tr>
<td>2018</td>
<td>17,292.17</td>
<td>150,507.04</td>
</tr>
<tr>
<td>2019</td>
<td>17,556.14</td>
<td>152,659.77</td>
</tr>
<tr>
<td>2020</td>
<td>17,853.38</td>
<td>155,059.82</td>
</tr>
<tr>
<td>2021</td>
<td>18,159.73</td>
<td>157,605.83</td>
</tr>
</tbody>
</table>

The distribution of these costs through municipalities can be seen in Figure 5.16. As expected, these values are quite similar to the distribution of needs represented in Figure 5.3, with small differences which might be explained by the different number of people with a caretaker.

Figure 5.16: Distribution of palliative care costs across municipalities in the Lisbon county in 2021

The distribution of costs per gender can be seen in Figure 5.17. In men, most of the costs are related to the provision of HC, while in women most of these costs come from IC services.
When it comes to the distribution of costs, presented in Figure 5.18, women are responsible for 41% of expenditure, with men being responsible for 59%. These values, which vary from the distribution of individuals requiring each type of care, might be explained by a higher percentage of women requiring AC than men, a service much cheaper to provide than IC or HC.

In Figure 5.19, the percentage of costs incurred in each type of service for male patients can be seen. As expected, for the younger age bracket, over 50% of the total costs are incurred when providing IC to the patient, due to the lower percentage of patients with a caretaker, whereas for the older age bracket, the higher percentage of costs is incurred with the provision of care in a home setting.
In Figure 5.20, the same values are presented for female patients, showing that the majority of costs always comes from the provision of IC though this percentage increases even further in the older age groups.

When it comes to the total distribution of costs per age group, these values can be seen in Figure 5.21a) for male patients and Figure 5.21b) for female patients. As expected, only a low percentage of costs is incurred with male patients younger than 65. For female patients, while the majority of costs is still incurred when caring for older patients, this value is slightly lower than the value for men, which
might be explained by cancer incidence in women during their fertile years being higher than cancer incidence for men during the same years.

![Figure 5.21: a) Percentage of costs across all service settings for male patient per age group in the Lisbon municipality in 2021. b) Percentage of costs across all service settings for male patient per age group in the Lisbon municipality in 2021]

5.3.7 Gap in PC provision

By January of 2021, there will be 277 patients requiring IC palliative care in the Lisbon county (as shown in Figure 5.2. With 105 IC beds currently available, the gap between the required number of beds and the available number of beds is then of 172 beds. In Table 5.12, the costs of providing that care in a PC unit is presented, along with the cost of providing it in an acute-care hospital, and the potential savings are presented.

<table>
<thead>
<tr>
<th>IC</th>
<th>Acute care</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>693,160</td>
<td>1,112,759</td>
<td>419,599</td>
</tr>
</tbody>
</table>

As expected, considerable savings are predicted to happen if PC is provided in a specialized unit, with potential savings of around 420 thousand euros per month.
6. Discussion

In this chapter, the contributions and possible limitations of the methodology developed are presented, and the results obtained when applying the methodology for the Lisbon county in the 2016 to 2021 period are discussed.

6.1 Contributions and limitations of the study

In this section the contributions and limitations of the study are presented.

6.1.1 Contributions of the study

With this study, a gap in the literature has been filled. As mentioned in Chapter 3, no simulation methodologies to estimate current demand for PC could be found. With this study, a Markov Cycle Tree methodology was implemented, estimating current needs based on publicly available data, which can easily be applied to other regions or expanded to include other pathologies.

The results obtained yielded a higher degree of disaggregation than any found in the literature, and allowed the assignment of patients to each setting of care, according to phase of the disease, level of dependency, income level and presence or absence of an informal caretaker, while determining the costs associated with those assignments.

Furthermore, future need for PC was also determined, using the same demographic variables, which to the best of our knowledge had not been done before, thus allowing health care providers to develop a PC network taking into consideration not only the current values of need, but also future numbers of patients with cancer. Additionally, with the cost analysis performed, it was possible to determine potential savings from a PC network capable of providing care to all those that require it, and the expected costs of providing care in an acute hospital.

Overall, this study is a valuable contribution in the area of PC, especially in the planning of current and future expansions or implementation of a PC network, allowing the health care provider to determine the effect demographic factors have on need for PC, as this work gives a much more detailed view of the current and future level of need, by providing estimates disaggregated by factors such as age, gender, type of care and income level, for a smaller time period. With this information, the effect of changes in the number of patients requiring each type of care over time can be studied, as well as the influence of factors like income level or presence of a caretaker. The connection between age and gender and their influence on care setting can be explored, improving and optimizing the PC network in place.
6.1.2 Limitations of the model

Some limitations are presented in this study, both in the methodology and in the approximations done to the data.

Regarding the model, the effect of migration on the number of people in each age group was not accounted for. While the results might have been different if this had been included, it must be noted that most immigrants are typically young, from age groups with low cancer incidence, so the influence of migration on total results would be minimal.

In a broader sense, only monthly needs for PC were calculated. Average length of stay was not determined and information regarding how long each patient requires each service is not studied, so the annual number of patients requiring PC cannot be determined through this methodology.

Additionally, it is assumed that after five years in the stable state cancer patients reenter a non-cancer state, which might not accurately represent the disease evolution of many cancer patients. This might underestimate the number of remissions, and subsequently overestimate the number of cancer patients, which in turn overestimates the number of PC services required. Additionally, the differences between incidence rates for individuals who'd already been cancer patients in the past and entered a remission state and incidence rates for individuals who'd never had cancer were also not considered, which might underestimate the number of cancer patients each year (and, consequently, the number of cancer patients requiring PC).

When it comes to cancer patients, these were not disaggregated by type of cancer but rather treated as a whole and average survival rates were applied, which might affect results as different cancers have different mortality rates. While this disaggregation could’ve been done, the future incidence rates determined presented a high error, and the results thus obtained would have been severely limited.

It must also be noted that the current methodology is only developed to account for cancer patients, and conclusions for the total need for PC regardless of pathology, cannot be drawn. Therefore, the results obtained and analysed here do not account for the total need for PC but only for a part of it.

6.1.3 Limitations associated with the model application

Some limitations directly relate to the approximations that had to be done to the data to apply the model.

When forecasting future incidence of cancer, some age groups returned a high error. This happened mainly in the lower age groups, characterized by a lower cancer incidence, so the effect on results is minimal.

Initially, cancer prevalence had to be estimated. For that, cancer patients diagnosed in the past five years were studied. This is not ideal, as patients may show signs of cancer for a longer period, or they might experience remission after a period shorter than five years.

The probabilities of transition between cancer states were assumed to be the same for all age groups, even though cancer affects age groups differently, as the incidence of faster killing cancers typically rises with age. This might underestimate the number of older patients in the later stages of
the disease and overestimate the number of younger patients in those stages, as well as affect the
number of deaths attributable to cancer.

The values used to estimate dependency in cancer patients are also not ideal, as they were
determined by observation of the proportion of total population living with dependency. With cancer
being a debilitating disease in the last months of life, these values might differ from the ones observed
in the general population.

To study if a caretaker was present, marital status was used as a proxy, and it was assumed
that married patients had a caretaker and unmarried patients did not. This is not necessarily the
case. A married patient can have a spouse who works for long periods of time or who also suffers
from conditions that make taking care of someone else too onerous. Additionally, younger unmarried
patients may have a parent who can provide informal care, and older patients can have children that
are available for this type of care.

Regarding the costs of care numbers from an inpatient unit in Spain were used to estimate the cost
of providing this type of care in Portugal, even though this value might vary from country to country,
and might have risen over time. It was also assumed that the values from all types of care remain
constant over time, even though they might change and become more expensive as the patient’s
illness progresses and the number of symptoms increases.

To calculate the gap in provision, the total number of beds in Lisbon was determined and it
was assumed all of them would be available for cancer patients, which is not necessarily true as
patients with pathologies other than cancer can also receive care. However, as for the time being the
overwhelming majority of patients receiving care within the network are cancer patients, this is an
acceptable approximation.

It must be noted that these limitations are not inherently a limitation of the model itself, but rather a
limitation due to the scarcity of data available and the rough approximations that needed to be made in
order to properly apply the model. Since the model was developed in generic terms, more thorough,
detailed data would yield more robust, accurate results.

6.2 Discussion of results

While there has been extensive work done to project and forecast future health care needs and
associated costs, these studies have not been applied to care. This may be due to several factors, as
care is still in an initial phase of development in most countries, and accurate and detailed information
of current usage and needs is difficult to find. In fact, most countries, such as Portugal, do not have
enough care teams available to provide care to all those that require it and patients have to receive care
through other means. This makes the exact number of current people requiring care in Portugal difficult
to determine, and severely complicates projections or forecasts of future needs. For that purpose, this
thesis was developed. As expected, the lack of data in the area proved to be critical, and several gross
approximations had to be made, which might effect the quality of the results obtained.

Due to the lack of studies in the area giving a detailed estimation of current, or even a rough
estimate of future need, there is no benchmark numbers against which to compare the results
obtained here. Additionally, this thesis studies the number of patients requiring PC each month, not allowing the calculation of the annual number of patients as length of stay in each service is not determined, while all the studies found focused on annual values. It must also be noted that most international studies focused on all pathologies requiring PC not disaggregating by disease, while this work focused solely on cancer patients.

Quantitative comparisons between the results obtained and expected results are thus difficult to make. However, qualitatively, the results obtained fall in line with the expected results.

As expected, it was possible to determine that overall the current offer for PC services in our country is far from meeting all the demand for this type of care, which make the expansion of the current network a necessity, not only for the important role it plays in improving patients’ QoL but also by the associated savings to the NHS.

It was also determined that the number of patients requiring each type of service rises each year, a result expected due the rising values of cancer incidence, though it might be overestimated given the assumptions made regarding the possibility of remission, making the expansion of current services being offered even more necessary.

When it comes to each type of care, it was determined that the need is highest for ambulatory care, which is explained by the lower number of patients in terminal phases of the disease. In this regard PC appears to be relatively well provided in the Lisbon region, as there are hospital teams currently present in 9 hospitals of the Greater Lisbon region [25].

The number of patients requiring IC is very similar to the number of patients requiring HC which suggests patients are evenly split in the later phases of the disease regarding the presence of a caretaker and their income level. The international standards for the number of HC teams are given per total population and no information on the recommended number of patients to receive care from each team could be found, so no commentary can be made on the provision of HC. However, when it comes to the provision of IC, the literature recommends each unit to have, at most, 15 beds available [38]. With only seven PC units operating in the Lisbon county for now [103], this number is very far from meeting the projected demand.

The distribution of patients requiring PC across municipalities is as expected, with more populous municipalities having a higher number of patients needing PC. These values remain constant over the years, as there are no major population changes considered in the model and a direct link exists between number of inhabitants and number of cancer patients.

When a closer look is taken at the data, it is seen that the type of care required is heavily affected by the presence of a caretaker. For example, inhabitants of the Lisbon municipality—which presents the higher percentage of unmarried individuals of all municipalities in the county—present the highest level of need for IC. The same can be seen for women, who have a higher probability of being unmarried at an older age, and thus require IC more than men.

Age plays an important role as well, with the percentage of patients who require PC rising with age. Again, this is as expected, as the incidence of cancer rises with age. Once again, the distribution of type of care required varies directly with the presence or absence of an informal caretaker.
When it comes to the costs determined, they rise in line with the number of patients requiring PC increasing steadily over the years and being directly influenced by the number of patients and their distribution across types of care. However, when the costs of providing PC inside a specialized network are compared to the costs of providing it in an acute hospital, the potential savings are evident.

This is especially relevant given the current economic context of Portugal, with several budget cuts being experienced by the country. It suggests that although a considerable investment might be required to expand the PC network, it is an important one in a long-term horizon, permitting considerable savings for the NHS.

Overall, it was seen that the number of patients requiring PC rises each year, as does the level of need for each type of care. Most studies and experts in the area suggest the expansion of the HC network first. However, these results, presenting a similar level of need for HC and IC suggest that focus should also be placed on IC so as to provide patients with all the care they require in their last months of life.
7. Conclusions and Future Work

In this chapter, the main conclusions to be drawn from the work developed are presented, as well as suggestions for further work.

7.1 Conclusions

With the ageing of the population and the rising incidence of diseases such as cancer, the importance of a well-developed PC network only grows. This network, still in an initial stage in our country, has been the target of several expansions over the years, with more teams and services being added. However, an efficient, balanced expansion requires detailed information of current and future needs, which was not available at the time of writing. For that purpose, this study was developed, with the aim of estimating the current PC needs of cancer patients and projecting these values for the future, taking patients’ characteristics into consideration, and determining the need for each type of service, as well as the associated costs.

This presents an innovation in the area, as all the current methods to estimate needs did not provide detailed information on patients, did not consider their progression through the different phases of the disease and did not establish a relation between the patients and the type of services required. Furthermore, these values were also projected for the future, which had not been done before. This was done with a Markov model, which despite being commonly used to predict health care needs in general, had not yet been applied to PC. This way, it was possible to determine the monthly number of patients requiring PC and associated costs, disaggregated by age, gender and municipality, and taking into consideration factors such as phase of the disease and income level.

The application of the methodology developed was severely hindered by the critical lack of data available, and several gross approximations had to be made in order to properly implement the model designed, and to apply it to the small area level, in the Lisbon county, which might negatively effect the quality of the results obtained.

Nevertheless, the results fall in line with what was expected, showing that the current offer of PC services is not enough to provide care to all those patients that require it. Over the years, the model found an increasing need for PC with associated rising costs, more pressing in older age groups, and subject to worsen even more over the years, as the population ages. The need for PC becomes even more evident in the potential savings from providing these services in a PC network. It also becomes clear, however, that the current offer of services is not enough to meet all the demand for it, and an expansion of the PC network is essential, both to improve the quality of life of patients suffering from life-threatening disease, and to lessen the economic burden placed upon health care providers.

Overall, the proposed goal of this thesis was achieved, with a methodology to predict current and future detailed need of cancer patients for PC having been developed, and successfully applied to the
Lisbon county and its municipalities, determining both the current and future level of need for PC of cancer patients and the associated costs.

7.2 Future work

There are several ways in which additional work can be done and the methodology developed here can be expanded on in the future. First and foremost, additional data (especially data directly relevant to the Portuguese reality) would allow the determination of more accurate predictions, significantly improving the quality of the results obtained. This is especially relevant in the case of cancer prevalence and remission, which considerably affect the results obtained.

Regarding the methodology itself, it can be expanded to further disaggregate patients across different types of cancer. This allows more exact results, as cancer mortality varies from cancer to cancer.

On the same note, it can also be expanded to include different pathologies, accounting for all the patients that require PC regardless of whether or not they're cancer patients. This would give health care providers an idea of the total number of individuals requiring PC not just cancer patients. However, with cancer patients being the main group of patients requiring PC cancer patients having very specific needs and disease progressions, the rising incidence of cancer cases and of cancer deaths and the level of PC provision to cancer patients being a criterion used to determine the effectiveness of a PC network, the focus on cancer patients is an appropriate first step in the estimation of current and future demand for PC.

It would also be relevant to apply this method to other regions in Portugal, and then to other countries, showing how the needs for PC differ across regions with different cancer patterns and socio-economic characteristics.

Furthermore, it would be interesting to apply it for a longer time period, and see how the need for each type of service evolves, though this would require additional data, so that parameters such as mortality could be allowed to change over time, and the trends of lower mortality experienced in the last century could be accounted for. This would allow health care planners to have a more extensive look at the possible future, and plan the PC network accordingly.

Another possible expansion is the inclusion of scenario analysis. This way, different policies regarding the implementation and expansion of the PC network could be tested and the efficiency of its implementation could be studied. This would enable health care providers to test the effect of other measures, destined for example at reducing cancer incidence, and study the effect they would have on the need for PC. Furthermore, even factors such as economic levels and the presence or absence of a caretaker could be studied more in-depth, with a closer look being taken at the direct effect they have on need for PC.

More work could be done to expand these predictions to annual values, either through changing the time step used or determining the length of stay of patients in each stage. This would allow health care planners to know how many new patients there are each month, and how many are already integrated in the network.


[100] INE, “População residente (N.º) por Local de residência (à data dos Censos 2011), Sexo, Grupo etário, Estado civil e Relação de conjugalidade; Decenal.” [Online]. Available: https://www.ine.pt/xportal/xmain?xpid=INE[&]xpgid=ine[&]indicadores[&]indOcorrCod=0006364[&]contexto=bd[&]selTab=tab2


A. Appendix A

Assuming a total population to be $P$, the annual rate to be $M$ and the monthly rate to be $m$, the formula for the calculation of the monthly rate can be obtained with the following deduction:

$$P \times (1 - M) = P \times (1 - m)^{12} \Leftrightarrow$$
$$\Leftrightarrow (1 - M) = (1 - m)^{12} \Leftrightarrow$$
$$\Leftrightarrow (1 - M)^{\frac{1}{12}} = 1 - m \Leftrightarrow$$
$$\Leftrightarrow m = 1 - (1 - M)^{\frac{1}{12}}$$

This is used to calculate both the cancer mortality rates when the annual mortality rates are given, and monthly cancer incidence, when only annual cancer incidence is given.
### Appendix B

**Table B.1:** Number of male cancer patients in January 2016 in the Lisbon municipality by age and state

<table>
<thead>
<tr>
<th>Age</th>
<th>S0</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>T</th>
<th>EOL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>0.640</td>
<td>0.502</td>
<td>0.393</td>
<td>0.315</td>
<td>0.279</td>
<td>0.060</td>
<td>0.006</td>
<td>2.195</td>
</tr>
<tr>
<td>14</td>
<td>0.643</td>
<td>0.512</td>
<td>0.410</td>
<td>0.340</td>
<td>0.307</td>
<td>0.063</td>
<td>0.006</td>
<td>2.282</td>
</tr>
<tr>
<td>15</td>
<td>0.691</td>
<td>0.568</td>
<td>0.465</td>
<td>0.396</td>
<td>0.364</td>
<td>0.071</td>
<td>0.007</td>
<td>2.562</td>
</tr>
<tr>
<td>16</td>
<td>0.611</td>
<td>0.525</td>
<td>0.446</td>
<td>0.385</td>
<td>0.356</td>
<td>0.067</td>
<td>0.007</td>
<td>2.397</td>
</tr>
<tr>
<td>17</td>
<td>0.592</td>
<td>0.499</td>
<td>0.426</td>
<td>0.375</td>
<td>0.350</td>
<td>0.064</td>
<td>0.006</td>
<td>2.312</td>
</tr>
<tr>
<td>18</td>
<td>0.559</td>
<td>0.466</td>
<td>0.395</td>
<td>0.347</td>
<td>0.325</td>
<td>0.060</td>
<td>0.006</td>
<td>2.158</td>
</tr>
<tr>
<td>19</td>
<td>0.552</td>
<td>0.458</td>
<td>0.386</td>
<td>0.337</td>
<td>0.315</td>
<td>0.059</td>
<td>0.006</td>
<td>2.112</td>
</tr>
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<td>20</td>
<td>0.588</td>
<td>0.458</td>
<td>0.385</td>
<td>0.335</td>
<td>0.313</td>
<td>0.059</td>
<td>0.006</td>
<td>2.143</td>
</tr>
<tr>
<td>21</td>
<td>0.813</td>
<td>0.565</td>
<td>0.415</td>
<td>0.340</td>
<td>0.312</td>
<td>0.068</td>
<td>0.007</td>
<td>2.520</td>
</tr>
<tr>
<td>22</td>
<td>0.951</td>
<td>0.719</td>
<td>0.530</td>
<td>0.408</td>
<td>0.355</td>
<td>0.083</td>
<td>0.008</td>
<td>3.056</td>
</tr>
<tr>
<td>23</td>
<td>1.047</td>
<td>0.831</td>
<td>0.643</td>
<td>0.504</td>
<td>0.438</td>
<td>0.098</td>
<td>0.010</td>
<td>3.569</td>
</tr>
<tr>
<td>24</td>
<td>1.179</td>
<td>0.992</td>
<td>0.727</td>
<td>0.601</td>
<td>0.641</td>
<td>0.122</td>
<td>0.012</td>
<td>4.403</td>
</tr>
<tr>
<td>25</td>
<td>1.219</td>
<td>0.962</td>
<td>0.777</td>
<td>0.664</td>
<td>0.615</td>
<td>0.121</td>
<td>0.012</td>
<td>4.370</td>
</tr>
<tr>
<td>26</td>
<td>1.695</td>
<td>1.329</td>
<td>1.120</td>
<td>0.979</td>
<td>0.914</td>
<td>0.171</td>
<td>0.017</td>
<td>6.223</td>
</tr>
<tr>
<td>27</td>
<td>2.454</td>
<td>1.722</td>
<td>1.276</td>
<td>1.053</td>
<td>0.969</td>
<td>0.209</td>
<td>0.020</td>
<td>7.702</td>
</tr>
<tr>
<td>28</td>
<td>2.761</td>
<td>2.100</td>
<td>1.560</td>
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Table B.4: Number of female cancer patients in January 2016 in the Lisbon municipality by age and state (continued)

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