Combining hospital pathways modeling with value-based healthcare:

Building methods for care improvement at IPO-Lisboa

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Declaration

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

Preface

The work presented in this thesis was performed at Centro de Estudos de Gestão do Instituto Superior Técnico, University of Lisbon (Lisbon, Portugal) and at Instituto Português de Oncologia de Lisboa Francisco Gentil, during the period March-November 2020. The thesis was supervised at Instituto Superior Técnico by Professor Mónica Duarte Correia de Oliveira and co-supervised by Doctor Júlio Paulo Candeias Pedro. This work was also developed within the scope of the MEDI-VALUE project (Developing HTA tools to consensualise MEDIcal devices' VALUE through multicriteria decision analysis; http://medivalue.tecnico.ulisboa.pt/; PTDC/EGE-OGE/29699/2017).

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Abstract

Hospitals are faced with pressure to improve their patient's clinical pathways and to involve hospital stakeholders in such improvements. This thesis aimed to develop a novel approach to assist IPO-Lisboa health professionals in improving hospital pathways, combining a simulation model with value-based healthcare instruments.

For this purpose, a socio-technical approach was developed in which a discrete event simulation model is integrated with a multicriteria evaluation model built with the MACBETH method. Regarding the social component of the approach, different hospital stakeholders, namely physicians and administrative staff members, participated in the construction and validation of the models developed. The models helped simulating the pathways taken by breast cancer patients from their first consultation to the performance of surgeries, as well as analyzing how it is possible to generate added value improvements to the pathways.

Through the application of this approach, it was analyzed not only the current breast cancer pathway but also the impact of improvement actions on the pathway. Subsequently, and considering the view of different healthcare professionals, it was possible to reach a consensus on which improvement actions have the highest value for money. Moreover, discussions and reflections concerning possible ways to implement those actions were promoted.

Participants provided positive feedback regarding the approach, suggesting its potential use in future studies, for instance in combining clinical pathways from different pathologies.

Keywords: Clinical Pathways; Value-Based Healthcare; Breast Cancer; Discrete Event Simulation; MACBETH; Process Improvement.

Resumo

Os hospitais enfrentam pressão para melhorar os percursos clínicos dos seus pacientes e para envolver os intervenientes hospitalares em tais melhorias.

Esta tese teve como objetivo desenvolver uma abordagem inovadora para auxiliar os profissionais de saúde do IPO-Lisboa na melhoria dos percursos hospitalares, combinando um modelo de simulação com instrumentos *value-based healthcare*.

Para este propósito, foi desenvolvida uma abordagem sociotécnica na qual um modelo de simulação por eventos discretos foi integrado com um modelo de avaliação multicritério construído com o método MACBETH. Relativamente à componente social da abordagem, diferentes profissionais de saúde, nomeadamente médicos e membros da administração, participaram na construção e validação dos modelos desenvolvidos. Os modelos ajudaram a simular os percursos percorridos por pacientes com cancro da mama desde a sua primeira consulta até à realização das cirurgias, bem como a analisar como é possível gerar melhorias com valor adicional para estes percursos.

Através da aplicação desta abordagem, analisou-se não só a situação do atual percurso do cancro da mama como também o impacto de ações de melhoria neste circuito. Posteriormente, e considerando a visão de diferentes profissionais de saúde, foi possível chegar a um consenso acerca de quais as ações de melhoria com uma maior relação custo-benefício. Além disso, foram promovidas discussões e reflexões acerca de formas possíveis de implementar estas ações.

Os participantes providenciaram um retorno positivo em relação à abordagem, sugerindo o seu potencial uso em estudos futuros, como, por exemplo, na combinação de percursos clínicos de diferentes patologias.

Palavras-Chave: Percursos Clínicos; Value-Based Healthcare; Cancro da Mama; Simulação por Eventos Discretos; MACBETH; Melhoria de Processos.

Contents

List of Figures

List of Tables

Abbreviations

ABM	Agent-Based Modeling
ASCO	American Society of Clinical Oncology
BN	Bayesian Network
BPMN	Business Process Modeling Notation
CP	Clinical Pathway
CT	Computed Tomography
DCIS	Ductal Carcinoma in Situ
DES	Discrete Event Simulation
DM	Decision-Maker
DSS	Decision Support System
DT-STM	Discrete-Time State-Transition Modeling
EC	European Commission
EHR	Electronic Health Record
EMR	Electronic Medical Record
ER	Estrogen Receptor
EU	European Union
HER2	Human Epidermal Growth Factor Receptor 2
HIT	Health Information Technology
IPO-Lisboa	Instituto Português de Oncologia de Lisboa Francisco Gentil
IT	Information Technology
MACBETH	Measuring Attractiveness by a Categorical-Based Evaluation Technique
MBC	Multidisciplinary Breast Clinic
MCDA	Multicriteria Decision Analysis
MRI	Magnetic Resonance Imaging
NHS	National Health Service
PCP	Patient Centricity Project
PR	Progesterone Receptor
QoL	Quality of Life
SD	System Dynamics
SDC	Surgical Decision Consultation
t.BPM	Tangible Business Process Modeling
TA	Timed Automata
UAS	Unscheduled Attendance Service
UK	United Kingdom
USA	United States of America
VBHC	Value-Based Healthcare

1. Introduction

1.1. Motivation

Every year, millions of people are diagnosed with cancer. According to the International Agency for Research on Cancer, breast cancer is the most common type of tumor in women and the second most frequent worldwide [1]. In 2018, about 2.1 million new cases of breast cancer were recorded, and more than 626 thousand deaths occurred worldwide. In Portugal, in that same year, more than 6800 new cases of breast cancer and around 1700 deaths from this cause were identified [2]. Time is known to be a critical factor for breast cancer patients, as delays in detection, diagnosis, and treatment can lead to decreased survival and lower probability of curative treatment [3].

Thus, health professionals are under daily pressure to improve healthcare delivery, that is, to make improvements along the pathways that patients pass through. Also, it is important to note that oncological pathways are particularly complex, as they involve many processes, multidisciplinary teams, and require combinations of different health technologies [4]. Further to organizational and efficiency issues, pathways need to be aligned with the delivery of value-based healthcare (VBHC), taking into account the impact on patients and the views of hospital stakeholders. In this way, the delivery of care must involve coordination and collaboration across professionals, a shared accountability for optimizing health, continuous relationships with patients over time, and the delivered care should be centered on patients and tailored to their needs, preferences and concerns [5].

IPO-Lisboa is considered a national reference center in the delivery of healthcare in the oncological area [6]. Moreover, it is an institution that is concerned with constantly updating the clinical pathways of its patients to improve their experience in the hospital environment. In this way, it becomes necessary to use tools capable of modeling hospital pathways, analyzing them, and understanding how these processes can be improved.

Simulation techniques are widely used in several areas, such as industrial management and manufacturing, when it is intended to model and analyze a complex process [7]. Furthermore, the current proliferation of the utilization of simulation models in the field of medical research and healthcare service management is evident [8]. This growth has happened due to the capacity these models have in addressing complex problems, allowing to evaluate the efficiency of the practices used in the management of healthcare delivery, as well as carrying out analyzes that compare different situations, where it is possible to identify bottlenecks existing in hospital pathways, discover approaches capable of reducing waiting times, improving the usage of human resources and equipment involved [8][9].

However, to implement changes to clinical pathways, it is necessary to take into account the opinion of health professionals, as well as to use instruments to consensualise the value, which wrongly is not a very common practice [10]. These health professionals are those who choose the most attractive improvements to be implemented, that is, those that have the highest value. Thus, it is necessary to create tools to be used in decision-making processes, which need to be able not only to model the hospital processes that are intended to be improved but also to discover how added value is generated.

1.2. Objectives and Methodology

This thesis aims to develop methods for assisting the decision-makers (DMs) of IPO-Lisboa to improve hospital pathways, more specifically the pathways used in the delivery of healthcare to breast cancer patients. Also, it has the objective of combining clinical pathways modeling with VBHC instruments so that IPO-Lisboa can identify value-based improvements in the delivery of care.

In this study, a novel methodological approach was developed that uses the combination of two techniques: one used for pathways modeling and the other for value modeling.

For the pathways modeling task, the discrete event simulation (DES) method was used [11], and for the value modeling task, a multicriteria decision analysis (MCDA) approach was applied: the MACBETH method [12]. This technique has the potential to develop an evaluation model based on qualitative judgements and to support complex decision situations, and allows considering the multiple criteria that are relevant in the decision-making process [13]. In the specific case of this study, it was possible to build multicriteria evaluation models that reflect how value is generated by IPO-Lisboa activities from the point of view of different health professionals.

The combination of a simulation model with a multicriteria evaluation model can be seen as a contribution to the literature since not many studies use MCDA as an integral part of problem-solving methodologies that try to improve hospital processes [14]. By combining these two methods, it is possible to analyze the impact caused by simulated changes in the clinical pathways and to identify the most attractive improvements to be made to hospital pathways taking into account the perspective of different stakeholders. Moreover, this type of approach promotes discussion and reflection about the best actions to be taken for improving the delivery of VBHC [15].

1.3. Thesis Outline

This document is divided into seven chapters, besides this introductory section. Chapter 2 sets the context of this work, where several important concepts are presented to understand and recognize the importance of addressing the proposed topic, namely clinical pathways, value-based healthcare, and breast cancer. Chapter 3 presents a literature review, describing different approaches applied in pathways modeling, as well as the advantages of combining different techniques. Through this chapter, it is concluded which techniques are most suitable to use, taking into account the objectives of the thesis, as well as the scope for developing a new approach. Chapters 4 and 5 describe the proposed methodological approach and its implementation, respectively. The results are presented in Chapter 6 and the discussion in Chapter 7. Finally, Chapter 8 draws the main conclusions of this study and highlights proposals for future work.

2. Context

To develop an approach to help IPO-Lisboa, it is necessary to bear in mind some concepts that become fundamental both for its understanding and for recognizing the relevance of addressing the proposed topic. This chapter summarizes essential aspects concerning clinical pathways, namely their definition, importance, advantages, and main challenges, as well as key aspects regarding the concept of value-based healthcare (VBHC). Furthermore, some general notions about cancer and, particularly, about breast cancer at IPO-Lisboa, are presented, as clinical pathways will be addressed in the context of this oncological field in the following chapters.

2.1. Clinical Pathways

The origin of clinical pathways dates to the 1980s when they were used for the first time in the USA. This happens when a hospital staff has felt the need to improve the management and efficiency of its operations [16]. In this sense, clinical pathways have emerged in order to decrease variability and provide efficient care delivery. This improvement in healthcare management has the potential to reduce costs, as well as to contribute for patients receiving the best care available. Clinical pathways are the result of documents used in quality management and show an enhancement in the efficiency and quality of the provided care. Also, they evaluate the complete journey of a patient and not only the contribution of each independent sector [12].

Thus, clinical pathways can be defined as structured and multidisciplinary care plans that detail the essential steps in providing care for a patient who has a specific clinical problem. These plans aim to build the link between the best evidence available and clinical practice, providing recommendations, processes, and frameworks for the management of medical conditions or specific treatments with optimized clinical outcomes, which maximize clinical efficiency. They are also referred to as “integrated care pathways”, “critical pathways”, “care paths”, “care maps” and “care protocols” [18][19].

In 2010, Rotter and his colleagues created four criteria that an intervention should meet to be identified as a clinical pathway [15]. Therefore, many studies use the following criteria:

(1) the intervention was a structured multidisciplinary plan of care;
(2) the intervention was used to translate guidelines or evidence into local structures;
(3) the intervention details the steps in the course of treatment or care in a plan, pathway, algorithm, guideline, protocol, or timeframes;
(4) the intervention aimed at standardized care for a specific population.

Furthermore, clinical pathways and guidelines are presented as similar concepts, although they possess some differences. A guideline is a list of all treatments that are considered by a group of experts as part of the standard care for a given presentation of disease. However, guidelines do not formally cover costs and resource utilization. Its main objective is not to standardize, but rather to ensure that the delivered care has been demonstrated as effective from evidence reviews [21]. On the other hand, clinical pathways aim to choose a single therapy based on acceptable options, which is the best for a given presentation of disease [21].

2.1.1. The Importance of Clinical Pathways in Oncology

Clinical pathways can also be used in the oncology sector [22]. Cancer is one of the most common diseases worldwide, with breast cancer being part of the most common ones. This is a disease that widely affects the patients' quality of life and a lot of money is spent on cancer-related care. Hence, it has emerged the necessity for creating strategies that improve the patients' quality of life, minimize toxicities, and provide cost-saving advantages. Moreover, there is an increase in the complexity of cancer treatments and the teams involved. These aspects motivate the use of oncology pathways, to the extent that such structured care plans are implemented to prevent the management of patients from becoming chaotic and inconsistent [12].

Whenever possible and appropriate, the use of clinical pathways provides standardize care, allowing a reduction of costs, increasing the quality, and improvement of outcomes, avoiding unwarranted variability. Furthermore, we are not in an era of singular opinions, but rather of scientific evidence and group consensus. What happens is that the fast dissemination of results makes it difficult for a single provider to know all the nuances and details of the treatments in the different states and stages of disease presentation [23]. In this sense, the adoption of clinical pathways can help healthcare professionals in delivering better care to their patients.

2.1.2. Advantages of Clinical Pathways

Regarding the advantages that clinical pathways present, some studies have shown and concluded that its application has reduced the complications from invasive interventions in a significant way [18][19]. According to theories in health economics, it is known that the most invasive procedures are more easily standardized, given their low variance when compared to other treatment strategies, which is why the advantages of these procedures are easier to highlight. Furthermore, there is an association between the use of clinical pathways and a reduction in terms of length of stay and hospital costs [18][19].

In a context more related to healthcare professionals, studies have identified that there is a relationship between clinical pathways and the improvement of staff knowledge, communication between team members, and even their satisfaction [20]. The work of junior physicians and nurses is also facilitated by using this approach. These team members acquire clear instructions on what to do, becoming more independent from the senior staff [24]. Also, studies have shown that the participation of all levels of healthcare personnel, as well as continuous feedback, makes the use of clinical pathways more accepted by them [24][25]. However, in some cases, it is also important to note that physicians express concerns about the loss of opportunity in treating patients according to their judgements. Thus, clinical pathways must not limit healthcare professionals to make their individual decisions when justified, as there is always variability among patients. In this sense, it is important to know when a patient should be on the pathway or off-pathway and, when a deviation from the initial pathway occurs, a justification for its occurrence must be provided.

Having this in mind, it can be highlighted that clinical pathways do not claim to have 100% adherence. Studies have shown that in every 100 patients, 20 of them need to get off the initial pathway so that their treatments are the most accurate [24]. Patients vary not only by their disease type, stage, and molecular markings but also by what they are able to tolerate in terms of therapies and by what they can access because of their geographic location [24][25].

It is also possible to emphasize other benefits of this approach, namely about health information technologies (HIT). Examples of implemented HIT interventions include electronic patient records, as well as electronic prescribing and ordering systems. In this way, positive effects are reported with the implementation of HIT-supported clinical pathways. Some studies have reported that the benefits can include reductions in thromboembolic complications, mortality, myocardial infarction, stroke, and retinopathy, and improvements in biochemical markers of glycemic control. Also, a positive impact is recognized in both the quality and quantity of medical records when pathways are used [18][26]. This issue may also be subject to some controversial opinions since some nursing staff points, as a negative aspect, of the fact that eye contact with patients is reduced, and the completion of this documentation takes longer by using electronic devices instead of paper records [26]. However, these negative aspects come from the HITs and not from the clinical pathways approach.

Regarding patients' perspective, it is also necessary to pay attention to how they can interpret clinical pathways since they are often unfamiliar with its concept. Thus, it must be highlighted to them that it is not a contradiction of the personalized medicine concept [25]. Patients need to realize that care providers have the opportunity to move away from the initial pathway when necessary, that is, due to specific patient conditions.

2.1.3. Clinical Oncology Pathways

Oncology pathways have been increasingly used by institutions, clinicians, commercial organizations, payers, and other health systems. This approach has shown that it is a way to improve the care provided to patients by limiting unwarranted variability and reducing costs, while the quality of care provided is maintained or even improved [27][28]. Studies have demonstrated that its practice has several benefits, especially when used in first-line care [22]. Regarding chemotherapy, dosing strengths and the number of cycles is more standardized, improving the quality of treatments. There is also a reduction in costs in terms of chemotherapy and other medications, not considering, for instance, the third-line cares, which have higher associated costs. Furthermore, physicians who adhere to the pathways tend not to prescribe what is more expensive, unless there is strong evidence to validate its usage [22].

Not only in Portugal, but also, for instance, in Brazil, cancer is a disease that affects an increasing number of people, with breast cancer being the most common type. Studies have indicated that, in this country, there is a lack of mechanisms to organize the care flow, and specialists are often unavailable or limited [29]. Hence, there are delays in diagnosis confirmation and a very long-time interval between the first consultation and the beginning of therapy, a delay that is associated with worse survival rates. Thus, there is a need to create strategies that improve these kinds of situations.

Also, in European studies, the results of the clinical pathways usage have been reported. As an example, in a study carried out in Belgium, a reduction in length of stay, costs, bad practices, and errors was verified, as well as an increase in the staff satisfaction and the knowledge and satisfaction of the patients [17].

2.1.4. Challenges of Clinical Pathways

Despite all the positive aspects that are the result of the oncology pathways approach, it has been also presented some challenges. Therefore, in 2016, the American Society of Clinical Oncology (ASCO) developed recommendations for the development and implementation of clinical oncology pathways [28], presented in Figure 2.1.

1	A collaborative approach is needed to remove the administrative burden associated with the unmanaged proliferation of oncology pathways, and the stakeholders that are involved need to work together to obtain the best single pathways used in a group of patients that have the same diagnostic characteristics.
2	Oncology pathways should be developed consistently and transparently for all stakeholders involved, avoiding possible conflicts between them.
3	Oncology pathways should cover the entire spectrum of cancer care, including aspects from diagnostic evaluation to medical, surgical, and radiological treatments, as well as imaging, laboratory tests, and palliative care.
4	Oncology pathways should provide the best evidence-based care possible. Also, due to the rapid development of scientific knowledge as well as the expert's opinions, pathways must have been continuously updated.
5	Oncology pathways must recognize that there is variability between different patients.
6	Oncology pathways should be implemented in such a way that there is administrative efficiency among oncology providers and payers.
7	Oncology pathways must enable the integration of clinical trials.
8	Oncology pathways should ensure high-quality cancer care that reflects the latest scientific advances.
9	Pathways developers, users, and private and governmental agencies should support research to understand the impact of pathways on care and outcomes.

Figure 2.1. Recommendations developed by the American Society of Clinical Oncology for clinical pathway development and implementation in the oncology setting.

One of the challenges about this issue is that many times the pathways are not integrated as entities within electronic health records (EHRs) systems, arising the need to integrate them more easily into the flow of the daily practice. Thus, the associated software should be compatible with the existing EHRs [25]. In this way, data is used efficiently and usefully to achieve the objectives intended by the pathways.

Currently, there is also a large growth of new scientific evidence, as it was mentioned before, which are instructions on how patients should be treated and what is the best available care. Therefore, the pathways should be constantly updated and consider the existing nuances. There must be a continuous integration of scientific knowledge, and the oncology pathways should incorporate aspects from diagnosis to treatment, follow-up, and end-of-life since they lead with multidisciplinary teams. However, it is also necessary to assure there are no conflicts between the different team elements.

On the other hand, although there is an increase in the use of clinical pathways as a strategy to improve patient and systems outcomes, there are challenges concerning their conceptualization, implementation, and assessment. Studies have tried to create methods to explain how clinical pathways can work in a more realistic hospital context [20]. They may initially be based on the search in the literature for existing evidence between them and the improvement of hospital outcomes. Thus, it is necessary to select studies that fit into the problem, meaning these studies should mention strategies that meet the definition of clinical pathways and, subsequently, analyze them. Through this, it is possible to create plausible methodologies for implementing and evaluating pathways. Also, the appropriate stakeholders must be involved in these methodologies, to assure that the fundamental aspects are addressed, and possible changes are made when required. It is important to understand how, why, to what extent, and in which contexts the implementation of clinical pathways brings benefits and an improvement in the outcomes, such as length of stay, costs, in-hospital complications, in-hospital mortality, and adherence to recommended practice.

Furthermore, the pathways need to be centered on patients and not only on studying the economic impact on the health sector [30]. They should improve the communication and education of patients, serving as a way to help in understanding what treatment they are receiving, and which are the reasons for it.

2.2. Value-Based Healthcare

In 2004, Professors Michael Porter and Elizabeth Teisberg came up with the concept of value-based healthcare (VBHC) for the first time [31] and according to them, "the way to transform healthcare is to realign competition with value for patients". Nevertheless, the concept of value in the health sector was redefined, as it depends on results and not on inputs, as is the case of other sectors. Value is measured through outcomes that are achieved instead of the volume of delivered services. Hence, it was redefined as outcomes achieved in relation to the cost, in dollars, spent to achieve them.

VBHC aims to improve the quality of delivered care by measuring and improving outcomes that reflect value rather than volume, and these outcomes reflect patient-oriented results [32]. However, what happens many times is that there are no ways to measure outcomes through patients, who truly matter in this approach, and, consequently, governments have only a partial view of the performance of healthcare systems.

Porter & Teisberg (2006) argued that for identifying the source of healthcare system problems, it is necessary to look at how competition works in this sector. Here, the patients are the customers, and the delivered services are rewarded, whether they bring value to the patients or not, resulting in a "zero-sum competition". In this way, the authors proposed a "positive-sum competition" approach, in which all stakeholders could benefit. When a provider delivers high-quality services, patients will have better outcomes and receive clearer information, care coordination will be improved, and outcomes will be achieved at lower costs. This competition is a value-based one, and it has 8 main principles, as described in Figure 2.2.

To move from a "zero-sum competition" system to a "positive-sum competition" approach, the way healthcare delivery is organized must be restructured, as well as the way it is measured and reimbursed. In 2006, Porter & Teisberg also proposed a strategic agenda (Figure 2.3), which presents the steps an organization should follow for implementing a VBHC system [31].

Regarding the advantages of VBHC, it is possible to highlight that patients will spend less money to achieve better healthcare, and providers will achieve better efficiencies and great patient satisfaction. Also, payers can control costs and reduce risk, and suppliers can align prices according to the outcomes. Finally, society becomes healthier, with not so expensive care.

1	The focus should be on value for patients and not just on costs.
2	Competition must be on results and not on processes.
3	Value is created in caring for the patient's medical condition over the full cycle of care.
4	High-quality care is not necessarily expensive care.
5	Value must be driven by provider experience, scale, and learning at the medical condition level.
6	Competition should occur at a regional and national level, not just at a local one.
7	Patient outcomes information must be collected and widely available.
8	Innovation that increases value must be strongly rewarded.

Figure 2.2. Principles of value-based competition.

1	Organize into Integrated Patient Units.
2	Measure outcomes and costs for every patient.
3	Move to bundled payment for care cycles.
4	Integrate care delivery across separate facilities.
5	Expand excellent services across geography.
6	Build and enabling information system platforms.

Figure 2.3. Value-based healthcare strategic agenda.

2.2.1. Value-Based Healthcare: Current Situation

Currently, health systems deal with great pressure in terms of adapting the costs associated with new technological developments, the increase in the number of patients who have multiple conditions and chronic diseases and, therefore, complex patients, and also an increase in volume and intensity of clinical practices. Hence, health systems must spend their resources wisely and efficiently, and the VBHC concept is discussed as a way to improve resource allocation [33].

Systems pursuing VBHC try to improve the quality of services delivered to patients, as well as making healthcare more cost-effective. Nevertheless, it is always difficult to define the concept of VBHC in addition to the fact that what is considered valuable to a patient often does not correspond to what a physician considers valuable. Usually, the aspects that are considered as those that increase value in the health sector are: [33]

(1) prevention, not only the primary prevention of disease but also tertiary prevention;
(2) improving outcomes, providing only cost-effective interventions, using cost-benefit analysis;
(3) improving outcomes by increasing the quality and safety of processes;
(4) increasing productivity.

However, in all countries, obstacles in the health sector are constantly reported, and one can highlight the following ones: [33]

(1) unwarranted variations, that is, variations in the use of health services that are not explained and justified by variations in the diseases that patients have or by their preferences;

(2) underuse of effective interventions, which results in inequalities and failures in the detection or use of medical interventions;
(3) overuse, which results in waste and harm for patients (in terms of over-diagnosis, anxiety, overtreatment, and side effects of unnecessary care). In this case, physicians can adopt the "choose wisely" initiative as a basis for communicating with patients to reduce overuse. It is important to emphasize that by using this initiative, cost savings can consequently be verified, but increasing the quality of services provided to patients is its fundamental underpinning since there is greater communication with patients and physicians;
(4) lack of instruments to operationalize the implementation of VHC.

Having this in mind, it is necessary to have a balance between the investment costs and the health benefits that result from it. It is important to note that if the cost of provisions increases too much, additional benefits are not brought to patients. When more resources are invested in care systems, it becomes more likely that more treatments will be offered to patients who have less severe illnesses, and, consequently, these patients will benefit less from these treatments since their problems are also minor.

Thus, it is essential to identify possible waste, transfer resources used in low-value activities to high-value ones, ensure that the right people are being treated at the right time in the right place, and, finally, find the balance between what contributes for improving outcomes and achieving the goals that matter to patients, with communication with patients playing a key role [33].

2.2.2. Value-Based Healthcare: Defining Value

In 2019, in a report of the European Commission (EC), a panel of experts recommends as key concerns the awareness of health as an essential investment, and centralization of European values of solidarity, in which individuals contribute according to their abilities and obtain benefits according to their needs. Based on Art 35 of the "Charter of Fundamental Rights" of the European Union (EU) and the "European Pillar of Social Rights" stating that "everyone has the right to timely access to affordable, preventive and curative healthcare of good quality", healthcare is one of the policy priorities of the EU "to build a more inclusive and fairer European Union and to ensure social cohesion within the EU" [33].

In this sense, many European countries use health systems based on solidarity, and, for that, it is necessary to bear in mind some essential principles, as explained in more detail in Table 2.1, which underpin this type of systems, and are seen as indicators for achieving its goals, taking into account the fair distribution of resources used in healthcare.

The concept of VBHC is discussed as an idea to improve healthcare systems, although its definition is always subjective. Frequently, the concept of value is referred to as the health outcomes related to the monetary inputs. However, this approach becomes too centered on providers, as well as its major goal is the increase of cost-effectiveness. It is necessary to count that "the meaning of the value of healthcare is "equitable" achievement of health of groups of people or the whole population as a precondition for pursuing a good life" so that one can have a definition more centered on patients, their families, and their preferences [33].

Table 2.1. Essential principles of health systems based on solidarity.

Essential Principles	Meaning
Access and equity	Access to high-value health care means that access to immunization and prevention programs cannot be restricted; equity means that healthcare services do not depend on social groups, and are not worse for socio-demographic groups, which live in worse economic situations.
Quality and performance	Health systems with high quality and good performance are those that are adequate and contribute to achieving the correct objectives, delivering care to all who need them. Thus, high-quality care is not directly related to a high value, because high-quality care can be delivered to the wrong individuals and/or their preferences may not be considered. Performance is centered on improving health, responding to the needs of the population, and assuring fairness of financial contribution.
Efficiency	This indicator is related to the fact that good outcomes are achieved with the available resources.

As described in the aforementioned EC report of 2019, the EXPH (Experts Panel on effective ways of investing in Health) proposes "to define value-based healthcare as a comprehensive concept built on four value-pillars: appropriate care to achieve patients' personal goals (personal value), the achievement of best possible outcomes with available resources (technical value), equitable resource distribution across all patient group (allocative value) and contribution of healthcare to social participation and connectedness (societal value)" [33]. In Table 2.2, the meaning of these four value pillars is explained in more detail.

Table 2.2. The four value pillars for value(s)-based healthcare in the European Union.

Value Pillars	Meaning
Personal value	It means that an individual receives appropriate care, and the outcomes are related to the individual goals of the patients.
Allocative value	It is related to the fact that resources are distributed equally among the different subgroups of a given population, i.e., individuals who have different socio-demographic characteristics.
Technical value	It is associated with the fact that the best outcomes are achieved with the available resources. Also, it indicates that the allocation of resources was made according to the needs of the different subgroups of a population.
Societal value	It refers to the fact that it is observed that interventions in healthcare contribute to social cohesion, based on participation, solidarity, mutual respect, equity, and recognition of diversity.

Moreover, it is important to emphasize that the value in health for an individual is not only directly related to the benefits that are achieved, but also with components that result from one's own experience. In this way, patients tend to value the fact that they have a short time waiting for a particular treatment, whether they are involved in a decision or not, the fact that they are treated with respect and they receive the appropriate amount of information, and costs should not be too high.

Consequently, from the patients' perspective, what is needed to have high-value healthcare is the shift from a disease-centered approach to a person-centered approach, where patients are active participants in their delivered care, which takes into account their needs, aims, priorities, and preferences, and keeping in mind that their individual experience also contributes to this. However, this experience is not easily captured in health indicators and the measurement of outcomes, which are equally important when VBHC is delivered. Therefore, it is needed that the possibility for patients to be able to express their opinions, and narratives are integrated into the delivered care. Patients must receive quality information about the care they are receiving, as well as meaningful communication with health professionals [33].

To sum up, the EC aims to support its Member States in achieving effective, accessible, and resilient health systems: “effective” in the sense that health systems are capable of producing positive outcomes to improve the health of populations; “accessible” regarding the fact that patients can easily obtain the care that corresponds to their needs; “resilient” in the sense that health systems are trained to adapt to constantly changing environments and face challenging situations with limited resources. The EXPH brings a new definition of VBHC, but, above all, there must exist a cultural change in the health sector so that a treatment or procedure brings value to patients, improving their quality of life or their prospects for recovery. Thus, a list was created with the following recommendations: [33]

(1) Create awareness that investment in health is essential;
(2) Develop long-term strategies so that the VBHC approach can be used;
(3) Develop methodologies considering what is appropriate for patients and limit unwarranted variations;
(4) Encourage health professionals to feel accountable for increasing the value of healthcare;
(5) Support the creation of communities where healthcare professionals can share clinical experiences and practices, to learn from each other, and implement better actions across the EU;
(6) Support patients’ involvement in shared decision-making, recognize the importance of their goals, values, and preferences, and provide them with high-quality information.

2.2.3. Value-Based Healthcare and Clinical Pathways

The idea behind patient-centered delivery care is difficult to integrate into a patient’s entire journey since there is a wide range of clinical pathways. Furthermore, the pathways involve different stages and sectors, the clinical departments are complex, the services involved are diverse, the diseases are often complex, and with heterogeneous outcomes, besides the multiple treatment strategies [34].

Considering what is currently done in the development and implementation of clinical pathways, it is, therefore, possible to highlight some factors that are lacking and that need to be considered so that they would be more patient-centered, and able to integrate the VBHC concept. In this way, the following recommendations can be made: [34]

(1) Engagement of patients with health providers and with developers of clinical pathways. It is necessary to request feedback, which considers the objectives, preferences, priorities, and concerns of patients and their families;
(2) Clinical pathways developers should provide directed information to patients about specific pathways;
(3) Improved interoperability and integration between the pathways’ IT infrastructures and patients’ EMRs to facilitate communication between patients and providers;
(4) Improvement in the integration between pathways and monitoring of outcomes or evaluation of effectiveness, accuracy, quality, and appropriateness of the care delivered to patients.

It is important to emphasize that in this thesis there is an attempt to build a bridge between classical methods used to model the clinical pathways in order to improve them, being aligned with the delivery of VBHC. Thus, to realize how value is added to a healthcare system, health stakeholders have to be active participants to discover their objectives, concerns, and preferences.

2.3. Cancer and Breast Cancer

Cancer is the designation that includes a group of more than one hundred different diseases, which have in common an uncontrolled cell growth and the spread of abnormal cells [6]. In a normal human body, cells renew themselves in an orderly manner, enabling the repair and harmonious growth of the tissues of the organism. Cancer arises when a lesion of the genetic material occurs, that is, a lesion of the cell's DNA, leading to the presence of mutations. Uncontrolled proliferation of abnormal cells is the next step, and it is called "promotion" [6]. In a healthy person, these cells are eliminated by the immune system, but if the body is unable to recognize and destroy them, cancer may occur.

In Portugal, breast cancer together with lung cancer are both the types that affect a larger number of people. The same situation occurs in other countries, as is the case in the UK, where breast cancer is the most common type, affecting in the majority of cases women over 50 years of age [35]. Although being rarer, breast cancer can also occur in male individuals, and, in these cases, it appears mostly in patients older than 60 years.

The first signs to be considered are the presence of some lumps, which are mostly not cancerous, or thickened breast tissue. Also, it is necessary to visit a physician when there is a change in the size of one or both breasts, secretions from or around the nipples, lumps in the armpits, and changes in the appearance of the nipples, as, for instance, they became sunken [35].

Breast cancer can be considered curable in 70-80% of cases, when patients are diagnosed at an early stage of the disease, and when there are no metastases. When the patient has metastases in distant organs – advanced breast cancer – the disease is considered incurable, at least with the currently existing therapies. The main places where breast cancer metastases occur are the bones, lungs, and liver. In this case, cancer is only treatable, and the approaches used have as main objectives to prolong the life of patients and control their symptoms, always focusing on improving their quality of life, that is, improved quality-adjusted life expectancy [36].

The development of breast cancer can be associated with some main causes, such as age, family history, different types of cancer in a previous situation, obesity, or alcohol consumption [35]. Although there are no definitive conclusions, studies [37][38] show a connection between breast cancer and diet, existing benefits from adopting a healthy lifestyle, namely the practice of exercise and a balanced diet. Furthermore, it is also important to highlight that the incidence of breast cancer varies according to geographic location, with developed countries having a higher number of cases, but these are also the countries that have the highest health expenditure and where they are more tests and screens. Although developing countries have fewer cases, the survival rate is lower, and patients tend to be diagnosed when the disease is at a more advanced stage [36].

2.3.1. Causes

As previously mentioned, most cases of breast cancer occur in women over 50 years of age, which is, therefore, an older age associated with menopause. The risk of developing this type of cancer is also increased when there are cases of breast cancer or ovarian cancer in the family. The presence of the BRCA1 and BRCA2 genes increases the possibility of developing cancer, and these genes can be passed on to their descendants. Furthermore, the TP53 and CHEK2 genes are also associated with an increased probability of having cancer [35]. In most cases, the lumps are not cancerous. However, there are some types of benign changes in breast tissue that can increase the risk of developing cancer, namely, atypical ductal hyperplasia and lobular carcinoma in situ.

The breasts are formed by thousands of small glands called lobules that produce milk (Figure 2.4). This type of breast tissue has a higher concentration of breast cells than other types of tissue, becoming denser. If a tissue is denser, there is a greater risk of developing cancer since it could exist a greater number of cancer cells. An important note, in this matter of tissue density, is that it becomes more difficult to see lumps in denser breast tissue when a mammogram is performed. This occurs in younger women who have denser breast tissue than older women in whom this type of tissue is replaced by fat, making the breasts less dense [35].

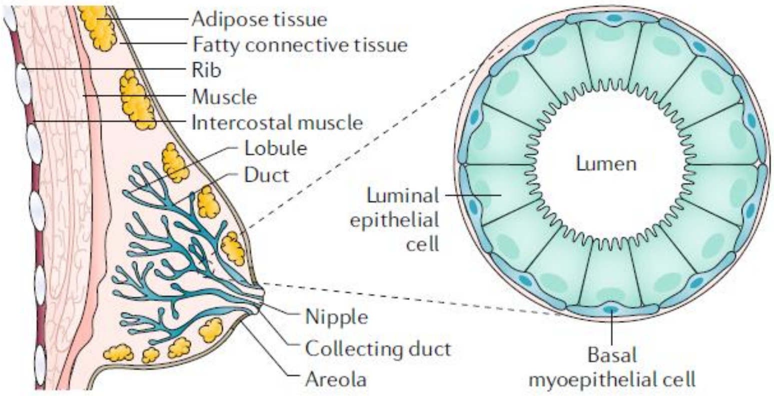


Figure 2.4. Simplified anatomy and histological aspects of the female breast [36].

Estrogen can stimulate cancerous breast cells, making them grow [35][36]. The ovaries release estrogen to regulate menstrual cycles, and this starts happening during puberty. During menstrual cycles, there is an imbalance between estrogens and progesterone, causing cell proliferation, which can consequently cause an accumulation of DNA damages. With the repetition of this process in each cycle, DNA repair may not be effective, dealing with mutations and leading to the appearance of cancer cells. At this stage, estrogen stimulates the growth and proliferation of these cells, which leads to the development of cancer. Therefore, when a woman has had no children or has had them at an older age, this means that the production of estrogens was not interrupted during pregnancy, increasing the risk of developing cancer [36]. Also, overweight or obesity after menopause are factors that cause increased production of estrogens and, consequently, the possibility of having cancer is higher [35].

2.3.2. Diagnosis

One should see a physician as soon as possible when some of the symptoms above-described are experienced, whether it is an unusual lump or a change in the appearance or size of the breasts. There is evidence that population screening has a positive effect on significantly reducing breast cancer mortality when a comparison is made between populations that resort to this procedure and those that do not [36].

The most common technique for making this diagnosis is mammography, and the effectiveness of this screening depends on the age of the patients. There is evidence that those who benefit most from this procedure are women between the ages of 50 and 69. It is also important to note that, although mammography screening has been implemented in many countries with more developed health systems, different agencies present different recommendations on how this screening show be done [36]. For instance, the US Preventive Services Task recommends screening every 2 years for women between the ages of 50 and 74. The American Cancer Society recommends annual screenings for women aged between 40-54 and screening every 2 years for women aged 55 and over. European recommendations do not recommend an annual screening, stating that this should be done every 2/3 years on women aged between 45 and 74 years [36].

Although mammography is the most common imaging technique, other approaches can also be used. Thus, in women who have predisposed to genetic mutations, it may be advisable to use MRI as a diagnostic technique, since it increases the screening's sensitivity.

When a patient is under 35 years of age, an ultrasound scan or MRI are also common approaches for performing the diagnosis since the breasts are denser and, therefore, mammography is not as effective as this type of imaging technique. Also, an ultrasound scan is recommended to find out if the lumps on the breasts are solid or contain liquid [35][36].

A biopsy is also a diagnostic technique, which consists of removing a sample of cells and testing them to understand if they are cancerous. This procedure helps in distinguishing cancer from a non-invasive change, particularly ductal carcinoma in situ (DCIS).

Tests that determine whether cancer responds to specific types of treatment are also used to have a more complete view of the condition of patients and to understand how they should be treated. When hormonal treatment is needed, this type of procedure is applied [35].

2.3.3. Types of Breast Cancer

Breast cancer can be divided into two main types: non-invasive breast cancer and invasive breast cancer. Non-invasive breast cancer (or DCIS) is found in the ducts of the breasts and is not spread by the breast tissue that surrounds the ducts. This type of cancer is usually found during a mammogram and rarely appears as a lump. Invasive breast cancer is the most common type of cancer, in which cancer cells are already spreading through the lining of the ducts, affecting the surrounding breast tissue. Regarding invasive breast cancer, the most common types are invasive ductal carcinoma (which corresponds to 70-75% of all breast cancers) and invasive lobular carcinoma (referring to 10-14% of all breast cancers) [35][36].

Moreover, there are still other less common types of cancer, such as inflammatory breast cancer and Paget's disease of the breast. Also, breast cancer can spread to other parts of the body, creating a secondary cancer. This usually occurs through blood or axillary lymph nodes [35].

2.3.4. Treatment

When patients are diagnosed with breast cancer, they must be assigned to a multidisciplinary team, who will work together to try to provide the best possible treatment. The main types of treatment include surgery, radiotherapy, chemotherapy, hormonal therapy, and targeted therapy (see Appendix A). The adoption of a single treatment or the combination of treatments will depend on how the cancer was diagnosed, the stage and grade of cancer, the patients' general health, and whether they have already experienced menopause. The multidisciplinary team should always discuss with the patient which treatment is more appropriate [35].

If cancer is diagnosed at an early stage, the first line of treatment typically used is surgery, followed by (adjuvant) radiotherapy or chemotherapy, or, in some cases, endocrine or targeted therapies [35][39][40]. Treatment at a more advanced stage is different, and when cancer is diagnosed at an advanced or secondary stage is not curable. Thus, the treatment allows the shrinkage or disappearance of the cell tissues affected by cancer [35][41].

Moreover, in early breast cancer patients, the therapies used are highly effective, with adjuvant endocrine therapy and adjuvant chemotherapy capable of reducing patient mortality by approximately one third. The therapies used are often dependent on the surrogate intrinsic subtypes of breast cancer, as is summarized in Table 2.3. The surrogate intrinsic subtypes are based on histology and immuno-histochemistry expression of key proteins: estrogen receptor (ER), progesterone receptor (PR), human epidermal growth factor receptor 2 (HER2), and the proliferation marker Ki67 [35][36].

Table 2.3. Management of early breast cancer based on the surrogate intrinsic subtype.

<table>
<tr><th>Subtype</th><th>Characteristics</th><th>Therapies</th></tr>
<tr><td>Luminal A-like</td><td>ER+ and/or PR+; HER2- and low proliferation; low Ki67 index</td><td rowspan="2">The standard is adjuvant endocrine therapy to block the ER activity, Also, the recommendation for chemotherapy (neoadjuvant and adjuvant) depends on the individual risk of recurrence.</td></tr>
<tr><td>Luminal B-like</td><td>ER+ and/or PR+; HER2- and high proliferation; high Ki67 index</td></tr>
<tr><td>HER2+ (luminal)</td><td>ER+ and/or PR+; HER2+ and high proliferation; high Ki67 index</td><td rowspan="2">Neoadjuvant chemotherapy together with anti-HER2 therapy has become the standard of care.</td></tr>
<tr><td>HER+ (non-luminal)</td><td>ER-; PR-; HER2+; high Ki67index</td></tr>
<tr><td>Triple-negative</td><td>ER-; PR-; HER2-; high Ki67index</td><td>The standard is chemotherapy, which is preferred in the neoadjuvant setting.</td></tr>
</table>

It is also important to mention that clinical trials are a tool in the treatment of cancer, representing a way to evaluate new treatments or the combination of treatments and compare them with the most standard ones.

After both surgeries and treatments are finished, the patient needs to remain at rest for some time since the treatments make them feel very tired. Furthermore, the healthcare team involved should provide the patient and their general practitioner with a plan that contains the details of the follow-up. It is possible to highlight that regular mammograms should be offered after the treatment is finished, and the patient should contact a physician in case of experiencing any abnormal symptoms [35][36].

2.3.5. IPO-Lisboa

In Portugal, IPO-Lisboa is considered the biggest reference for the treatment of oncological diseases in the whole country, receiving about 6000 new patients per year, and a sixth of them are women with breast cancer. This is an institution whose main values are the patient-centered attitude, social responsibility, culture of knowledge as a good in itself, the culture of technical, scientific, and caring excellence, the internal culture of multidisciplinarity, and the good work relationship [6].

IPO-Lisboa is a healthcare unit with almost a century of experience in cancer treatment, study, and research. It is a public hospital of the National Health Service (NHS), certified as a National Reference Center for the treatment of various types of cancer by the Ministry of Health and is accredited by the Organization of European Cancer Institutes, with quality indicators identical to those of the best international reference centers [6].

Patient Centricity Project

The Patient Centricity Project (PCP) was a study carried out at IPO-Lisboa in 2018. The PCP aimed to evaluate the experience of breast cancer patients who are attended at this hospital, with the ambition of understanding how it is possible to improve the delivery of care.

Having in mind that the healthcare sector is constantly changing, and the expectations and needs of patients also vary in short periods of time, it is essential to assess their satisfaction.

The evaluation of their experience was obtained by conducting semi-structured interviews throughout their journey at this institute, allowing stakeholders to freely identify what they believe are the biggest constraints and strengths they face (or have faced) at IPO-Lisboa. Likewise, interviews were also conducted with family members who accompany patients, as well as with healthcare professionals. Thus, it becomes possible to identify potential points of improvement for this institution, through the analysis of information collected in the interviews of the three groups of participants. It was interviewed 103 patients (102 females and 1 male) between 15 to 90 years of age, 20 family members, and 23 healthcare professionals, including physicians, nurses, senior healthcare technicians, senior diagnosis and therapy technicians, technical assistants, secretaries, and other senior technicians.

Through the analysis of the several interviews, it was observed that this hospital is highly cherished by patients and their families, who highlight and value the humanistic provision of health care, which is the institution's unique brand.

On the other hand, the long waiting times, some infrastructures with inappropriate conditions and the perception of insufficient human resources are the main aspects that were considered as points that should be improved.

In addition to all observations and conclusions made from the interviews, this project also allowed for the development of some recommendations (Figure 2.5), which should be analyzed carefully and in detail, so that future solutions may be generated.

1	Map and optimize internal processes to increase efficiency.
2	Train and sensitize professionals in emotional intelligence, and good communication practices with patients.
3	Improve the infrastructure conditions, namely waiting rooms, inpatient areas, and car parking.
4	Group sessions with family members become important, providing information about the pathology and the treatment process so that they can support patients in the best possible way.
5	Co-creation sessions with the different IPO-Lisboa professionals are necessary for giving a voice to the professionals in the search for a solution to the identified problems.

Figure 2.5. Recommendations developed by the Patient Centricity Project.

Taking into account these recommendations and the objectives of this thesis, it is possible to highlight the particular interest in modeling the hospital pathways and analyze how to improve some problems that were identified by the stakeholders, namely long waiting times and the consequences of insufficient human resources.

For this purpose, it will be created an approach to assist IPO-Liboa health professionals in improving clinical pathways, being aligned with the delivery of VBHC. In this way, it will be possible to build a bridge between classical methods that examines the efficiency of processes and VBHC instruments. Ans for that, several stakeholders must be active participants to consider their different perspectives and realize how value is added to a healthcare system. To investigate different approaches used in the clinical pathways modeling, a review of the current literature will be presented in the next chapter.

3. Literature Review

The objective of this thesis is to assist DMs at IPO-Lisboa in improving clinical pathways, particularly for the breast cancer patients' journey. Moreover, for this hospital to be able to identify value-based improvements in patient care delivery, there is the opportunity and need to combine approaches used in clinical pathways modeling with VBHC instruments.

For the purpose of this thesis to be fulfilled, the first step is to investigate existing approaches that aim to improve clinical pathways and integrate VBHC concepts. Thus, a literature review needs to be performed so that information about the current situation in this area can be obtained, and it can be possible to reflect on the opportunities that exist to develop a good methodology.

This chapter summarizes how this literature review was conducted, namely, how the adequate articles were found, and how their analysis was performed. Also, it is presented who are the people involved in the studies as well as the different methodologies that were applied. This is a crucial step for understanding how to create a methodology that fits with the proposal of the thesis, which will be discussed later, in the fourth chapter.

3.1. Search Protocol

The main objective of this literature review is to research and study possible approaches that aim to improve clinical pathways, as well as the techniques used to consider VBHC elements within those approaches. Having this in mind, it is necessary to know if there are publications related to clinical pathways, more specifically, those that are used in the oncology sector.

Therefore, a search protocol was created, choosing databases to perform this research. In this case, two common ones were selected – PubMed and ScienceDirect – and a group of keywords was chosen to obtain publications that, in some way, addressed this topic. Then, and according to the number of obtained results, it may be necessary to apply filters to the search so that this number can be reduced. This happened with the research carried out in the ScienceDirect database, as can be seen from the numbers present in Table 3.1. In this context, it seemed appropriate to limit the type of publications to "Review articles" and "Research articles", besides considering only articles published between 2009 to 2019.

In this way, and as shown in Figure 3.1, when the keywords used are, for instance, ("clinical pathways" OR "clinical pathway" OR "care pathways" OR "care pathway") AND "modeling" AND "breast cancer", the number of results was reduced to 353 (instead of 874, as it can be seen in Table 3.1). Also, it is interesting to note that more than half of these publications were made in the last four years, as is depicted in the graph of Figure 3.1. The results presented in the Table 3.1 and Figure 3.1. refer to a search conducted on April 10, 2020.

Regarding exclusion criteria, articles that were not written in English or Portuguese were not considered and, although some articles contained the chosen keywords throughout their text, not all of them presented the objective of studying and analyzing approaches that aim to model and improve clinical pathways. Therefore, the abstracts of the articles were firstly analyzed to verify this. Finally, a group of 20 articles was then read and analyzed.

Table 3.1. Keywords that were chosen to perform the research, and the number of the results obtained in the two selected databases: PubMed and ScienceDirect.

Keywords	PubMed	ScienceDirect
“clinical pathways” AND “breast cancer”	32	639
“care pathways” AND “breast cancer”	48	728
“oncology pathways”	15	49
“clinical pathways” AND “modeling”	32	4 432
(“clinical pathways” OR “care pathways”) AND “modeling”	54	8 980
(“clinical pathways” OR “care pathways”) AND “modeling” AND “cancer”	14	3 485
(“clinical pathways” OR “care pathways”) AND “modeling” AND “breast cancer”	2	874
(“clinical pathways” OR “clinical pathway”) AND “modeling”	44	4 432
(“clinical pathways” OR “clinical pathway” OR “care pathways” OR “care pathway”) AND “modeling” AND “cancer”	21	3 485
(“clinical pathways” OR “clinical pathway” OR “care pathways” OR “care pathway”) AND “modeling” AND “breast cancer”	4	874

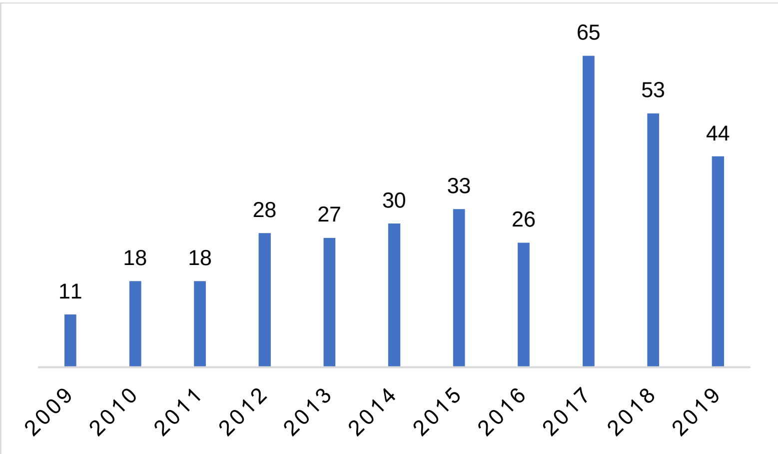


Figure 3.1. Number of publications obtained, per year, in the ScienceDirect database when searching for “Review articles” and “Research articles” published between 2009 to 2019 using the keywords: (“clinical pathways” OR “clinical pathway” OR “care pathways” OR “care pathway”) AND “modeling” AND “breast cancer”.

3.2. Analysis Protocol

During the analysis of the 20 selected articles, it is necessary, first of all, to identify what is the aim behind its publication. In this way, it was noted that publications may have as main objectives: (1) the creation of a new clinical pathway; (2) the improvement of a pre-existing clinical pathway; and/or (3) the use of clinical pathways so that outcomes or some added value can be measured. Secondly, it is necessary to recognize who was involved in the study, how and what was the purpose of including certain participants, besides recognizing the collected data. Then, it is necessary to identify which methods were used and their purposes. Also, the main conclusions that were made during the studies should be collected to observe if the objectives initially proposed were accomplished.

In Table 3.2, one can observe the main objectives of the different analyzed articles, and it is possible to note that the three objectives mentioned above can be all present just in one single article. The measured outcomes or accessed added value are also denoted when the paper has this purpose.

Table 3.2. The main objectives of the different analyzed articles and the outcomes measured/ added value accessed.

Authors	Creation of a new CP	Improvement of a pre-existing CP	Use of CP to measure outcomes/ Access added value	Outcomes measured/ Added value accessed
Daniyal et al. (2009) [42]	✓	×	×	---------------
Tsumoto et al. (2018) [43]	✓	×	×	---------------
Scheuerlein et al. (2012) [44]	✓	×	Future Work	---------------
Patkar & Fox (2008) [45]	✓	×	✓	detection, mortality and morbidity rates
Sicotte et al. (2016) [46]	✓	×	✓	waiting times
Liu et al. (2018) [47]	×	✓	×	---------------
Taylor et al. (2019) [48]	×	×	✓	predictions about complications
Joranger et al. (2014) [49]	×	×	✓	survival of patients and costs
Degeling et al. (2018) [50]	✓	×	✓	hospital costs
Degeling et al. (2017) [51]	✓	×	✓	quality of life during treatment and costs
Babashov et al. (2017) [52]	✓	✓	✓	waiting times and delays
Te Marvelde et al. (2019) [53]	×	×	✓	survival of patients
Kul et al. (2013) [54]	×	×	✓	in-hospital mortality, length of stay, costs
Beyer-Berjot et al. (2017) [55]	×	×	✓	training staff satisfaction
Mahony et al. (2019) [56]	×	✓	✓	patients' satisfaction
Klinkhammer-Schalke et al. (2008) [57]	×	✓	✓	quality of life
Klinkhammer-Schalke et al. (2007) [58]	×	✓	✓	quality of life
Lefeuvre et al. (2017) [59]	×	✓	✓	length of time between treatments
Van Hoeve et al. (2014) [60]	×	✓	✓	waiting- and throughput times
Alfano et al. (2019) [61]	✓	✓	**Future Work**	---------------

Overall, in Table 3.2, it was possible noting that, when outcomes are measured, in most cases, these are associated with in-hospital costs, length of stay, waiting times, mortality rates, and survival of patients. On the other hand, in some studies, clinical pathways modeling also has the purpose of measure aspects related to the satisfaction of patients and medical staff, as well as the quality of life (QoL). Generally speaking, the people involved are mostly medical, nursing, and administrative staff or health experts. Also, the data used consists of medical and hospital records, interviews with health professionals, guidelines used in clinical practice, literature data, and experts' opinions.

In this way, it is possible to observe that the approaches aiming for the clinical pathways improvement have the healthcare providers as their main participants since these are the people who possess a greater scientific knowledge in the health area, and those who are more familiar with studies in a constant update on the evidence of which best practices should be used in the delivery of care. However, it should be noted that there is a lack of patient involvement during these processes and approaches, and, when this happens, tools such as QoL questionnaires are being used, as will be described in the next section of this chapter.

3.3. People Involved

After reading several articles, it was possible to observe that in the approaches used in the creation of clinical pathways, in their improvement, or the measurement of outcomes, the people involved in the processes were not always the same. Thereby, it was possible to note that, although clinical pathways, by definition, involve a multidisciplinary team, this does not mean that professionals from all departments who are involved, in some way, in care delivered to patients, are always present. Also, it is possible to observe that, in some studies, the people involved are only physicians, as can be seen in Table 3.3. In these cases, interviews were usually conducted directly with these providers either to understand how the guidelines are used in clinical practice or to collect data, provided by them, which will be used in the clinical pathways modeling. These studies choose in having only the participation of physicians because it is considered they are the professionals more involved in the diagnosis and treatment processes, which are intended to be modeled. Moreover, for instance, when it is intended to create models capable of making predictions about possible complications that arise from surgeries, as was the case of the study published by Taylor et al. (2019), only surgeons were involved.

On the other hand, there are studies in which the people involved belong to different departments and, therefore, the modeling of clinical pathways has the cooperation of a multidisciplinary team. In addition to physicians, as mentioned above, also nursing staff [42][43][44][61] or even administrative staff [44][59][61] can be found as part of the team involved in these processes. This happens due to the fact that medical and hospitalization records, which contain relevant data and information to use in the clinical pathways modeling, are filled not only by physicians but also by other health professionals, who are able to understand how it is possible to improve the processes since these are the people behind the management of the delivered care.

Moreover, the training staff can also be part of the participants' group present in the modeling approaches of clinical pathways, as mentioned in the study published by Beyer-Berjot et al. (2017). This involvement was intended to demonstrate there is an improvement in the performance of trainees during surgeries when the simulation-based care pathway approach is used. What this means is that, by using patient data, it was possible to create virtual patients, using them as a learning tool for the training staff. Trainees followed patients in three stages of the process associated with surgery so that an appropriately managed care plan was delivered to patients. Here, aspects related to process compliance and patient outcomes were assessed and, subsequently, trainees answered a satisfaction questionnaire about the use of this approach. Regarding feedback, all the participants involved in the study showed a high degree of satisfaction and considered this approach as useful, besides the quality of the care delivered to real patients improved after the participants had undergone the training program. In this study, it was also concluded that the care pathway approach training can involve other teams and procedures, where decision-making and strategy are paramount.

Table 3.3. Identification of people involved in different analyzed articles and a summary of the purpose of their involvement.

Authors	People involved	For what purpose are they involved?
Daniyal et al. (2009) [42]	physicians and nursing staff	**Interviews and data collection** provided by health professionals to understand which are the steps and processes that are behind the management of prostate cancer.
Tsumoto et al. (2018) [43]	physicians and nursing staff	These professionals fill **hospital records**, which contain relevant information for the creation of a new CP.
Scheuerlein et al. (2012) [44]	medical, nursing, and administrative staff	**Interviews** were made with a multidisciplinary team of health professionals to obtain relevant information for the creation of a new CP.
Patkar & Fox (2008) [45]	physicians	**Interviews** were made with physicians to understand how the guidelines are used.
Sicotte et al. (2016) [46]	clinical staff, project managers, IT specialists	Health professionals provided relevant information for the creation of a new CP. IT specialists analyzed changes observed after the implementation of an EMR.
Liu et al. (2018) [47]	physicians	Physicians are the professionals involved in the cancer diagnosis that was analyzed to improve it. They also provided **medical records** for this purpose.
Taylor et al. (2019) [48]	surgeons	These are the professionals involved in the surgery whose predictions about its complications are intended to be made. Surgeons also provided **hospital records**.
Joranger et al. (2014) [49]	health experts	These professionals provided their **opinions** and referred **data from the literature** about outcomes measured using a CP.
Degeling et al. (2018) [50]	physicians	Physicians are the professionals involved in the cancer treatment that was modeled and analyzed. They provided **experimental data** for this purpose.
Degeling et al. (2017) [51]	physicians	**Interviews** were made with physicians to understand how the guidelines are used. They also provided **experimental data** to model CPs.
Babashov et al. (2017) [52]	therapists and administrative staff	These are the professionals involved in the cancer treatment that was modeled and analyzed. They also provided **medical records**.
Te Marvelde et al. (2019) [53]	physicians	These are the professionals involved in the delivery of cancer care for patients that were analyzed. They also provided **patient records**.

Authors	People involved	For what purpose are they involved?
Kul et al. (2013) [54]	physicians	These are the professionals involved in the process that was analyzed: treatments for patients with heart failure. They also provided medical records.
Beyer-Berjot et al. (2017) [55]	physicians and training staff	By using **patient data**, it was possible to create virtual patients, using them as a learning tool for training staff. Physicians supervised their performance.
Mahony et al. (2019) [56]	**patients** and nursing staff	**Interviews** were made with patients to understand their degree of satisfaction after the implementation of personalized service.
Klinkhammer-Schalke et al. (2008) [57]	**patients**, clinicians, therapists, experts in QoL	Patients answered **QoL questionnaires**, which are subsequently analyzed by experts. Also, physicians filled out **health status forms** and made **judgements** about patients' QoL.
Klinkhammer-Schalke et al. (2007) [58]	**patients**, clinicians, therapists, experts in QoL	Patients answered **QoL questionnaires**, which are subsequently analyzed by experts.
Lefeuvre et al. (2017) [59]	medical and administrative staff	Involvement of a multidisciplinary team to understand how to improve a CP and how national guidelines are used in the clinical practice. They also provided **hospitalization records**.
Van Hoeve et al. (2014) [60]	physicians	These are the professionals involved in the processes that were analyzed: breast cancer diagnosis and treatment. They also provided **medical records**.
Alfano et al. (2019) [61]	medical, nursing, and administrative staff	**Interviews** were made with a multidisciplinary team of experts to understand how to implement and improve a CP.

3.3.1. Patients Involvement in Clinical Pathways Modeling

Regarding the active participation of patients in these processes and approaches, there was a notable lack of involvement by those who benefit the most from the improvement of clinical pathways. Only in some publications was found that patients were part of the participants' group in the developed studies [56][57][58]. It was also observed that for making possible their participation, either through interviews made directly to them or QoL questionnaires were used.

Analyzing this issue in more detail, in the paper published by Mahony et al. (2019), it was demonstrated that the use of a personalized program – in this case, the Breast Cancer Nurses – allows to facilitate the continuity of delivered care and to provide psychosocial support to patients diagnosed with breast cancer and who are undergoing treatment. Interviews made directly with the participants of this program were conducted, and questions were asked to understand whether it improves the quality of life of women diagnosed with breast cancer as well as whether access to information provided to them improves. Then, the advantages brought to patients were analyzed and it was concluded that programs like this or similar ones should be integrated into the existing clinical pathways so that in all stages of diagnosis, treatment, and follow-up there is continuous monitoring, resulting in better communication between health professionals and patients, more efficient and better-coordinated management and savings. This was not translated in monetary terms, but in an increase of capacity for clinical work, because there was a reduction in the time and number of consultations as well as a reduction in the number of visits to the Emergency Department and the number of unplanned hospital admissions. Hence, patients who participate in these types of programs have a high degree of satisfaction, besides they become more informed about the processes in which they are involved.

It was also observed that the use of questionnaires about the patients' QoL is a tool for making possible the participation of these people in some of the analyzed studies [57][58]. The study of QoL has gained increasing importance in recent decades, and several questionnaires have been developed so that this aspect can be accessed in a standardized way. It can be noted that, in the previously mentioned studies, the same type of questionnaire – EORTC QLQ-C30 – was performed since this is often used when the participants involved are cancer patients. This questionnaire consists of 30 items and incorporates five functioning scales (physical, role, emotional, social, and cognitive functioning), three symptom scales (fatigue, pain, and nausea/vomiting), a two-item global health status/QoL, and some single items to access additional symptoms, commonly reported by cancer patients (namely dyspnea, appetite loss, insomnia, constipation, and diarrhea), as well as to realize the negative impact of this disease in financial terms [62][63][64]. All scores are linearly transformed into a 0-100 scale. Furthermore, it is noted that higher functioning scores represent a better QoL, whereas higher symptom scores represent nefarious effects for the patient. Also, it was found that both in the study published by Klinkhammer-Schalke et al. (2007), and Klinkhammer-Schalke et al. (2008), modules were added to these questionnaires. The reason behind this inclusion is because relevant information can be provided, in detail, to assess the QoL of a specific patient population. In the case of these two mentioned studies, the module used was the same – BR23 – since, in both cases, patients with breast cancer were involved. Side effects of treatment, arm symptoms, breast symptoms, body image, sexual functioning, alopecia, and future perspectives are items analyzed in the particular case of this module (see Appendix B). These questionnaires are a useful tool when integrated into the process of improving clinical pathways, and after patients answer to them, their responses are analyzed for obtaining QoL profiles. These results allow making recommendations by physicians [57] or experts [58] about which aspects can be changed to improve the QoL.

Finally, it is interesting to mention that, although there are few publications in which the active participation of patients is present in the clinical pathways modeling, some studies state that their involvement is an aspect that must be worked on in the future. As an example, in the study published by Van Hoeve et al. (2014), it was concluded that "future studies about effects of patients' satisfaction after the implementation of care pathways are necessary to estimate the value of pathways for patients and patients' quality of care". Sicotte et al. (2016) also mentioned this aspect, considering that, in future studies, the analysis of patient satisfaction should be taken into account as a form of feedback when a new clinical pathway is developed and implemented.

3.4. Methods Involved

Regarding the methods involved in the clinical pathways modeling, they are diverse. Through the analysis of the different articles, it was possible to note these methods can be divided into two main groups: when descriptive approaches are used (Table 3.4), and when the authors apply computational approaches (Table 3.5).

3.4.1. Descriptive Approaches to Analyze Pathways

Frequently, the data collected is only analyzed statistically, using more descriptive approaches. This is the case of the study published by Van Hoeve et al. (2014), whose objective to understand if the use of clinical pathways is related to the improvement in the quality of care delivered to patients with breast cancer. Here, quality indicators were analyzed before and after the implementation of clinical pathways, and it was possible to perceive, through statistical methods, that there was an improvement in terms of waiting- and throughput times after their implementation.

Also, Lefeuvre et al. (2017) used a descriptive approach to describe the used clinical pathways and the time interval between breast cancer treatments. For making this possible, data from hospitalization records were used to identify different types of patients, grouped them according to their breast cancer classification, who follow different types of clinical pathways since they need different treatments. Thus, it was possible to statistically analyze whether the time intervals between treatments were within the recommendations made by experts. This kind of analyzes is important to understand what are the aspects that need to be improved in the existing clinical pathways.

This type of approach is used repeatedly in more recent studies, such as in the study published by Te Marvelde et al. (2019). In this case, the objective was to investigate whether there is an association between improving patients' outcomes and the use of clinical pathways. Once again, only data presented in medical records were collected, as well as some characteristics of the patients that belonged to the studied population. These data were grouped according to the different stages that a cancer patient goes through, namely, prevention, diagnosis, treatment, and end-of-life care. Then, it was possible to understand if the patients' survival rates improve, by doing a comparison between results obtained when patients have their care aligned with clinical pathways and when usual care services are delivered. Through these types of approaches, it is possible to verify that the use of care pathways can improve patients' outcomes. Also, in other studies, different outcomes such as in-hospital mortality, length of stay, and costs are analyzed by using descriptive methods.

On the other hand, it is important to note that the Delphi method has also been used for modeling clinical pathways. This technique consists of a questioning process, performed in a sequence of rounds. It is noted that this type of participatory processes allows establishing an environment of communication, recognition of different perspectives, and knowledge construction among large numbers of people since, in each round, the participants will have access to the summary of the answers from the previous round, and they can change their responses in light of this new information, always anonymously. In this way, it is believed that, throughout the process, the range of responses will decrease, and the group of participants will converge on what will be considered the "correct" answer. In the article published by Alfano et al. (2019), this method was used, where the objective was to reach a consensus on what should be present in a personalized follow-up clinical pathway for cancer patients who had undergone treatments and who still need an appropriated follow-up care, according to their needs. At the end of this process, it was possible collecting information to understand how stratifying the clinical pathway in a better way.

Table 3.4. Identification of methods/ software involved in different analyzed articles and a summary of the purpose of their involvement. In the articles specified in this table, the authors used more descriptive approaches.

Authors	Methods/ Software involved	For what purpose are they involved?
Te Marvelde et al. (2019) [53]	data analyzed only statistically (statistical package R)	To **investigate if there is an improvement** in terms of the survival of cancer patients **when CPs are used**.
Kul et al. (2013) [54]	data analyzed only statistically (statistical package R)	To **investigate if there is an improvement** in terms of in-hospital mortality, length of stay, and costs **when CPs are used**.
Beyer-Berjot et al. (2017) [55]	satisfaction questionnaires analyzed only statistically (SPSS software)	To **demonstrate that there is an improvement** in the performance of training staff during surgeries **when a simulation-based care pathway approach is used**.
Mahony et al. (2019) [56]	data analyzed only statistically	To demonstrate that the use of the **Beast Cancer Nurses program brings benefits to patients** and, therefore, it is advantageous to integrate it into CPs.
Klinkhammer-Schalke et al. (2008) [57]	QoL questionnaires (EORTC QLQ-C30) analyzed statistically	To **have a view of patients and doctors both regarding the QoL of patients**, in order to implement a system of QoL diagnoses and therapy in CPs.
Klinkhammer-Schalke et al. (2007) [58]	QoL questionnaires (EORTC QLQ-C30) and QoL profiles	To **assess patients' QoL** when they undergo cancer diagnosis and treatment, to adjust the CPs used.
Lefeuvre et al. (2017) [59]	data analyzed only statistically (SAS software)	To **describe CPs** and the time interval between breast cancer treatments at the level of the entire population.
Van Hoeve et al. (2014) [60]	data analyzed only statistically (Stata software)	To **analyze quality indicators before and after the implementation of multidisciplinary CPs** to understand if their use is related to the improvement of care delivered to patients with breast cancer.
Alfano et al. (2019) [61]	Delphi method	To **reach a consensus** on what should be present in a personalized follow-up CP.

3.4.2. Computational Approaches to Analyze Pathways

In addition to this type of technique, in which the collected data only undergo statistical analysis, other methods are also applied in the clinical pathways modeling. This is the case of the article published by Daniyal et al. (2009), in which ontologies were used to create a decision support model. In this study, modeling a clinical pathway through an ontology consisted of creating a model in which concepts are defined within a given domain and the relationships that exist between them. In this paper, a cancer care planning and management system based on semantic web technologies were presented. For this to be possible, firstly, it was necessary to interview the health professionals who deliver care to cancer patients, to understand what processes are involved. Then, an ontology web language-based cancer clinical pathway ontology was developed, which represents the diagnosis, treatment, and operational concepts within the clinical pathway, in addition to linking these concepts using semantic and clinical pragmatic relationships. Finally, it was necessary to convert this model to an executable format and develop an execution engine to perform the clinical pathway with patient data. In this way, it was obtained a computerized system where, through the provision of data, it is possible to observe what are the actions that need to be performed, the decisions that can be made, satisfying possible constraints, and obtaining information about the possible next steps that need to be followed.

Moreover, in the paper published by Scheuerlein et al. (2012), the aim was also to develop clinical pathways, but this time according to the Business Process Modeling Notation (BPMN) and Tangible Business Process Modeling (t.BPM). Although these types of methods are usually applied in the context of industry and economics, it has been found that they can also play an important role in the health sector. In this study, firstly, the clinical pathway was created using the t.BPM method since learning the symbols and notations used is very intuitive, besides it can be built only with a large spread-out paper sheet. To make this possible, interviews were carried out with a medical, nursing, and administrative staff to design the skeleton of the clinical pathway, as well as to analyze more specific and complex cases. From the created model, it was possible to develop a pathway using the BPMN method, which, in general, is "a computer program which enables the description and a relatively easy graphical imaging of complex processes". Also, through this method, it was possible to carry out optimizations and simulations, in the sense that it is possible to analyze costs, increase of costs and their causes, as well as resources used in different scenarios.

It is also interesting to note that, in previous years, other authors have already resorted to using software for modeling clinical pathways, as well as using them to measure some outcomes. This is the case of the article published by Patkar & Fox (2008), whose objective was to create clinical pathways modeled using the PROforma software. In this study, it was intended to observe whether there are improvements in the care delivered to patients with breast cancer when physicians use decision-making tools. Since PROforma is "a guideline modeling language, in which clinical processes are represented in terms of "tasks" like decisions, plans, and clinical actions organized into processes, pathways, workflows", it was the software chosen to be used by the authors. Through the collection of guidelines used in clinical practice and information that can be presented as justifications and recommendations during decision-making, it was possible to model the complete journey of a breast cancer patient. After completing this step, simulations of patients with diversified clinical conditions were created to compare the differences in their outcomes when physicians use or not this tool. Through this publication, it was possible to conclude that decision support tools are appreciated in the making of more complex decisions, and the justifications presented during the decision-making increase the physicians' level of confidence. However, the software did not allow a flexible workflow, and, sometimes, physicians want to be capable of changing the order of certain tasks presented there.

The idea of using techniques that aim to improve the delivery of care to patients through the development of systems and integrate them into the clinicians' workflow, is also presented in other studies, as is the case of the article published by Sicotte et al. (2014). Here, it was analyzed how the implementation of an electronic medical record (EMR), designated as "a collective care pathway-oriented workflow system", brings beneficial results in terms of patients' waiting times. In this case, the created system can coordinate the sequence of activities that need to be followed by all staff members, who are treating patients, improving the communication and information throughout the continuum of care. Thus, it was possible to observe that the development and use of the EMR in clinical practice resulted in better-optimized sequencing and timing of the steps in the process, improving patients' waiting times. These are positive effects in a society where the average age of the population is constantly increasing, and the number of cancer patients continues to rise, making the delivery of optimizing cancer care something crucial.

Table 3.5. Identification of methods/ software involved in different analyzed articles and a summary of the purpose of their involvement. In the articles specified in this table, the authors used more computational approaches.

Authors	Methods/ Software involved	For what purpose are they involved?
Daniyal et al. (2009) [42]	ontologies	To **create a CP** that describing the steps to be followed, the decision options, and additional information using a system based on semantic web technologies.
Tsumoto et al. (2018) [43]	clustering techniques	To **form groups of processes** observed in medical records and decompose different clinical cases into categories, generating a CP for each subcategory.
Scheuerlein et al. (2012) [44]	t.BPM and BPMN methods	To **model a CP** using t.BPM since the learning of the symbols and notations used are more intuitive. The BPMN method was used to perform simulations and optimizations.
Patkar & Fox (2008) [45]	PROforma software	To **model CPs using the PROforma software as a decision-making tool** and observe if there are differences between physicians who use these tools and those who do not.
Sicotte et al. (2016) [46]	implementation of an electronic medical record (EMR)	To **analyze the changes in terms of patients' waiting times after the implementation of an EMR** dedicated to ambulatory cancer treatment.
Liu et al. (2018) [47]	machine learning (Bayesian network)	To **discover probabilistic dependencies** that exist between breast cancer data features and to identify their contribution to the diagnosis.
Taylor et al. (2019) [48]	machine learning techniques	Four different machine learning models were created to **make predictions about complications** resulting from a radical cystectomy.
Joranger et al. (2014) [49]	semi-Markov model	To describe how the costs associated with cancer care and its survival rates can be modeled. The probabilities of recurrence and death of patients were used.
Degeling et al. (2018) [50]	DT-STM and DES (AnyLogic software)	To **compare two simulation models used to make predictions** in cost-effectiveness analyzes of treatments in cancer patients.
Degeling et al. (2017) [51]	TA and DES (UPPAAL and AnyLogic software, respectively)	To **compare two simulation techniques** used to model personalized cancer treatment decisions.
Babashov et al. (2017) [52]	DES (SIMUL8 software)	To **model the entire radiation therapy planning process** and understand how to improve it, by analyzing **simulated scenarios**.

These are examples of articles whose authors used computational approaches for modeling clinical pathways. Also, it is interesting to note that, when analyzing Table 3.2, these are the articles whose main objectives are both the creation of new clinical pathways and the use of clinical pathways to measure outcomes. Moreover, Table 3.5 shows the methods used in the several analyzed articles, which were previously referred to in Tables 3.2 and 3.3. Many of these methods can be grouped into larger categories, among which supervised and unsupervised learning, stochastic modeling, and simulation techniques, which is further explain.

Supervised and Unsupervised Learning

Machine learning techniques are also applied in clinical pathways modeling. These types of methods can be used when one wants to improve the accuracy of the diagnosis and help healthcare professionals in decision-making. As an example of studies in which this approach has been applied, one can highlight the paper published by Liu et al. (2018). In this case, it was collected data from tests that are performed during the diagnosis of breast cancer and, then, a Bayesian Network (BN) modeling approach was used to discover probabilistic relationships between different data features of breast cancer. Therefore, using machine learning algorithms, the developed BN model can support clinical decisions when it is intended to know if a breast tumor is diagnosed as benign or malignant.

These techniques were also used in the article published by Taylor et al. (2019), aiming to create machine learning models capable of making predictions about complications and factors that cause an increase in the length of hospital stay and discharge to a higher level of care, after performing a surgery used in bladder cancer patients. In this study, four different predictive models were tested and compared to find out which one had the best performance. Through this approach, it was possible to make predictions about complications resulting from the surgery and identifying which are the variables linked to adverse events that result from it, allowing the creation of future strategies to reduce these postoperative adverse events.

In both of these studies, supervised learning techniques were used. However, it is also possible to apply unsupervised learning techniques in pathways modeling, as is the case of clustering techniques. This approach was used by Tsumoto et al. (2018), forming groups of medical processes, observed in medical records, to decompose the different clinical cases into several categories, generating a clinical pathway for each subcategory. Clustering is a technique which aims to automatically group data according to their degree of similarity and, therefore, in this study, as an attempt to replace what is manually done by physicians and nurses, schedules of medical care were created, which were optimized so that the management of clinical processes was more efficient. It has been concluded that plausible pathways have been obtained using this method.

Stochastic Modeling

Clinical pathways can also be modeled using other techniques, as in the study published by Joranger et al. (2014), where a semi-Markov model was applied. In this case, the objective was to estimate costs and survival times at different disease stages, using the probabilities of recurrences and death of patients. The created model can also be applied to estimate changes in resource use and costs when changing guidelines and adjust for future variations in treatment over time. Moreover, in this study, it was possible to observe an improvement in outcomes when a timely diagnosis of cancer patients was made.

Simulation Methods

Simulation methods can also be utilized for pathways modeling, indeed, in several studies, as presented in Table 3.5, the authors resort to the discrete event simulation (DES) method. This is a method of simulating the behavior and performance of a real-life process, having been currently applied in healthcare services. Generally speaking, DES models a system as an ordered sequence of well-defined events over time, assuming there are no changes in the system between events. Therefore, these events correspond to changes in the system's state at a specific point in the time, for example, when a test is performed. It is also interesting to note that, in two different studies, this simulation method was compared with others – discrete-time state-transition modeling (DT-STM) [50] and timed automata (TA) [51] – and, in both cases, the DES was considered as the preferable one. In these cases, simulation methods were used for analyzing patients' outcomes during cancer treatment, as well as the costs associated with them.

Furthermore, DES also allows testing hypothetical scenarios, when it is intended to answer the question "what if?". Thus, as was the case of the paper published by Babashov et al. (2017), it was possible to apply this technique to model the patient's complete journey, including resources and constraints. In this specific case, the DES method was used to observe the impact on waiting times and delays, when the number of available physicians and dosimetrists changed. Hence, DMs were able to test different alternatives, analyze changes in the performance of a hospital, and understand what the best solutions are, before implementing them in real cases.

In fact, simulation methods have gained particular interest, and the great proliferation of these methods is evident in the field of medical research and medical service management. Besides DES, there are other simulation techniques, with different characteristics, such as system dynamics (SD) and agent-based modeling (ABM) [7][11].

3.5. Comparing Different Simulation Methods

DES can be considered as a classical operational technique, designed to optimize the performance of the most varied types of systems at a very detailed level. It is a modeling approach that has a stochastic nature, being quite suitable for queuing network systems, where state changes occur at discrete points of time. Also, the entities that populate the model move stochastically along with the queuing system and activities, whose durations are sampled from probability distributions. Lorenz & Jost (2006) stated that DES can capture "detail complexity", "the system behavior that results from the possible combinations of many random processes, coupled with the system structure, leading to interconnection effects". However, DES presents limitations, which are related to the fact that this technique is unable to adequately capture the feedback dynamics associated with the holistic structure of a system, it requires a great amount of data to populate these models, and there is the need of performing multiple replications, so this technique has long runtimes associated to it [65].

SD, on the other hand, is a more strategic tool used to understand the overall system behavior. Unlike DES, it is an approach less concerned with detail, having a top-down perspective. The basic principle behind this technique is that the structure of a system determines its behavior over time. In this case, Lorenz & Jost (2006) stated that SD models capture "dynamic complexity", defined as "the way variables can influence one another causing nonlinearities, delays and accumulative or draining relationships". When quantitative SD modeling is performed, the use of stock-flow diagrams is required. These models can be conceptualized as a system of tanks connected by pipes, where water flows. Here, the rate of flow is controlled by taps or valves, and the water, which flows through the system, is a continuous and homogeneous quantity. SD models are therefore deterministic, producing the same result run after run, and not capturing individual variability. Mathematically they are described as a set of ordinary differential equations that represent the rates of changes in the level of each stock [66].

Although these two approaches (DES and SD) have different characteristics and, therefore, are used in different situations, it is also interesting to note some studies try to combine the two techniques. These publications state there are real-life problems that cannot be categorized separately as being strategic or operational. In the paper of Viana et al. (2014), a DES model from an outpatient clinic in a UK hospital was combined with an SD model that provided an understanding of the complex dynamics involved in the spread of the sexually transmitted infection Chlamydia, and an assessment of the impact of different interventions. Thus, the benefits of both techniques were combined in order to study how the prevalence of an infection at the community level affects operational level decisions made in a hospital outpatient department [65][66].

On the other hand, it is also necessary to highlight the ABM technique, which can be considered an extension of DES. ABM approach is also stochastic by nature, but it provides an extremely detailed representation of the interaction between agents. Agents are autonomous (self-directed) entities that follow a set of predefined rules to achieve their goals while interacting with each other and with their environment. Furthermore, in this approach, there is no concept of queues.

Lorenz & Jost (2006) highlighted a set of features that characterize this simulation technique: (1) models an agent that has an individual behavior and observes the behavior that exists in the interaction of a population of these agents; (2) describes and demonstrates how the interaction of independent agents creates a collective phenomenon; (3) identifies single agents whose behavior has a predominant influence on general behavior; (4) identifies crucial points in the time when qualitative changes occur.

When compared with the DES approach, it is possible to observe that, in a DES model, the entities are not independent and self-directed. Moreover, in the ABM approach, each agent has its own behavior and, therefore, can be classified as "active". Conversely, in a DES model, the entities' behavior is determined by the system and, consequently, they are classified as "passive" [66].

Regarding the use of these simulation techniques in the healthcare sector, DES models are those that stand out the most, being cited as "the most powerful and intuitive tool for the analysis and improvement of complex healthcare systems" [67].

3.6. Challenges of Discrete Event Simulation

DES is a decision support tool that is used widely to solve problems in several areas, such as industrial management, manufacturing, among others [68]. However, it is important to note this is a tool whose main objective is to improve the comprehension that a user must have regarding the functioning of a system. A DES model should not be built to accurately predict the behavior of a system, nor should be thought that it can replace human reasoning in decision-making processes. This simulation method does not provide the "correct" solution for solving a problem. The model should be used by DMs for understanding and being able to respond to the behavior of different variables (elements, resources, queues) that are part of the system as well as the relationships that exist between them.

Depending on the complexity of these systems, further analysis may need to be performed about their behavior. These systems can involve many elements and variables that interact with each other simultaneously, and therefore, it is necessary to observe and evaluate several decision criteria, which deal with multiple objectives. Thus, another decision support methodology can be incorporated, as is the case of multicriteria decision analysis (MCDA), expanding the capacity of DES, and thus creating a decision support system (DSS) that combines these two methodologies [68].

3.7. Multicriteria Decision Analysis in Healthcare Systems

MCDA is a structured DSS technique used to deal with problems, in which multiple and complex criteria influence the decision process, allowing the visualization of the logical/rational structure of the problem, representing and quantifying the importance of its elements, relating them according to the general objectives, and allowing the execution of tradeoff studies.

Authors state that the main advantages of MCDA are "the maintenance of the unity of the problem, complexity understanding, criteria interdependence relationship representation, capability of measuring criteria preference, maintenance of consistency, synthesis, tradeoff evaluation, consideration of decision-makers' value judgements, and consensus reaching" [68].

Moreover, several studies use this approach to successfully address highly complex problems, which have multiple objectives. Oliveira et al. (2012) built a multicriteria model, using a socio-technical approach, where decision conferences and the MACBETH method were used to choose which programs should be invested by healthcare centers in Portugal. Also, it was taken into account the existence of a limited budget to cover such programs. Through this study, it was possible to conclude which programs should be funded, that is, which are the ones that present a cost-benefit ratio that fits with the objectives of healthcare centers, and that respect the financial constraints [69].

In the article published by Bana e Costa et al. (2012), a multicriteria model was built, once again using the MACBETH method, so that managers could measure the performance of a predictive maintenance program and its added value for a Spanish hospital. The MACBETH method allowed the creation of an audit model, proving to be important for the continuous improvement of maintenance policies. The model was based on qualitative judgements about the differences in attractiveness between the performance levels of the predictive maintenance program, in the multiple dimensions of auditing. Moreover, this approach was used at three different moments, that is, in an initial phase, six months, and one year, after improvements were made in the hospital systems [70]. Thereby, it was possible to observe that the score associated with the chosen criteria increased in general, which revealed the scope of these improvements. Also, it was possible to identify which criteria did not have its score increased over time, allowing to reflect on what necessary actions need to be taken to enhance the situation.

3.8. Combining DES with MCDA

Considering the aspects observed in this literature review, it is possible to conclude that different techniques are suitable to use when clinical pathways are attempted to be modeled. However, the literature does not provide many studies where MCDA is combined with other Operational Research and Management Science methods [14]. Furthermore, it was possible to conclude through the previous sections that while DES is a tool that discovers alternatives that fit in a satisfactory way with the needs of users, MCDA allows quantifying the importance of the multiple elements, which are part of the different alternatives [68]. In this way, MCDA should be seen as an integral part of problem-solving methodologies. For example, combining simulation with MCDA allows to obtain the performance of a system in different situations and also to convert this performance into value scores. Moreover, this integration enhances greater engagement with the final user.

In the next chapter, a methodological approach that integrated a DES model with a multicriteria evaluation model built with the MACBETH method. The application of this approach can fulfill the objectives of this thesis once it can assist DMs at IPO-Lisboa so that better healthcare can be delivered to patients, namely, to breast cancer patients. As will be presented later, the long waiting times between the processes that make up the journey taken by a patient at this institution, are one of the outcomes that have a particular interest in being measured and analyzed. Bearing this in mind, a simulation method, and more particularly the DES method, appears to be an appropriate technique, since, as previously mentioned, it is able to model a system as an ordered sequence of well-defined events over time, as well as allowing to test what could happen in hypothetical scenarios. Moreover, the combination of this method with the approach of an MCDA will also allow dealing with problems that present multiple criteria, enabling users to make better decisions taking into account their objectives, preferences, and concerns.

4. Methodological Approach

In this chapter, it is proposed a novel methodological approach to assist DMs at IPO-Lisboa to improve the clinical pathways, more specifically those that are used in the breast cancer healthcare delivery. Moreover, there is the aim to combine approaches used in clinical pathways modeling with VBHC instruments.

4.1. General Overview of the Socio-Technical Approach

From the literature review, it was possible to conclude that the use of simulation methods seems to be the most suitable approach to model clinical pathways so that they can be analyzed, and improvement proposals can be discussed. On the other hand, it was also concluded that the combination of simulation models with MCDA is an effective tool in decision-making processes in complex systems. Also, it promotes a greater engagement with the participants involved, whose perspectives need to be considered to understand how added value can be generated.

This chapter presents a social-technical approach [71] that integrates these two methods for achieving the objectives of the study. The combination of these methods has a strong social component with the collaboration of several stakeholders, and this involvement is essential for constructing and validating all the developed models. Also, there are multiple points of view to consider in the decision-making processes. Figure 4.1 illustrates the main steps that constitute this methodological approach, which will be detailed throughout this chapter.

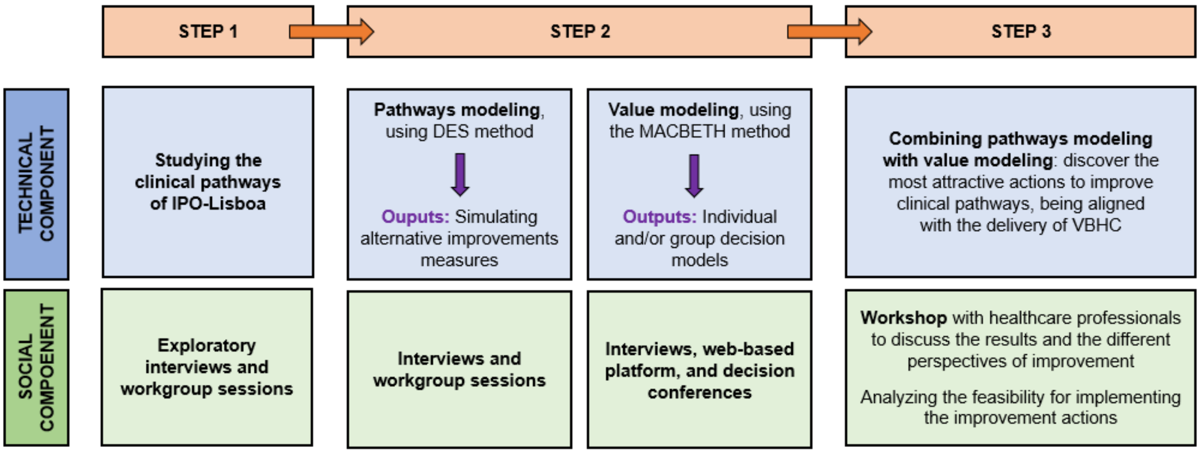


Figure 4.1. Methodological approach steps.

With the elements involved in this approach, it is possible to build a bridge between classical methods that analyzes the efficiency of processes and VBHC instruments (Figure 4.2). It is important to remember that the value in healthcare is not only directly related to the benefits that are reached but also with components that result from the individual experiences. To realize how value is added to a healthcare system, it is necessary to consider the view of different professionals, who are responsible for performing activities that constitute the patient's journey. Thus, by adding value to the hospital's activities, it becomes possible to add value to the care delivered to patients.

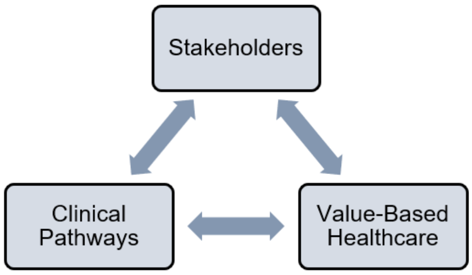


Figure 4.2. Three main elements involved in the methodological approach.

Each step of the methodological approach includes a technical and a social component. In Figure 4.3, the steps of this approach are presented in more detail.

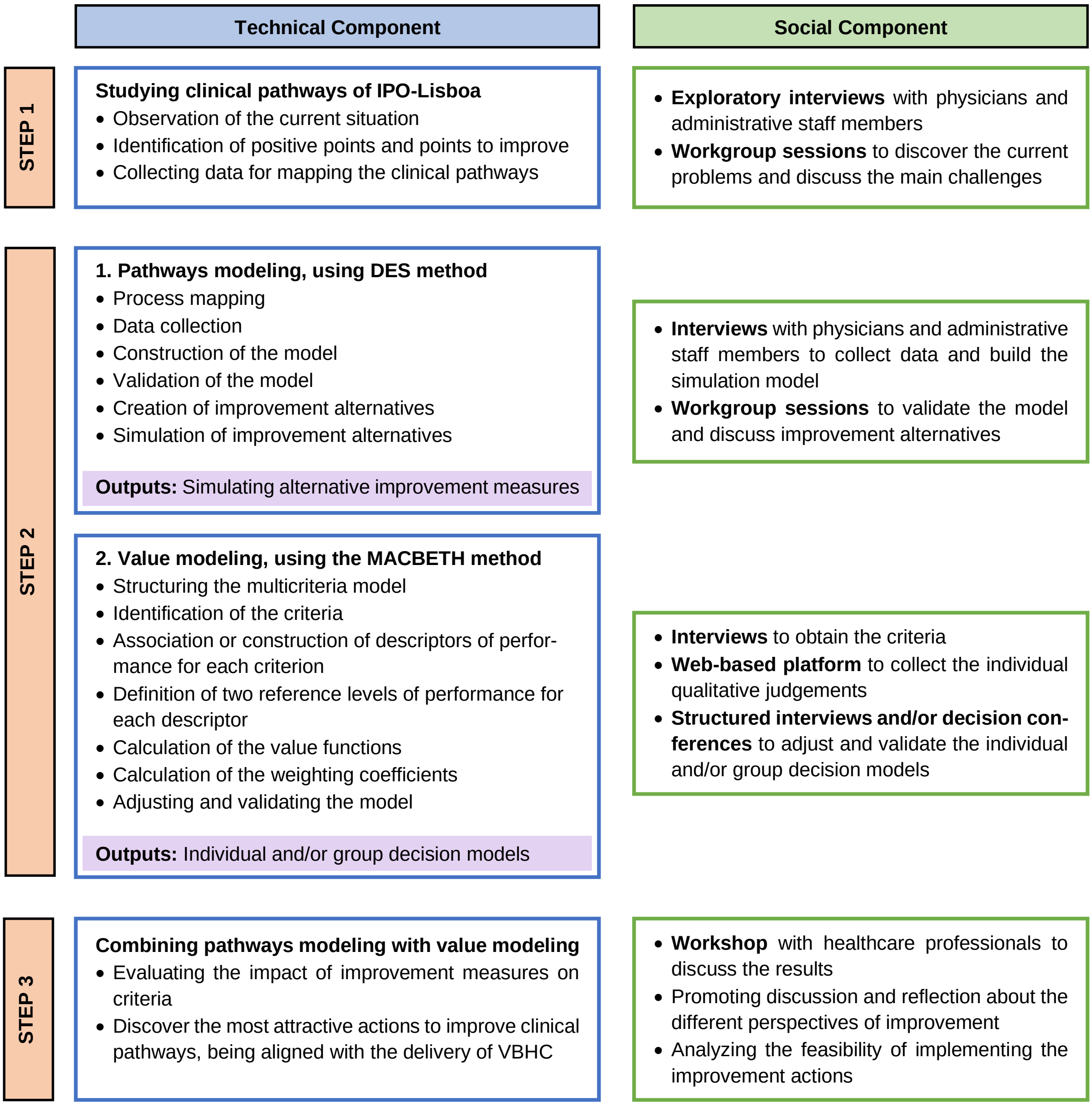


Figure 4.3. Detailed methodological approach steps within a socio-technical structure.

Studying Clinical Pathways of IPO-Lisboa

Firstly, if the objective of this study is to create tools to improve the clinical pathways used in breast cancer healthcare delivery, they need to be studied. Through exploratory interviews with physicians and administrative staff members, it is possible to discuss the current situation of the pathways.

Furthermore, as a way to understand which are the positive and negative aspects, data from previous projects should be examined. Thus, and with the participation of different stakeholders, it is possible to realize how to improve the delivery of care at this hospital.

Pathways Modeling

Then, a simulation model needs to be created for modeling the clinical pathways used in breast cancer healthcare delivery. A specific technique will be used to build this model: the DES method [11]. The advantages of using this method will be presented later in this chapter, as well as the stages of constructing this type of model. The simulation model can be implemented using the SIMUL8 software.

Regarding the social component presented in this step of the methodological approach, physicians and administrative staff members must participate in order to collect the necessary data for the construction of the model, as well as its validation. Also, it must be discussed with them how the clinical pathways could be enhanced, through the proposal of alternative improvements that can be simulated in the model.

Value Modeling

Multicriteria decision models are also created to help different stakeholders in decision-making processes. In the context of this study, the use of these tools becomes imperative since multiple criteria must be considered. Thus, when DMs choose, among several, which is the most attractive proposal to improve a process, they need to be assisted by these types of models, which take into account their objectives, values, and preferences. To build the multicriteria decision model, the MACBETH method and the M-MACBETH software will be used [12].

For structuring and constructing the model, interviews are conducted with different stakeholders, to obtain their fundamental points of view, when the objective is to discover how value is generated through the IPO-Lisboa activities. Also, their participation is essential to obtain the qualitative judgements necessary for constructing and validating the decision model.

Combining Pathways Modeling with Value Modeling

Finally, it is possible to combine the simulation model with the multicriteria evaluation model. In this chapter, it will be explained how these models are integrated in order to discover the most attractive actions to improve the clinical pathways, being aligned with the delivery of VBHC.

The combination of these techniques is responsible for promoting discussion and reflection about the different perspectives of improvement. Also, it is crucial to highlight that the feasibility of implementing the improvement actions must be analyzed to complete the decision-making process.

4.2. Step 1: Studying Clinical Pathways of IPO-Lisboa

For studying the clinical pathways of this hospital, it is necessary to collect information regarding the current situation, namely the positive points and the ones that should be improved. To complete this task, exploratory interviews with different stakeholders should be conducted, and data from previous projects may be examined.

In this section, the breast cancer pathways will be analyzed by using data from the Patient Centricity Project (PCP), a study carried out at IPO-Lisboa in 2018, as was mentioned in Chapter 2. The data from this project were provided by healthcare professionals of this hospital.

4.2.1. Breast Cancer Pathways

Along their journeys at IPO-Lisboa, breast cancer patients go through different services, where they attend several consultations, perform exams and treatments.

In Figure 4.4, an illustrative journey of these patients is presented. It is also important to mention there are still other hospital services that are not present in this illustration, namely the unscheduled attendance service (UAS) – in Portuguese, *serviço de atendimento não programado* –, the nuclear medicine service, the clinical pathology service, the pathologic anatomy service, and the psychology service.

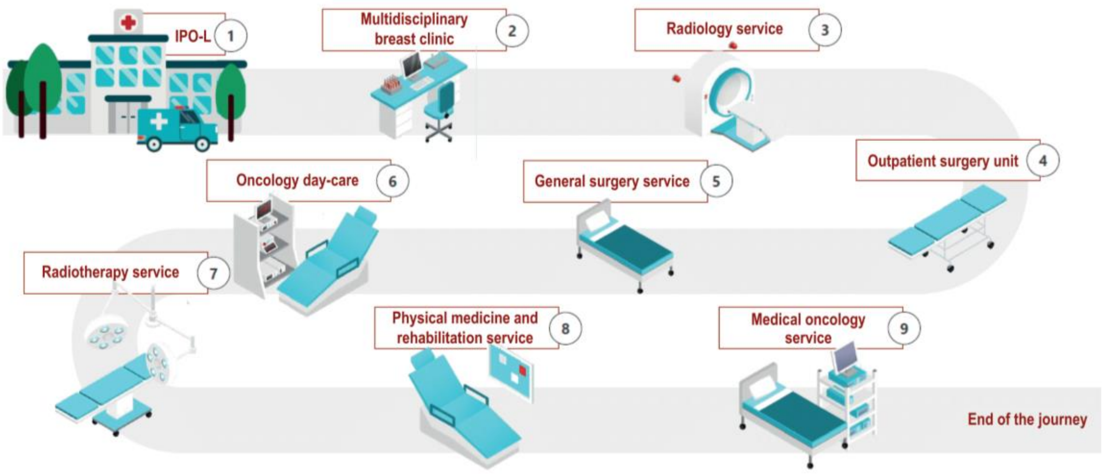


Figure 4.4. Illustrative representation of the services where breast cancer patients pass by along their journeys at IPO-Lisboa [Adapted from the Patient Centricity Project].

The hospital services present in Figure 4.4 are the following ones:

(1) **IPO-L:** this "service" represents the institution as a whole, that is, aspects related to the admission of patients, the processes, infrastructures, and healthcare professionals, in a generalized way.

(2) **Multidisciplinary breast clinic:** where the first consultations, subsequent consultations, and surgical/therapeutical decision consultations of breast cancer patients take place;

(3) **Radiology service:** the place where one seeks to provide the best diagnostic imaging, articulating with all hospital services that prescribe exams in this department;

(4) **Outpatient surgery unit:** where patients enter, when they are going to perform surgeries with no forecast of post-surgical hospitalization;
(5) **General surgery service:** the place where patients who need to stay in the hospital undergo surgeries;
(6) **Oncology day-care:** where chemotherapy treatments are performed;
(7) **Radiotherapy service:** where treatments that use radiation are performed;
(8) **Physical medicine and rehabilitation service:** where patients have consultations and treatments with physiotherapists;
(9) **Medical oncology service:** the medical oncology service is divided into two pavilions. In the *Pavilhão da Escola de Enfermagem*, consultations are held with patients with metastatic breast disease, and, in the *Pavilhão de Medicina*, there is the ward service.

As it was previously stated, if one has the objective of enhancing the current hospital pathways, it is crucial to gather information about the positive aspects and the main points that should be improved.

In the PCP, testimonies from patients were collected in different hospital services, where they pass by, along their journeys, aiming to evaluate their experience, with the ambition of understanding how it could be possible to improve the healthcare delivery.

4.2.2. Observations of the Current Situation at IPO-Lisboa

The satisfaction expressed by patients can be referred to as the sum of a set of different elements, namely their relationship with professionals, the perception of processes and infrastructures, as well as material resources, combined with beliefs, values, expectations, and previous experiences. It is also important to note that the needs, constraints, and expectations of patients change significantly according to their age.

In the PCP, three personas were created, that is, fictional characterizations of a typical patient, to represent the different groups of female patients. Table 4.1. presents a summary of the characteristics of these three profiles. Regarding male patients with breast cancer, a single person was interviewed, presenting a different profile compared to the other ones. Therefore, the information collected in this interview was analyzed separately.

Table 4.1. Fictitious characterization of the three typical patients of different ages who have diverse needs, constraints, and expectations during their journeys at IPO-Lisboa.

Persona	Representation	% of the interviewed patients
Persona 1 (P1)	It represents women aged up to 45 years	17
Persona 2 (P2)	It represents women aged between 46 and 65 years old	38
Persona 3 (P3)	It represents women over the age of 65	45

Through the analysis of the several interviews, it was possible to observe that patients, their family members, and healthcare professionals presented multiple positive points during the journey at the hospital, but also highlighted a great set of points that should be improved.

Patients

It was possible to observe that patients consider IPO-Lisboa as being a multidisciplinary hospital, and they have a good relationship with healthcare professionals. Patients reported that there are a great dedication and affection from all workers, and consider that the message system with prior notification of treatments has a good functioning, as summarized in Table 4.2.

Table 4.2. Summary of the positive points reported by the interviewed patients, the percentage of patients who highlighted these points and services where these points were most referenced, as well as the personas who most highlighted them.

Positive points	**Services where these points are most referenced**					**Personas who most highlight these point**		
Relationship with professionals (68%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Prior notice of treatments (11%)	1	2	3	4	5	P1	P1	P3
	6	7	8	9	UAS			

As summarized in Table 4.3, the interviewees detected, as the main problems, the long waiting times in the different services and, given a large number of patients, the inappropriate conditions of the infrastructures. From their perspectives, the waiting rooms are small and sometimes noisy, and car parking does not have enough parking spaces. Moreover, some services are dispersed, which is a constraint for patients who are weak and who need to travel between the different pavilions. There is also the perception that the low capacity response in different situations is due to the lack of human resources, which also causes difficulty in telephone contact.

Table 4.3. Summary of the points to improve reported by the interviewed patients, the percentage of patients who highlighted these points and services where these points were most referenced, as well as the personas who most highlighted them.

Points to improve	**Services where these points are most referenced**					**Personas who most highlight these points**		
Long waiting times (73%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Infrastructures with inappropriate conditions (39%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Inadequate communication (27%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Difficulties in telephone contact (19%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Holding consultations without exam results (17%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Perception of insufficient human resources (17%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Decentralized hospital services (16%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Waiting rooms with inappropriate conditions (16%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			
Car parking constraints (15%)	1	2	3	4	5	P1	P2	P3
	6	7	8	9	UAS			

Family Members of Patients

By interviewing patients' family members who accompany them in their consultations and treatments, it was possible to highlight that many of them (50%) revealed a high level of confidence in the competence and capacity of the IPO-Lisboa professionals. Also, 40% of the interviewees considered that there is a good relationship established between them and the healthcare staff. In this way, patients' family members have considered this institution as being the country's leading specialist in oncological diseases and have shown that health professionals are attentive, establishing a good close relationship with patients, which is beneficial in the delivery of health care.

Concerning the points that should be improved, the most outstanding was the fact that the car parking does not have enough parking spaces (25% of family members mentioned this problem), and also 15% of the interviewees considered the existence of communication failures between professional teams, that can cause constraints in the delivered care. These participants also have the perception that there are constraints in the computer system, and that the management of surgery appointments is inadequate. Regarding the infrastructures, they considered that the spaces are insufficient and small, namely the waiting rooms, as well as the fact that there are pavilions with difficult access.

It was also possible to observe that 35% of the family members considered that their presence during the patients' journey is essential, facilitating the whole process. Moreover, 25% of interviewees showed some fear and uncertainty about the pathway and consequences that may result from the disease. Some of them mentioned they would like to be more informed in order to provide greater support to patients.

Healthcare Professionals

Through interviews with healthcare professionals, it was possible to identify that some of them consider this hospital as the best place to work, showing that there is a good relationship between teams, a spirit of sharing, and a good working environment, besides physicians referring as a positive point the fact that in this institution there is an update of scientific knowledge. In general, this group of participants also recognized that there is a great humanization in the treatment of patients and a positive relationship between patients and health professionals, as summarized in Table 4.4.

Table 4.4. Summary of the positive points reported by the interviewed healthcare professionals, the percentage of healthcare professionals who highlighted these points and services where these points were most referenced.

Positive points	Services where these points are most referenced				
Relationship between teams (48%)	**1**	2	3	4	5
	6	7	8	9	UAS
Relationship with patients (13%)	1	**2**	3	4	5
	6	7	**8**	9	UAS

Healthcare professionals considered as being excellent the fact that the IPO-Lisboa culture always puts the patients in the first place, providing them all the necessary support. Thus, in the multidisciplinary dynamics of the hospital, the patient is always the center of concern, which is extremely important and positive.

On the other hand, Table 4.5 summarizes the aspects that IPO-Lisboa needs to improve from the point of view of healthcare professionals. It is possible to observe that all the interviewees, without exception, considered that the main problem is related to the fact that human resources are insufficient due to the high number of patients that have been growing, consequently causing an overload of work. Some interviewees mentioned that they feel demotivated by the fact that they do not receive the desired professional recognition. Also, many healthcare professionals highlighted several services that have small dimensions and the lack of adequate ventilation, as is the case of waiting rooms, which were considered small and with an insufficient number of chairs.

Table 4.5. Summary of the points to improve reported by the interviewed healthcare professionals, the percentage of healthcare professionals who highlighted these points and services where these points were most referenced.

Points to improve	Services where these points are most referenced				
Insufficient human resources (100%)	1	2	3	4	5
	6	7	8	9	UAS
Lack of installed capacity (57%)	1	2	3	4	5
	6	7	8	9	UAS
Small size premises (48%)	1	2	3	4	5
	6	7	8	9	UAS
Work overload (48%)	1	2	3	4	5
	6	7	8	9	UAS
Infrastructures with inappropriate conditions (35%)	1	2	3	4	5
	6	7	8	9	UAS
Lack of professional recognition (35%)	1	2	3	4	5
	6	7	8	9	UAS

Through the analysis of this data and having in mind the objectives of this thesis, it is possible to highlight the interest in modeling the hospital pathways in order to analyze them and discover the impact caused by improvement changes in the process.

4.3. Step 2.1: Pathways Modeling

Simulation techniques can be used to model the hospital pathways. These are valuable tools since currently, and as has been mentioned several times, there is great pressure in the healthcare sector, regarding the fact that the main objectives are to provide high-quality healthcare services and to maximize operational efficiency. At the same time, there is the aim to control operating costs, reducing those that are unnecessary [11][72].

In this section, the essential steps to build a simulation model using the DES method and its characteristics will be described, as this was the chosen technique to be used in the methodological approach of this thesis, cited in the previous chapter as a powerful and intuitive tool to analyze and improve complex healthcare systems [67].

4.3.1. Discrete Event Simulation (DES)

As described in the literature, "DES is a type of computer-based modeling that imitates the operation of a real-world system" [11]. The term "discrete" is due to the fact that DES moves at discrete intervals over time, that is, the model makes instantaneous jumps between the time for a given event and the time for the next one. Thus, the model's events are discrete, that is, mutually exclusive [11][73].

Generally speaking, the main functions of this technique are: (1) to analyze a system before its implementation; (2) understand the functioning of an existing system; (3) improving the functioning of an existing system; (4)compare results from hypothetical situations.

Moreover, the main reasons that justify the use of this simulation technique can be emphasized, which include: the fact that the real system does not exist, and then the simulation is employed as a tool to project the future; the experimentation with the real system is expensive, using the simulation to avoid unnecessary expenses; and the fact that the experimenting with the real system is not appropriate [68].

DES was developed in the 1960s and used in the fields of industrial engineering and operational research, helping to analyze and improve industrial processes and business. However, through the years, DES models have become popular in the health sector, being seen as effective tools for the allocation of resources and improvement of the patient flow, which can lead to a reduction in costs and an improvement in patient satisfaction. According to data from the literature, in this sector, the use of DES has as its main objectives: (1) improving patient flow; (2) managing bed capacity; (3) scheduling staff; (4) managing patient admission and scheduling procedures; (5) using ancillary resources (e.g., labs, pharmacies) [11][74].

Moreover, and unlike static tools, such as spreadsheets, DES can model interactions between different departments. It allows DMs to be able to test many what-if scenarios, analyzing the impact that some changes have on multiple variables, and modifying solutions until an optimal scenario is obtained. For example, by using DES, it is possible to demonstrate the negative impact that high rates of bed occupancy can have on waiting times in the emergency department of a hospital.

In order to understand how this approach works, it is necessary to take into account what its key elements are and how they relate to each other, as depicted in Figure 4.5. The key elements of DES models include: [11]

- **Entities:** entities (or work items) represent what will flow through the system that is being studied. In the case of the healthcare sector, entities can represent, for example, patients, lab specimens, supplies, among others;
- **Arrival rates:** arrival rates are defined as the rates at which an entity arrives at a specific location. This information can be extracted from several sources, namely, historical archival data, EMRs, and schedules;
- **Locations:** the location is based on the floor plans and represents the physical areas where the entities are processed;
- **Resources:** resources are defined as what is responsible for processing entities throughout the system. In the case of the healthcare sector, they include both human resources and medical equipment. Information about available resources can be obtained through organizational staffing schedules and equipment inventory;

- **Service Times:** service times are defined as the time required for resources to process entities. It is based on the time an entity spends at each stage of a process. This information can be obtained through staff interviews, EMRs, or on-site observations. Also, in many industries, including the health sector, service times follow a specific probability distribution, such as exponential, and lognormal [11][74];
- **Queues:** if a resource is "occupied" when an entity needs it, then that entity needs to wait, forming a queue. Queues can have a maximum capacity and how entities exit them can take into account different approaches, namely, first-in-first-out (e.g., a typical waiting room queue), last-in-first-out, or when some kind of priority is defined [73];
- **Processing logic:** links all the model elements together, determining the rules for how entities flow through the system and how resources and entities interact [11].

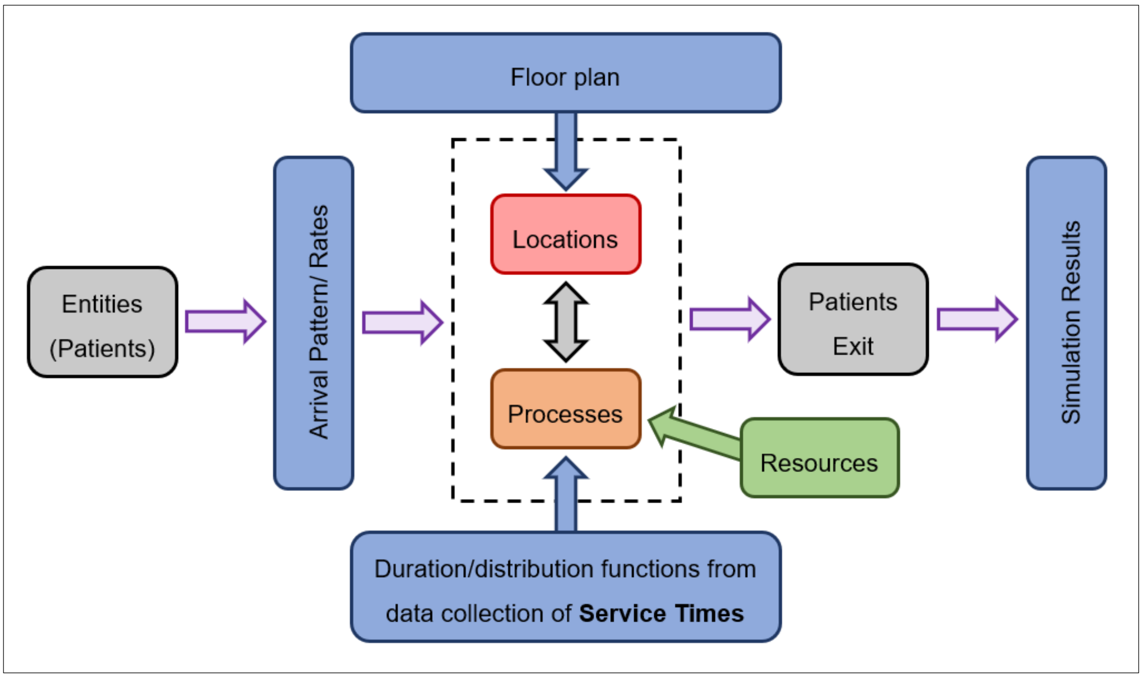


Figure 4.5. Key elements of discrete event simulation models. Adapted from [11].

4.3.2. Developing a DES model

Frequently, healthcare DMs use subjective information provided by staff members, providers, and other stakeholders so that decisions are made in order to improve hospital processes. However, changes made both at the structural level (e.g., change in floor plan or layout) and at the level of processes, are attempts to improve the current system, which can often be demonstrated costly in terms of time and capital.

In this sense, DES emerges as a valuable tool, as it is a low-risk and low-cost method to develop strategies, test assumptions, and observe potential outcomes. Thus, DMs can use computational methods and make decisions before their implementation [74].

When a system is modeled using a DES approach, this process contains the following steps:

- **Defining objectives for the simulation:** a DES must have clear objectives. Typically, in the health sector, one may want to analyze whether the space used is sufficient, whether the human resources and equipment used are able to provide efficient healthcare delivery, among others. Nevertheless, it is important to focus on a small number of goals. A narrowed focus reduces the complexity of the model, reducing the time required to complete the simulation;
- **Process mapping:** it can be considered as the pictorial representation of the workflow, for example, of a hospital, helping stakeholders to understand which processes are involved;
- **Data collection and analysis:** the extraction of appropriate data is fundamental in simulation techniques. Patient arrival patterns and volume, time distribution in the exam room, and staff schedules are examples of input data for the simulation model;
- **Constructing the base model:** the base model is built using historical data and using simulation software packages, such as MedModel, Arena, FlexSim, SIMUL8, and others. The base model needs to be verified and validated to understand if the computer model is a correct representation of the real-world system;
- **Sensitive analysis with simulation scenarios:** by changing parameters of interest, various simulation scenarios can be tested. In this step, an analysis of what would happen in hypothetical scenarios is made, for example, when changing the number of available resources, the location of certain activities, or changing schedules. According to the literature, it is recommended a systematic approach to introduce changes to a DES model, which involves changing one model's component at a time. Thus, it is possible to analyze the effects of these changes in isolation to understand which ones have the greatest impact in terms of the performance of the modeled system [11][74];
- **Results analysis:** the results are subsequently analyzed. Simulation outputs can include the number of patients in the system, the length of stay of patients in the system, analysis of queues, use of staff, among others;
- **Designing and planning decisions:** the results obtained are used to inform DMs about the consequences caused by certain changes. The performance of the different scenarios is analyzed in order to find an optimal solution that meets the initial objectives and the norms of the system that is being modeled [11].

It can be noticed that this method includes a strong social component to develop the DES model. In this sense, interviews must be conducted with the different stakeholders involved in the simulated process in order to define the objectives of the simulation, to structure and validate the model, and to discuss improvement alternatives, which will be simulated.

In the next chapter, it will be presented how this method was implemented in the case study, taking into account all the necessary steps for the development of a simulation model. Furthermore, it is also important to highlight that it was chosen the SIMUL8 software for constructing the model. SIMUL8 was launched in North America in 1995 and is a simulation tool used by engineers in worldwide companies [75]. It is an object-oriented modeling tool, incorporating a programming language with model visualization capabilities, having an easy-to-use interface, and allowing the rapid creation of robust simulations.

4.4. Step 2.2: Value Modeling

In the healthcare sector, decision-making is usually a complex task that involves confronting tradeoffs between multiple objectives, which can often be conflicting [76]. In this sense, it is crucial to develop models capable of measuring the value of the options involved in the decision-making process to discover which of them are the most attractive for the DMs.

Thus, it is necessary to build a multicriteria decision model, which is based on the fact that different concerns can be grouped into a single model, in an understandable and flexible way, in which its construction includes the collection of qualitative judgements. This type of approach allows the simplification of a complex problem into several smaller ones, which are analyzed independently and then integrated into a global analysis [77].

4.4.1. Multicriteria Decision Analysis (MCDA)

As stated in the literature review, while a simulation model allows discovering alternatives that fit with the needs of users, MCDA enables quantifying the importance of the multiple elements, which are part of the different alternatives. That is, with this approach is possible to understand how added value is generated by alternatives proposed to improve the clinical pathways that are being simulated.

Studies claim that an MCDA can help DMs to make more transparent and robust decisions, according to their preferences and values [69]. An MCDA requires a socio-technical design, in which the social component is related to the fact that it is necessary to identify who are the participants, and when and how they should be part of the process. The technical component, on the other hand, refers to which MCDA methods are being used, as well as the software chosen to carry out such analysis [76]. The socio-technical process improves communication within an organization, develops a sharing of knowledge, and generates a sense of common purpose about those projects that best achieve the objectives of the organization [71].

Social Component

As above-mentioned, an MCDA has a social component. Firstly, it is very important to develop a clear description of the problem at hand, defining which are the objectives of the DMs, by doing interviews with them [76]. In the case of this project In this way, there is an attempt to understand with healthcare professionals how value is generated by the IPO-Lisboa activities, which are part of the breast cancer patients' pathways.

Then, it is necessary to carry out meetings that count on the participation of key players who wish to solve important problems that are occurring in their organization. These meetings are attended by a facilitator, an expert in decision analysis, who works as a consultant of the process, using a model that has relevant data, which were collected in a first phase, as well as judgements created on-the-spot, which assist the DMs to be able to think more clearly about the problems at hand. It should be noted that the model is used to help for thinking and learning, not giving the correct answer or finding the optimal solution. Therefore, the model is “requisite”, that is, “sufficient in form and content to solve the issues at hand”, providing satisfactory and non-controversial answers to the questions that are being asked, and which are the motivation behind the construction of the model [71][76]. The facilitator, on the other hand, is guided by the principles of the consultancy process, and a particular principle that states: “it is the client who owns the problem and the solution”. Thus, he/she only has the function of guiding the DM or group of DMs regarding how they should think about the problems, and not what to think [70][71].

These are structured meetings and they are made up essentially of four steps, which are: (1) exploration of the issues; (2) structuring and building a model; (3) exploring the model; (4) agreeing to the way forward [71]. Through this procedure the individual or group multicriteria evaluation models are created. To build individual models, structured interviews are conducted, allowing to solve the problem rapidly and efficiently. On the other hand, decision conferences must be carried up when group models are intended to be built, enabling a greater sharing of knowledge and opinions to make higher quality decisions with a higher degree of acceptance [71].

Technical Component

Regarding the technical component of an MCDA, it is necessary to use a method capable of responding to the problems at hand. As it is referred to in the literature, a popular method to perform this type of analysis is MACBETH (Measuring Attractiveness by a Categorical-Based Evaluation Technique). [69] Bana e Costa et al. (1994) described this as an interactive approach that requires only qualitative judgements on the part of the DMs in order to measure the attractiveness of the existing options in the decision process [78].

For the application of the MACBETH method, it is necessary to use a user-friendly software named M-MACBETH, which allows the implementation of the entire multicriteria model. By using this software, for each time the judgements are expressed, their consistency is verified automatically, suggesting changes that must be made in the judgement matrix when inconsistencies arise [12][70][79].

4.4.2. Measuring Attractiveness by a Categorical-Based Evaluation Technique

In this study, the MACBETH approach was used to develop the multicriteria model. This technique uses a simple question-answer protocol, which involves only two options in each question, asking the evaluator to pairwise compare options by given a qualitative judgement of the difference in attractiveness between two options [78].

The MACBETH is a non-numerical method that generates numerical scores based on the qualitative judgements of the DMs. For each criterion, its value score is multiplied by its weighting coefficient. By aggregating this multiplication in an additive way to all criteria, an overall score is calculated for a given option, which reflects its attractiveness for the DMs [77]. The weighting coefficients, k_j, allow each partial value unit, v_j, to be converted to a global value unit, V. Then, one can mathematically determine the global value for each alternative, a, through the following additive model:

$$V(a) = \sum_{j=1}^{n} k_j v_j(a), \quad (1)$$

where $V(a)$ represents the overall value of option a, $v_j(a)$ the partial value of option a in terms of criterion j and k_j is defined as the weighting coefficients of criterion j [77]. The additive value model must meet the following conditions:

$$\sum_{j=1}^{n} k_j = 1 \text{ and } k_j > 0 \text{ with } j = (1,2,\dots,n); \begin{cases} v_j(target_j) = 100, \ \forall_j \\ v_j(current\ state_j) = 0, \ \forall_j \\ V(target\ overall) = 100 \\ V(current\ state\ overall) = 0 \end{cases} \quad (2)$$

To develop a multicriteria model, is necessary to identify the factors that interfere with DMs' choice, defining and clarifying the criteria considered relevant, which are also named Fundamental Points of View (FPV) [77]. The first step of this method is the structuring of the problem, in which it is important to represent all the decision components. Thus, through interviews, it is necessary to identify the factors that interfere with the DMs' choice, defining and clarifying the criteria considered relevant, which are also named Fundamental Points of View (FPV) [77]. To ensure that the analyzed criteria are consistent, they must meet the following conditions: [80]

- **Complete**, which include all the fundamental aspects to evaluate decision alternatives;
- **Controllable**, to identify the consequences of each alternative and its influence;
- **Measurable**, which defines precise objectives and allows the assignment of values to determine how they can be achieved;
- **Operational**, to render the collection of information required for an analysis reasonable considering the time and effort available;
- **Decomposable**, ensuring the independence of the criteria;
- **Non-redundant**, in order to prevent possible consequences from being considered more than once;
- **Concise**, restricting the number of assumptions to consider to those that are relevant;
- **Understandable**, to facilitate generation and communication of insights guiding the decision-making process.

Descriptors of Performance

For each criterion, a descriptor of performance must be associated or constructed so that the criterion becomes intelligible [70]. This descriptor consists of a set of impact levels, ordered by preference, and serve to objectively describe the impacts of alternatives concerning a criterion, which can be done either quantitively or qualitatively. It is important to note that there must be no ambiguities when classifying the performance of an alternative. Also, redundancy should not be introduced in the model, with each descriptor being assigned to only one criterion.

Moreover, the model also uses two reference levels for each descriptor. For instance, it can be adopted an approach that considers the “good” and “neutral” levels, which are referred to as a good and minimal acceptable proposal, respectively [77][79]. Also, the “good” level can be represented as a “target” that DMs want to achieve, and the “neutral” level as the “current state” of performance, as is the case of this study.

Value Functions

After defining the criteria and their descriptors of performance, the obtention of value functions is enabled using the M-MACBETH software. A value function is required to assign scores to the performance levels of a descriptor concerning fixed scores of 0 and 100, which are assigned to the “current state” and “target” reference levels, respectively [69].

In the software, each criterion has a judgement matrix where each cell is filled out with the DMs qualitative judgement about the difference in attractiveness between each pair of performance levels. For making qualitative judgements, the following categories of difference in attractiveness are used: “no difference”, difference “very weak”, “weak”, “moderate”, “strong”, “very strong”, and “extreme”, or a union of two successive categories.

It is important to bear in mind that there is no need for collecting all the judgements, although the more they are filled out, the better. Thus, if there are *n* levels of performance, it is only necessary to collect *(n-1)* judgements, and the not provided ones are filled up by the software through transitivity.

From the consistent set of judgements, M-MACBETH software proposes value scores for the performance levels by solving a linear programming problem (see Appendix C). Thus, it is created a value function, which is compatible with this matrix, and which must be validated by the DMs, that is, they must agree with it [12][69][79].

As collecting the judgements is a time-consuming task, alternatives to acquire this information may be used. For instance, through the creation of a web-based platform, the DMs can answer questions at their own pace and when it is most convenient for them.

Weighting Coefficients

Subsequently, it is also necessary to obtain the weights of each criterion, for which the following procedure is used: (1) the DMs are asked for ranking, in decreasing order of attractiveness, the swings between the “current state” and “target” levels in all the criteria; (2) the DM qualitatively judges the overall attractiveness of each swing, thus filling out the last column of the matrix of weighting judgements; (3) if desired, the DMs pairwise compare every two swings, completing the rest of the matrix [69]. Once again, this is a time-consuming process, so the usage of a web-based platform is a strategy to expedite this step of the MACBETH approach [12].

Afterward, the M-MACBETH software computes the weighting coefficients for each criterion. At the end of this process, the DM must be asked to validate the weights proposed and, when necessary, adjust the values obtained or even review the judgement matrix [12][70].

In the next chapter, it will be presented how this method was implemented in the case study, taking into account all the necessary steps for the development of a multicriteria decision model. As will be explained, in this case, individual models will be developed to understand how value is generated by IPO-Lisboa activities, thereby considering different points of view.

4.5. Step 3: Combining Pathways Modeling with Value Modeling

From the literature review, it is possible to state that the combination of simulation models with multicriteria decision models proves to be a useful approach when it is intended to analyze complex problems that deal with multiple objectives of different stakeholders [68]. In this study, the intention is to create tools that help DMs to discover how the clinical pathways used in IPO-Lisboa can be improved.

Thus, when using a simulation model of these hospital pathways, it is possible to obtain simulation alternative improvement measures. On the other hand, with this information, the multicriteria model is able to assess the impact of improvement measures on the criteria that are considered in the study. Basically, from the outputs of the simulation model, inputs are obtained for the multicriteria model, which will be able to identify which improvement alternatives are most attractive to the stakeholders involved in the study. The relationship that is then established between these two models is illustrated in Figure 4.6.

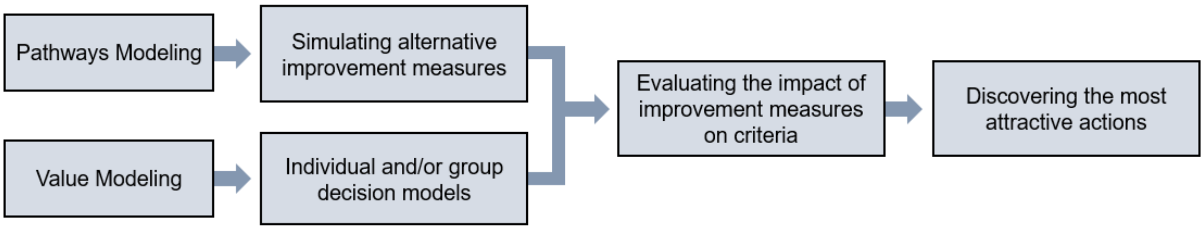


Figure 4.6. Relationship between the simulation model and the multicriteria decision model when combined.

These two types of models can then be combined for: (1) understanding the most attractive actions to improve the clinical pathways used in healthcare delivery, considering that these improvements must be aligned with the delivery of VBHC; (2) promoting discussion and reflection about the different perspectives of improvement; (3) analyzing the feasibility of implementing the improvement actions.

The implementation of this methodological approach (particularly its second step) in the case study will be presented in the next chapter, in which it will be explained how the involvement of different stakeholders allowed the construction of a simulation model and multicriteria decision models.

5. Implementation of the Methodological Approach

As mentioned before, a methodological approach was created, aiming to assist DMs at IPO-Lisboa in the improvement of the clinical pathways used in the delivery of VBHC at this hospital, namely to the breast cancer patients. In this chapter, it will be described how this approach was applied in the case study, particularly its second step.

5.1. Pathways Modeling

In this study, the objective is to model the clinical pathways traveled by breast cancer patients at IPO-Lisboa, using the DES method to create a simulation model. Thus, it is necessary to complete several steps in order to develop this model correctly. Through this model, it is possible to analyze the impact caused by changes in the pathways when improvement alternatives are simulated.

5.1.1. Process Mapping with Flowchart

Having in mind the objectives of the model development, it was necessary to map the process that was going to be simulated. Through interviews with different stakeholders (namely, 5 physicians and 3 administrative staff members), it was possible to realize there was a particular interest in analyzing the clinical pathway in a specific time interval, that is, from the first consultation at the multidisciplinary breast clinic (MBC) to the performance of the surgery.

Figure 5.1 illustrates a flowchart, representing the clinical pathway that most breast cancer patients go through, which was based on the information present in the IPO-Lisboa quality manual. In the flowchart, an oval represents a start or an endpoint, an arrow is a connector that shows the direction of the flow, a rectangle represents a process, and a diamond indicates a decision [81].

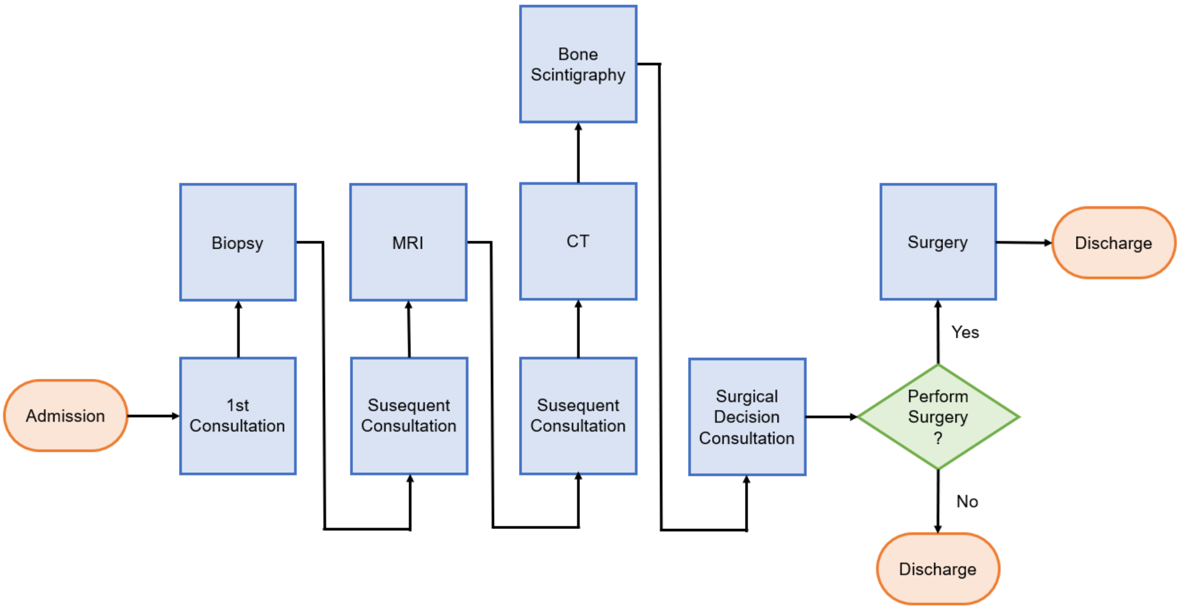


Figure 5.1. Flowchart of breast cancer patients' clinical pathways at IPO-Lisboa.

As was discussed with the different physicians and administrative staff members involved in this study, the provenance of the patients who enter this pathway can be diversified. For instance, they can be referred from healthcare centers to IPO-Lisboa for the first time, or they can already be IPO-Lisboa patients. However, the different origins of the patients were not considered, being defined that all of them begin the clinical pathway with the first consultation at the MBC, followed by a biopsy (at the radiology service). After this first exam, patients are submitted to three different exams: MRI and CT, both performed at the radiology service, and bone scintigraphy, performed at the nuclear medicine service. During the performance of these exams, patients also need to attend subsequent consultations so that physicians at the MBC can assess the situation state of these patients.

After all these exams and subsequent consultations, a surgical decision consultation (SDC) is carried out. This consultation aims to decide whether the patient will undergo surgery or not. According to data provided by IPO-Lisboa, in 2018, 69.9% of patients underwent surgery after SDC, with the remaining 30.1% beginning to start neoadjuvant chemotherapy treatment before any surgery. It should also be noted that these two alternatives are the result of the choice of a multidisciplinary team from the MBC in order to adapt the clinical pathway to the patients' needs.

For the purpose of the simulation model, neoadjuvant chemotherapy was considered as an exit point from the analyzed process since the main objective of the pathway modeling was to examine the journey from the first consultation until the surgery was performed.

5.1.2. Data Collection and Constructing the Base Simulation Model

After the first outline of the process was completed, in collaboration with MBC physicians, it was necessary to build it using a simulation software (in the case of this study, the SIMUL8 software) [82].

To build and run the simulation model, it was then necessary to collect data to populate the model. Thus, interviews were conducted with healthcare professionals from the MBC, the radiology service, and the nuclear medicine service. It is also important to note that only the MBC presented some of its data in an electronic format, all of which being corresponded to the year 2018.

The data collected were all from 2018, which were the following:

(1) number of breast cancer patients who traveled through the pathway represented in the flowchart in Figure 5.1;
(2) number of physicians who performed consultations at the MBC;
(3) number of consultations performed by a given physician at the MBC;
(4) number of exams performed per day;
(5) waiting time for scheduling exams and waiting time for obtaining their results;
(6) number of surgeries performed per month;
(7) percentage of patients who underwent surgery after SDC;
(8) waiting time between the first consultation and the SDC, waiting time between the SDC and the surgery, and waiting time between the first consultation and the surgery (average and maximum values).

Analyzing Table 5.1, it is possible to observe that, in 2018, 1468 patients traveled through the pathway represented in the flowchart in Figure 5.1, as this was the number of first consultations performed at the MBC. In this way, and for the purpose of the model, it was considered that, on average, 5.77 patients entered this circuit per day, from Monday to Friday. Having this in mind, an exponential distribution was associated with the entry point, in the SIMUL8 software. This is a classic distribution used for arrival rates of anything where one arrival is independent of the next one, as customers arriving at a store, or, as in the case study, patients who entered a hospital [82].

On the other hand, through the data present in Table 5.1, it was also possible to observe that although seven physicians attend consultations at the MBC, the number of consultations varies between them. The reason for this is essentially due to the fact that some physicians own multiple functions, not having the same workload to carry out consultations. However, for the purpose of the simulation model, it was considered that all physicians had the same availability, simplifying the model. Thus, it was considered that each physician performs, on average, 5.27 consultations per day, five days a week. Since only this average value was used, these activities were associated with an average distribution in the simulation software.

Table 5.1. Number of consultations performed per physician at the MBC, in 2018.

			N	%
Therapeutical/Surgical Decision Consultations			2588	27.9
General Consultation	**1st Consultation**	**Subsequent Consultations**	6702	72.1
Physician 1	289	979	1268	
Physician 2	245	993	1238	
Physician 3	361	1347	1708	
Physician 4	288	887	1175	
Physician 5	207	833	1040	
Physician 6	51	91	142	
Physician 7	27	104	131	
Total	**1468**	**5234**	**9290**	**100**

Period: 1 Jan, 2018 – 31 Dec, 2018

In Table 5.2, it is possible to observe that of the four performed exams, only one of them has a minimum waiting time for its performance, and three of them possess a minimum waiting time for obtaining their results. Consequently, it was only necessary to analyze, in more detail, the number of MRIs performed per day. There was no need to consider this information in the other three cases since it had reported that the number of tests performed per day is sufficient to cover the number of patients who need to perform them, and therefore, there is no need for scheduling in those cases. Through interviews with physicians at the radiology service, it was found that 5 MRIs have been usually performed per day, with a minimum of 4 of these exams being performed and a maximum of 8. Having this in mind, a triangular distribution is associated with this activity in the simulation software.

Appendix D presents information regarding the clock properties of the simulation model as well as the distributions associated with the patients' entry, the consultations performed at the MBC, and the four exams performed along the pathway.

Table 5.2. Information regarding the need for scheduling an exam of the clinical pathway, the minimum waiting time to perform the exam, and the minimum waiting time to obtain its results.

	Biopsy	MRI	CT	Bone Scint.
Need for scheduling	No	Yes	No	No
Minimum waiting time to perform the exam	--------------	5 days	--------------	--------------
Minimum waiting time to obtain the exam result	10 days	2.5 days	[not consider]	6 days

Finally, Figure 5.2 shows the number of surgeries performed per month in 2018. From these data, it was possible to calculate how many surgeries were performed, on average, per day in each month. In the simulation software, a probability profile was associated with this activity, in which all the mentioned information was contemplated. Moreover, it was also considered a minimum waiting time of 10 days associated with the performance of these surgeries, according to data provided by the MBC.

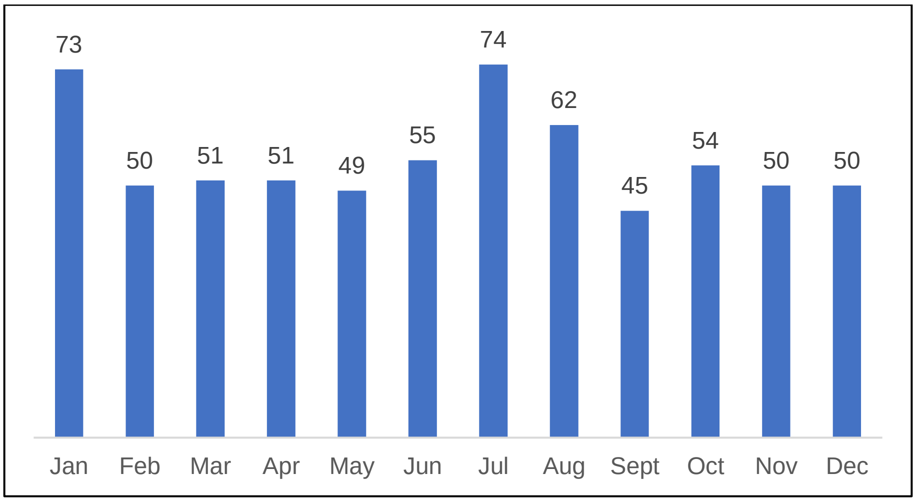


Figure 5.2. Number of breast surgeries performed per month in 2018.

In this way, all the information and data necessary to build the simulation model were obtained. Figure 5.3 illustrates how the model layout was implemented in the SIMUL8 software, which represents the clinical pathway of breast cancer patients at IPO-Lisboa. Through this user-friendly DES package, it was possible to create a visual model of this pathway by drawing different objects directly on the screen.

In the layout model, all the activities of the flowchart of Figure 5.1 are represented, as well as an entry point, which corresponds to the admission of patients, and the two possible exit points of the flow. It is also observed that after carrying out the SDC, a decision must be made and, therefore, in Figure 5.3, two branches correspond to the two possible choices, and a certain probability of occurrence is associated with each of them.

Furthermore, once the activities are carried out in different hospital services, three colored rectangles have been drawn, delimiting the main services: the MBC, the radiology service, and the nuclear medicine service. All activities (consultations) that are performed at the MBC are represented in an amount equal to the number of physicians who are available to perform these consultations.

The objects present in the simulation model built and their meaning are shown in Table 5.3 [82].

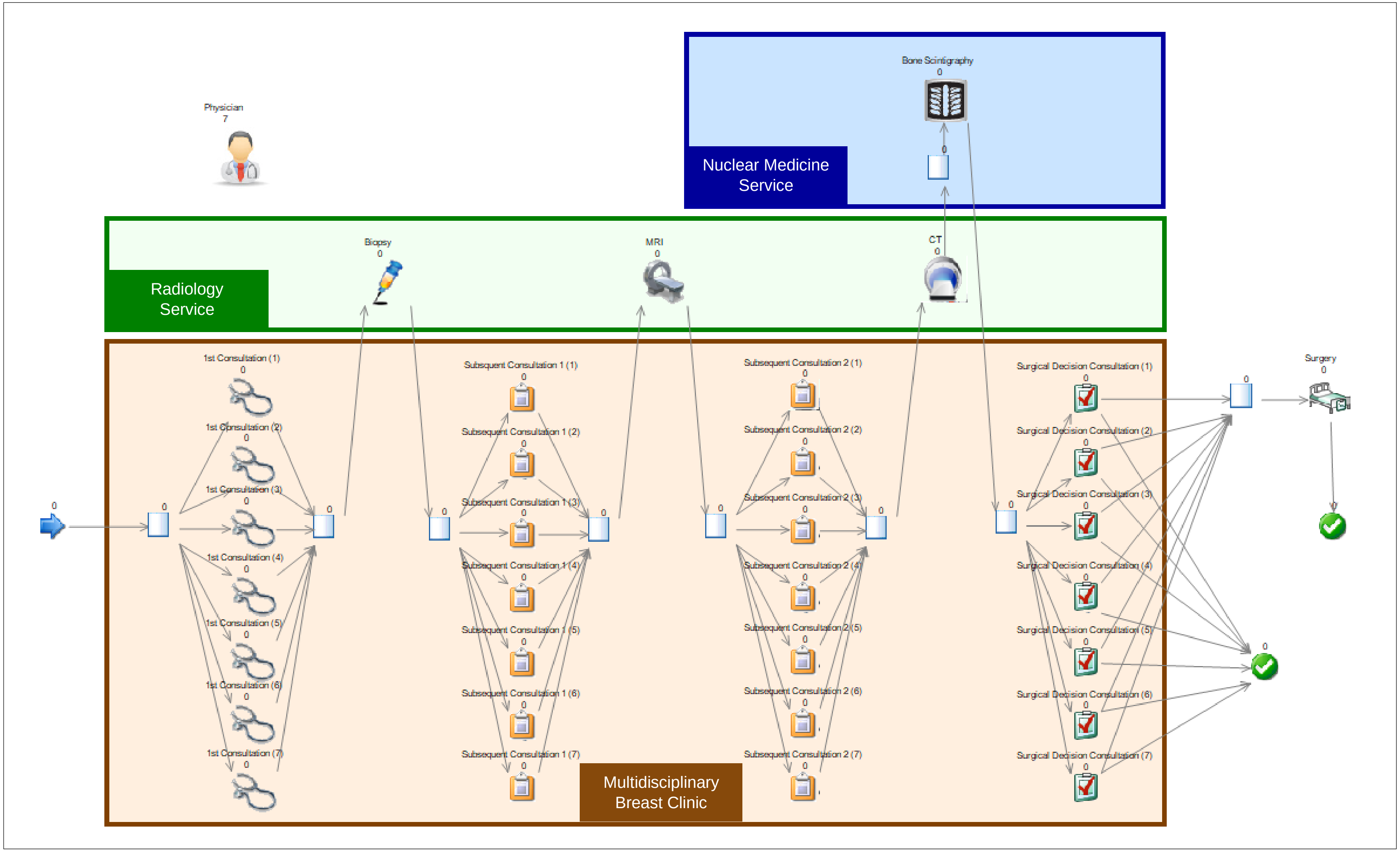


Figure 5.3. Computational implementation layout of the breast cancer patients' clinical pathway at IPO-Lisboa, using SIMUL8.

Table 5.3. SIMUL8 objects and their respective symbols used in the simulation model.

Objects	Symbols	Meaning
Work Entry Points		Work Entry Points are the places where Work Items enter the system. In this study, there is only one Work Entry Point that corresponds to the arrival of patients with breast cancer who are ready to start going through the flow of activities. The inflow is controlled by a statistical distribution.
Work Centers	(1)  (2)  (3)  (4)  (5)  (6)  (7)  (8) 	Work Centers are the places where Work Items go through and where different activities are carried out. Usually, each activity takes a particular amount of time to be carried out (represented by different statistical distributions) and may require resources to complete it. In this study, eight different types of Work Centers were defined: (1) First Consultation; (2) Biopsy; (3) Subsequent Consultation; (4) MRI; (5) CT; (6) Bone Scintigraphy; (7) Surgical Decision Consultation; (8) Surgeries.
Resources		Resources may be necessary for a specific Work Center to be able to carry out its activity. The availability of resources can be controlled through the use of shifts. In the case of this study, the resources represent the physicians at the MBC, who are necessary to carry out the following activities: First Consultation; Subsequent Consultation; Surgical Decision Consultation.
Queues		Queues are the places where Work Items wait until Work Centers and/or Resources are available. In this study, many of the Queues have a minimum waiting time associated with them, representing the minimum amount of time necessary for scheduling an activity (for example, in the Queue immediately before the MRI). Also, the minimum waiting time for obtaining the results of an activity (an exam), which is essential to perform the following activity (for example, at the Queue immediately after the Biopsy).
Work Exit Points		Work Exit Points are where Work Items leave the simulated system. In the case of this study, there are two Work Exit Point, one immediately after Surgical Decision Consultation and the other after Surgeries.

5.1.3. Validation of the Simulation Model

After constructing the simulation model, it is necessary to proceed with its validation. Thus, it was run to simulate the period of one year, more specifically the year 2018. However, at the beginning of the simulation, the system is empty, which does not correspond to reality, as this was not the opening year of the hospital. Thus, a warm-up period of 90 days was used since this is the average time a work item takes to go through the entire system. Therefore, the use of a warm-up period helps the model to be calibrated, creating realistic starting conditions [73].

When running the simulation model, the results summarized in Table 5.4 were obtained. It is observed that the waiting times between the first consultation and the SDC, the waiting times between the SDC and the surgery, and the waiting times between the first consultation and the surgery are very similar to the times recorded in the real system when both the average values and the maximum values are compared.

Table 5.4. Comparison between data from the real situation at IPO-Lisboa and outputs of the simulation model.

	Real Situation	Simulation
Number of patients	1468	1475
Number of days between first consultation and SDC (on average)	51	52.19
Number of days between first consultation and SDC (maximum)	68	62.38
Number of days between SDC and surgery (on average)	46	46.57
Number of days between SDC and surgery (maximum)	74	79.33
Number of days between first consultation and surgery (on average)	103	95.56
Number of days between first consultation and surgery (maximum)	134	137.76

Thus, it was possible to validate the simulation model since it is able to produce a very approximate representation of the real situation. These results were also presented to the stakeholders involved in the study, all of whom have revealed a high level of confidence about the built model. In this way, when using it to simulate hypothetical alternatives, that is, making changes to the parameters of elements present in the simulation model to observe its impact on the simulated clinical pathway, one has the confidence that the obtained results can, in fact, represent a hypothetical reality [11][74].

During the meetings to obtain the validation of this model, all the involved participants have realized the importance of this validation, which allowed them to understand how the model works and what its potential is.

5.1.4. Simulation of Improvement Alternatives

After the construction of the simulation model, the objective was to observe what would be the impact caused by hypothetical improvements in breast cancer patients' clinical pathways. In this sense, the different stakeholders involved in the study, namely physicians and administrative staff members, considered that the fundamental points of change were associated with three aspects:

(1) decreasing the minimum waiting time to obtain the biopsy results;

(2) increasing the number of MRIs performed per day;

(3) increasing the number of surgeries performed per month.

Thereby, seven improvement proposals were created, where different combinations of the three points of improvement highlighted by the stakeholders are presented. The participants of this study have considered interesting to analyze the following actions:

(1) decreasing the minimum waiting time for biopsy results from 10 to 6 days;

(2) doubling the number of MRIs performed per day in the current situation;

(3) increasing the number of surgeries performed per month by 40%.

Table 5.5 presents the values of the three analyzed aspects of each improvement proposal. In the next chapter, the outcomes obtained for these hypothetical improvements by using the simulation model will be presented. Moreover, it was also discussed with the different stakeholders which actions need to be taken in order to achieve these improvements. Once again, the results of these discussions will be presented in Chapter 6.

Table 5.5. Input parameters for alternative improvements in the clinical pathways at IPO-Lisboa.

Improvements	Minimum waiting time to obtain the biopsy results	Number of MRIs performed per day	Number of surgeries performed per month
Improvement 1	6 days	current number	current number
Improvement 2	10 days	2×(current number)	current number
Improvement 3	6 days	2×(current number)	current number
Improvement 4	10 days	current number	1.4×(current number)
Improvement 5	6 days	current number	1.4×(current number)
Improvement 6	10 days	2×(current number)	1.4×(current number)
Improvement 7	6 days	2×(current number)	1.4×(current number)

5.2. Value Modeling

This study aims to create methods that assist the DMs of IPO-Lisboa in decision-making processes. As these are complex processes with multiple criteria, the construction of an appropriate multicriteria decision model is necessary [76]. In this section, it will be presented the stages that have been completed in order to develop this model correctly, using the MACBETH method.

It is also important to note that this is an approach with a strong social component, thereby involving different stakeholders for constructing the multicriteria model. Exploratory interviews with healthcare professionals (namely, 5 physicians and 3 administrative staff members) were conducted for structuring the problem, defining the criteria and the descriptors of performance. On the other hand, two individual multicriteria decision models were built, one for a physician and the other for an administrative staff member. In this way, to calculate the value functions and the weighting coefficients, a web-based platform was used to collect the qualitative judgements of the health stakeholders, and structured interviews were conducted to adjust and validate the models.

5.2.1. Structuring the Problem and Defining the Criteria

The reason behind the need to develop a multicriteria decision model is due to the fact that it is important to build tools for assessing how value is generated by the IPO-Lisboa activities, highlighting the healthcare services delivered to breast cancer patients during their journey to surgery. In this way, several interviews were carried out with healthcare professionals, namely physicians and administrative staff members, to understand their fundamental points of view when it comes to answering the question "How value is generated by the IPO-Lisboa activities?". Essentially, it was sought to obtain the necessary information in order to define the criteria of the multicriteria decision model.

The interviews have addressed only topics to explore, not being restricted to a questionnaire with answer options to fill out. This approach is in accordance with the concept of value-focused thinking, originating conversations with stakeholders, in which they share their objectives and concerns. Thus, besides trying to understand how value is generated by the IPO-Lisboa activities, these interviews have also tried to comprehend how healthcare delivered to patients can be improved, as this is an institution that always considers patients as the center of their concerns [80].

After conducting these exploratory interviews, it was then possible to define the criteria of the multicriteria decision model. Figure 5.4. presents the value tree built in the M-MACBETH software, in which the identified criteria are highlighted in red.

The definition of these criteria was based on the fact that different stakeholders have considered as essential that the delivery of healthcare services might be accessible to all patients and that the improvement of patients' quality of life is one of the major objectives of the work carried out in this institution. Moreover, the services provided by IPO-Lisboa acquire greater value when their activities are performed efficiently. In the case of this study, breast cancer patients need to undergo several exams during their journey. Therefore, from the point of view of the stakeholders, it is important to perform these exams as soon as possible, without patients waiting for long periods. Also, the exam results must be obtained in a short period so that patients are not blocked in the system and are able to move forward.

Thereby, in the value tree of Figure 5.4, the five criteria that allow generating value through the activities of IPO-Lisboa are identified. It is possible to observe that the value can be generated directly for patients, in three of the criteria ("Access to diagnosis", "Access to surgery", and "Quality of life"), or it can be generated from the usage of hospital resources and equipment, in the case of the other two criteria ("Efficiency in performing exams" and "Speed in obtaining exam results").

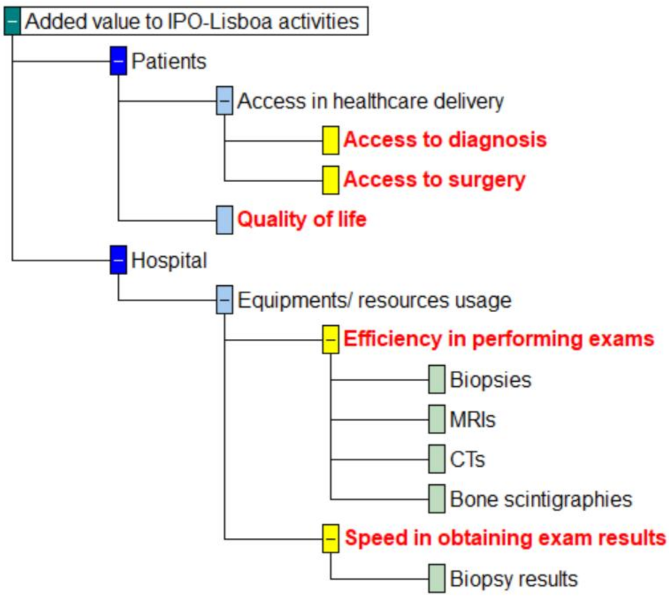


Figure 5.4. Value tree structure underlying the added value generated by the IPO-Lisboa activities.

5.2.2. Descriptors of Performance

For each of the criteria, it was necessary to associate or build a descriptor to measure its performance so that the criteria are operational. Moreover, in each descriptor, two reference levels were defined, essential to obtain the weighting coefficients. The choice of these levels was made based on the fact that the "current state" level represents the current situation in all criteria and the "target" level represents the level that the different health stakeholders intend to achieve, considering it as a satisfactory level of performance [70][77][79]. Table 5.6 presents, for each criterion, their descriptors of performance levels and the respective reference levels.

Table 5.6. List of the evaluation criteria and respective descriptors of performance levels. Each descriptor of performance has the reference levels identified as "TARGET" and "CURRENT STATE".

Criteria	Descriptors of Performance Levels
Access to diagnosis	The time interval between the first consultation and the SDC is: **L1:** 25 days **L2:** 35 days – **TARGET** **L3:** 45 days **L4:** 55 days – **CURRENT STATE** **L5:** 65 days.
Access to surgery	The time interval between the SDC and the surgery is: **L1:** 15 days **L2:** 25 days – **TARGET** **L3:** 35 days **L4:** 45 days – **CURRENT STATE** **L5:** 55 days
Quality of life	**L1:** The maximum time for diagnosis and the maximum waiting time for surgery (after the SDC) are both lower than the recommended values, that is, lower than 43 days and 13 days, respectively. **L2:** The maximum time for diagnosis and the maximum waiting time for surgery (after the SDC) are both approximate to the recommended value, that is, 43-47 days and 13-17 days, respectively. – **TARGET** **L3:** The maximum waiting time for surgery (after the SDC) is greater than the recommended value (>17 days). However, the maximum time for diagnosis is approximate to the recommended value, that is, 43-47 days. **L4:** The maximum time for diagnosis is greater than the recommended value (>47 days). However, the maximum waiting time for surgery (after the SCD) is approximate to the recommended value, that is, 13-17 days. **L5:** The maximum time for diagnosis and the maximum waiting time for surgery (after the SDC) are both greater than the recommended values, that is, greater than 47 days and 17 days, respectively. – **CURRENT STATE**
Efficiency in performing exams	**L1:** There is no need for scheduling none of the exams. – **TARGET** **L2:** There is a need for scheduling one of the exams. – **CURRENT STATE** **L3:** There is a need for scheduling two of the exams. **L4:** There is a need for scheduling three of the exams. **L5:** There is a need for scheduling all the four exams.
Speed in obtaining exam results	**L1:** It takes 4 days to obtain the biopsy results. **L2:** It takes 6 days to obtain the biopsy results. – **TARGET** **L3:** It takes 8 days to obtain the biopsy results. **L4:** It takes 10 days to obtain the biopsy results. – **CURRENT STATE**

Thus, for the criterion named "Access to diagnosis", the number of days between the first consultation and the SDC was used to describe performance. To measure the performance of the criterion named "Access to surgery", the number of days between the SDC and the surgery was used as the descriptor.

For the “Quality of life” criterion, a descriptor of performance was built, which was based on the fact that it is considered that when patients perform their diagnoses and surgeries within the recommended time intervals, there is a possibility of increasing their quality of life. Thus, when the waiting time for diagnosis and surgery is within this range of values, negative consequences for patients are not brought, in the short, and long term. However, this is just a proxy that has been used since measuring patients’ quality of life is a difficult task in the context [83]. Also, many healthcare professionals, due to their high experience and long years of monitoring multiple patients with heterogeneous characteristics, may not always agree with these values that are recommended by national and European organizations [84][85].

For the criterion named “Efficiency in performing exams”, the number of tests that need scheduling for their performance was used as the descriptor. This number can vary between 0 and 4, once breast cancer patients perform four exams during their journey to surgery. In this way, it is possible to analyze how many tests possess a waiting list associated with its performance, being that the absence of particular scheduling reveals that the number of performed exams is sufficient to cover the hospital’s needs, that is, it is sufficient to cover the number of patients who need to perform that exam.

Finally, for the “Speed in obtaining exam results” criterion, the number of days required to obtain the biopsy results were used as a descriptor. During the exploratory interviews within the scope of understanding how added value is generated by IPO-Lisboa activities, the health stakeholders have reported that this is the only exam with an excessive waiting time associated with the obtention of the results, and therefore, it is the only exam to consider when measuring the performance of this criterion.

5.2.3. Constructing Individual Multicriteria Decision Models

After completing these steps, the multicriteria model is structured, following its construction. In this study, it was considered interesting to understand the perspectives that different types of health stakeholders had about the developed value tree. Thus, two individual models were built, one for a physician and the other for an administrative staff member. By developing individual multicriteria decision models, some disadvantages of group decision models are not faced, namely the fact of being a time-consuming task and group work conflicts that can arise [71]. Thus, with different individual models, the problem can be solved rapidly and efficiently, and different opinions and points of view are also considered.

Then, it is necessary to calculate the value functions and the weighting coefficients for each criterion, based on qualitative judgements of different stakeholders involved in the study about the difference of attractiveness between the previously mentioned performance levels. To collect these judgements in a quick and simple way, a web-based platform developed on Google Forms was created, which presented all the questions necessary for developing the multicriteria decision model, allowing participants to answer when it was most convenient for them. The platform has two parts: one with questions necessary for making possible the calculation of the value functions, and another in order to calculate the weighting coefficients for each criterion.

5.2.4. Calculating the Value Functions

To obtain the value functions, it is necessary to collect qualitative judgements concerning differences in attractiveness between pairs of performance levels, in each criterion.

It is important to highlight that the DMs were asked to make qualitative judgements comparing each level with the least attractive level, as well as comparing consecutive pairs of performance levels. This is the same as saying that it was collected the judgements for filling in the last column and the diagonal above the main diagonal of the judgement matrix in the M-MACBETH software. The rest of the matrix entries are then filled in by transitivity. Therefore, it is was not required to make an excessive amount of comparisons, reducing the time consumption associated with the process [12][79].

As explained in the previous chapter, for making qualitative judgements, the following categories of difference in attractiveness are used: “no difference”, difference “very weak”, “weak”, “moderate”, “strong”, “very strong”, and “extreme”.

Figure 5.5 shows an example of the set of questions asked on the web-based platform to obtain the information necessary to complete the judgements matrix in the M-MACBETH software. In this first part of the platform, there was a similar section for each criterion.

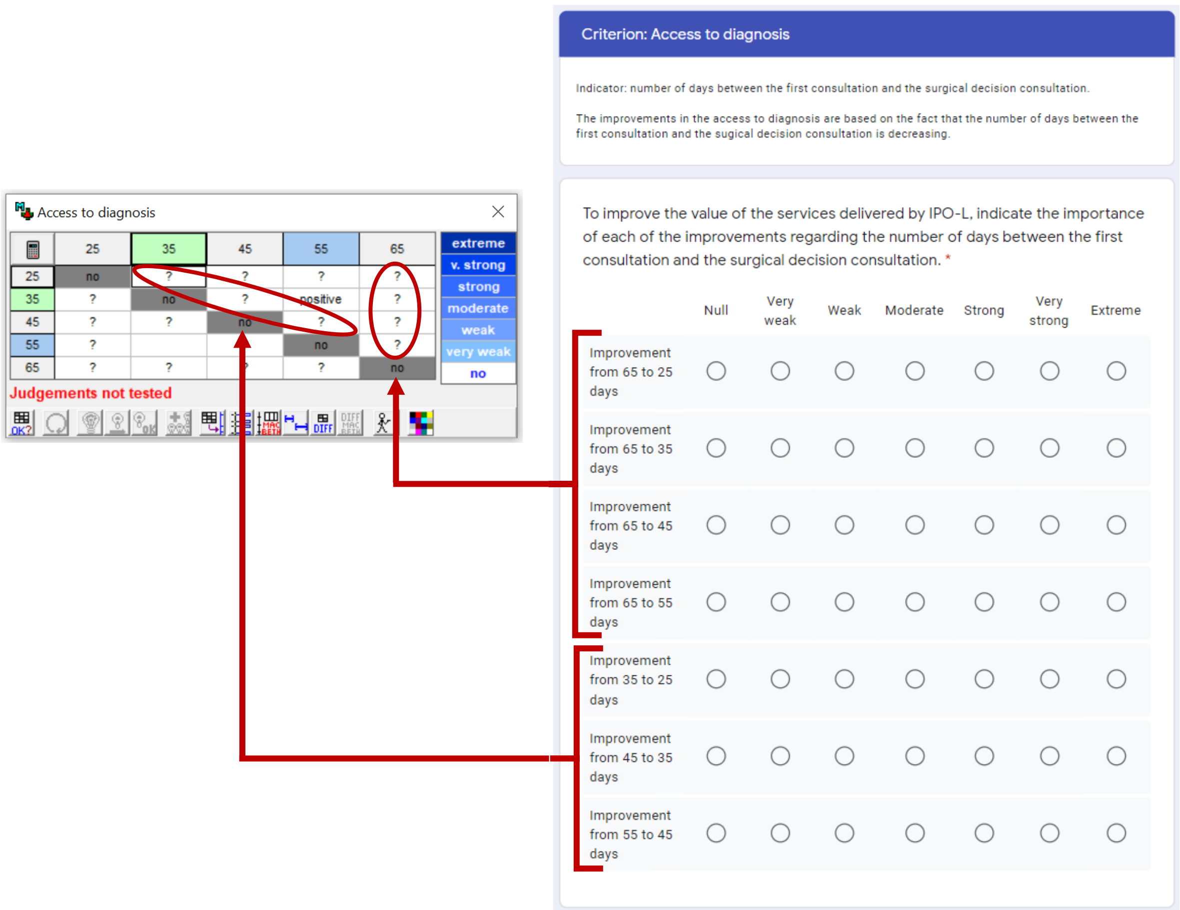


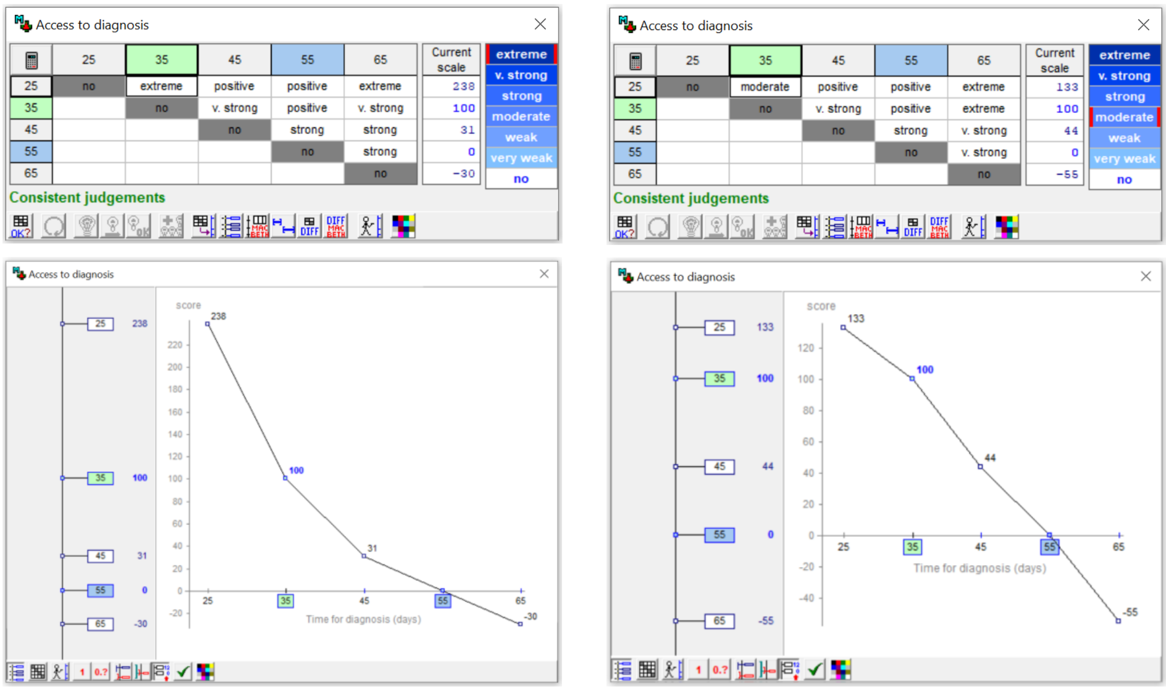
Figure 5.5. Question regarding the “Access to diagnosis” criterion in the first part of the web-based platform to evaluate the difference of attractiveness between some levels of performance – the levels that correspond to the last column and to the diagonal above the main diagonal of the M-MACBETH judgements matrix, as it is possible to see at left.

After collecting the qualitative judgements for each criterion, it was possible to fill in the judgements matrix in the M-MACBETH software, completing the remaining entries by transitivity. It is also important to note that when inconsistencies were detected, they were resolved through suggestions made by the software itself, which were then validated by the DMs, as exemplified in Figure 5.6.

(a) (b)

Figure 5.6. Example of a matrix in which inconsistent judgements were detected (a) and the same matrix after the modification of one judgement, according to the suggestions provided by the M-MACBETH software.

After this process, the resulting value functions were presented so that the DMs could validate them, making adjustments when necessary. It was found that the DMs have validated the presented value scales, adjusting only the values of the scales to integers, when they have appeared as decimals. The value functions for the "Access to diagnosis" criterion obtained from the point of view of the two DMs are shown in Figure 5.7. Appendix E presents the value functions for the other four criteria.



(a) (b)

Figure 5.7. Resulting value judgements matrix (above) and respective value function (below) for the "Access to diagnosis" criterion when the judgements were collected from a physician (a) and an administrative staff member (b).

5.2.5. Calculating the Weighting Coefficients

To obtain the weighting coefficients of the criteria, the first step is to rank all the criteria in decreasing order of their attractiveness. This can be done by asking the DM the following: “Suppose that all criteria had a “current state” level of performance and you had the opportunity to improve only one of the criteria, changing it to a “target” level of performance. What improvement would you choose?”. Then, the DM must choose which improvement he/she would choose next, repeating this process until there are no more options for improvement. It is important to emphasize that here the DM must make his/her choice based on the possible improvements and not just on the criterion.

Figure 5.8 depicts an illustration of the second part of the web-based platform, where a scheme is shown to represent the possibilities of improvements between the reference levels of performance for each criterion, that is, the “current state” levels (blue) and the “target” levels (green). To facilitate this requested task, it was presented the complete description of these levels, and a letter was assigned to each swing. Afterward, it is necessary to collect qualitative judgements concerning the attractiveness of each improvement (named from A to E, as can be seen in Figure 5.8). In the web-based platform, the following request was made to the DM: “Indicate the attractiveness of the improvement”. This request was repeated for each improvement, and the answer options were, once again, the following: “null”, “very weak”, “weak”, “moderate”, “strong”, “very strong”, or “extreme”.

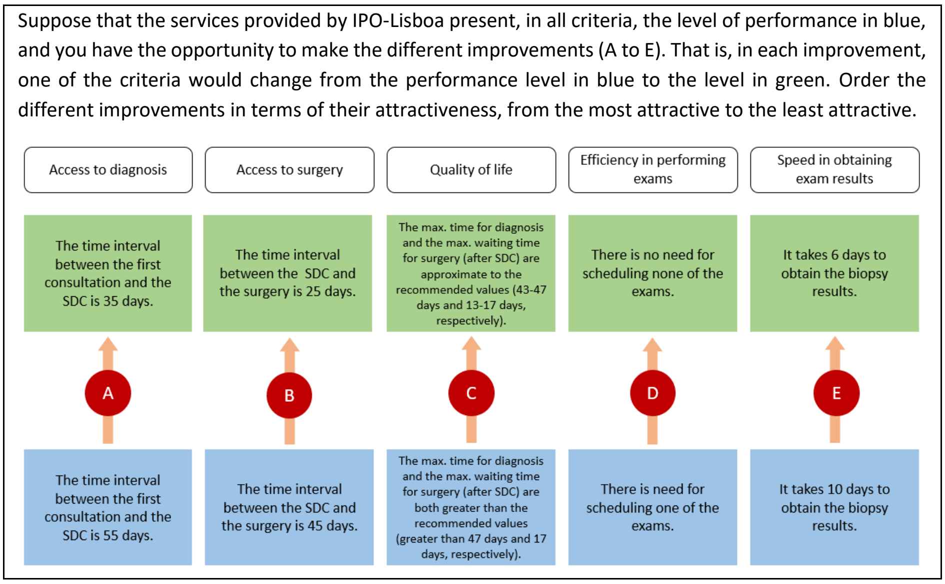
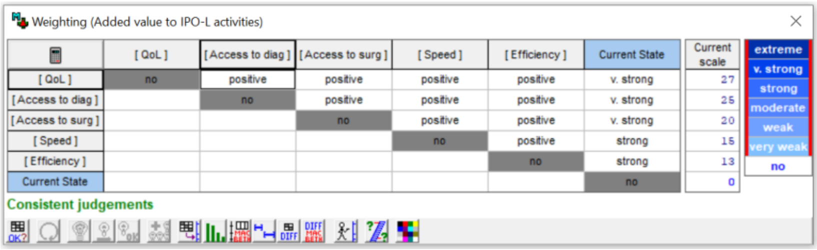


Figure 5.8. Question of the second part of the web-based platform in which the DMs chose the ranking of the improvements (named from A to E) from the “current state” (blue) to the “target” (green) level of performance.

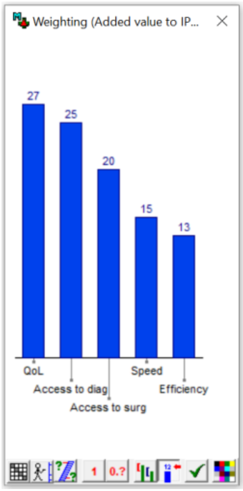
In this way, it was possible to insert all the collected information in the M-MACBETH software and was not detected any inconsistency. Then, it was possible to obtain the weighting coefficients of the criteria, which were presented to the DMs so that they could validate them. The first DM (a physician) chose to round the presented values to integer numbers, and asked to slightly increase the value proposed for the weight of the “Access to diagnosis” criterion, and to slightly decrease the weight of the “Speed in obtaining the exam results” criterion. The second DM (an administrative staff member) agreed with all the presented values, choosing only to round them to integer numbers. Also, this DM stated that, for his validation, the most important is the fact that the sum of weights of the “Access to diagnosis” and “Access to surgery” criterion is equal or greater than 50.

Figures 5.9 and 5.10 present the weighting matrix and the resulting criteria weights when the judgements were collected from a physician and an administrative staff member.



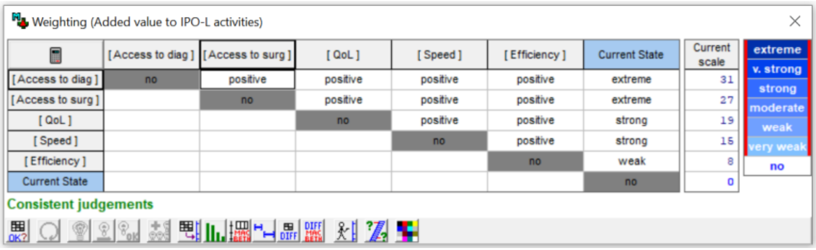
	[QoL]	[Access to diag]	[Access to surg]	[Speed]	[Efficiency]	Current State	Current scale
[QoL]	no	positive	positive	positive	positive	v. strong	27
[Access to diag]		no	positive	positive	positive	v. strong	25
[Access to surg]			no	positive	positive	v. strong	20
[Speed]				no	positive	strong	15
[Efficiency]					no	strong	13
Current State						no	0

(a)



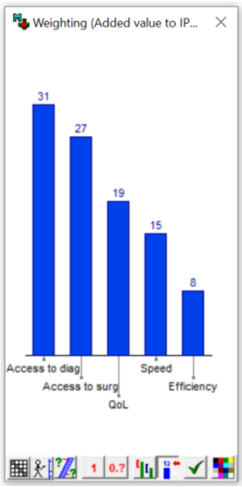
(b)

Figure 5.9. Resulting weighting judgement matrix (a) and respective criteria weights (b) when the judgements were collected from a physician.



	[Access to diag]	[Access to surg]	[QoL]	[Speed]	[Efficiency]	Current State	Current scale
[Access to diag]	no	positive	positive	positive	positive	extreme	31
[Access to surg]		no	positive	positive	positive	extreme	27
[QoL]			no	positive	positive	strong	19
[Speed]				no	positive	strong	15
[Efficiency]					no	weak	8
Current State						no	0

(a)



(b)

Figure 5.10. Resulting weighting judgement matrix (a) and respective criteria weights (b) when the judgements were collected from an administrative staff member.

After obtaining all the value functions and weighting coefficients, the model is prepared to be used, that is, it is possible to acquire the overall score of an option after inserting its performance in the M-MACBETH software [77]. In the context of this study, these options correspond to improvements that can be made in breast cancer patients’ pathways, and some of their parameters correspond to the performance obtained by using the simulation model built previously. In the next chapter, the results obtained when combining these two models will be presented, where the outputs of the simulation model are used as inputs of the multicriteria decision model.

6. Results

This chapter presents the results of implementing the methodological approach developed. Firstly, the outcomes obtained by the pathways modeling are presented, and thereafter the outcomes acquired through its integration with value modeling are shown.

The objective here is to present how the results obtained in the simulation model are integrated and quantified in the multicriteria decision model, to allow the DMs involved to discuss and reflect on which are the most attractive improvement options, as well as how they can be implemented so that value is generated to the services provided at IPO-Lisboa, aligning the breast cancer pathways with the delivery of VBHC.

6.1. Results of the Methodological Approach

As described in the previous chapter, the simulation model developed is ready to measure the impact caused by changes in the system. In this way, it was discussed with the stakeholders which are the main points that need to be analyzed in the breast cancer pathways, in order to improve them.

The stakeholders involved in the study found interesting the analysis of the impact caused by decreasing the minimum waiting time to obtain the biopsy results, by increasing the number of MRIs performed per day, and by increasing the number of surgeries performed per month.

From the point of view of these stakeholders, it was interesting to analyze the impact caused by decreasing the minimum waiting time to obtain the biopsy results from 10 to only 6 working days. This is the exam that currently has the largest number of days necessary for obtaining its results and, it is also the first exam performed by patients during their journey. Therefore, the reduction of these waiting days would control this bottleneck in the initial phase of the pathway.

Furthermore, from all of the exams that must be performed, MRIs are the only ones that need scheduling. In the other exams, this situation is not verified. For example, in the case of biopsies, there is no need for scheduling, that is, after the first consultation (the activity before biopsies), these are performed immediately, which means that, mostly, patients are able to execute this activity in the same day of their first consultation at the MBC. The same cannot be said for MRIs, as the number of exams performed per day is not enough to cover the number of patients who need to undergo them. In this way, stakeholders considered important the analysis of the impact caused by doubling the number of MRIs performed per day. Through this increase, patients will not wait for this activity during long periods, speeding up the flow of the clinical pathway.

Lastly, the stakeholders involved also considered important the observation of the impact caused by increasing the number of surgeries performed per month. It is relevant to remember that about 50 surgeries are performed per month and, therefore, it was interesting to analyze the impact of increasing this number, for example, to 70 surgeries per month, which translates into an increase of 40% relative to the current number.

These three main improvement measures were combined in seven different ways. Table 6.1 shows the performance of these improvement proposals when compared to the simulation of the current situation, that is, the situation corresponding to the year 2018. This table presents the time intervals between the first consultation and the SDC, the waiting time between the SDC and the surgery, and the time interval between the first consultation and the surgery. All these outcomes are exposed both on average and in their maximum values.

Table 6.1. Impact of the improvement measures in terms of some performance indicators: the number of days between first consultation and SDC, the number of days between first consultation and surgery, and the number of days between SDC and surgery. For each alternative improvement it is also presented the input parameters of the simulation model: minimum waiting time to obtain the biopsy results, number of MRIs performed per day, and number of surgeries performed per month.

Performance Indicators	**Current Situation**	**Imp. 1**	**Imp. 2**	**Imp. 3**	**Imp. 4**	**Imp. 5**	**Imp. 6**	**Imp. 7**
Number of days btw. 1st consultation and SDC (average)	52.19	48.41	41.52	37.52	52.19	48.41	41.52	37.52
Number of days btw. 1st consultation and SDC (maximum)	62.38	58.23	43.63	39.75	62.38	58.23	43.63	39.75
Number of days btw. SDC and surgery (average)	46.57	47.69	53.47	54.78	11.01	11.01	15.64	15.65
Number of days btw. SDC and surgery (maximum)	79.33	79.86	95.18	96.33	12.99	13.07	21.13	20.91
Number of days btw. 1st consultation and surgery (average)	95.56	92.85	95.56	92.75	63.21	59.42	58.15	54.16
Number of days btw. 1st consultation and surgery (maximum)	137.76	134.11	137.84	134.24	73.81	69.65	63.61	59.41
Simulation Input Parameters	**Current Situation**	**Imp. 1**	**Imp. 2**	**Imp. 3**	**Imp. 4**	**Imp. 5**	**Imp. 6**	**Imp. 7**
Minimum waiting time to obtain the bi-opsy results	10 days	6 days	10 days	6 days	10 days	6 days	10 days	6 days
Number of MRIs performed per day	curr. number	curr. number	2×(curr. number)	2×(curr. number)	curr. number	curr. number	2×(curr. number)	2×(curr. number)
Number of surgeries performed per month	curr. number	curr. number	curr. number	curr. number	1.4×(cur. number)	1.4×(curr. number)	1.4×(curr. number)	1.4×(curr. number)

To analyze the performance of the different improvement proposals, firstly, it is important to highlight that, in some of them, only parameters of activities that occurred before the SDC were changed (improvements 1, 2, and 3). In improvement 4, only the parameter of an activity that occurs after SDC – the execution of surgeries – was modified. Moreover, in the remaining improvements (5, 6, and 7), parameters of activities that take place during the entire pathway were changed, either before or after the SDC.

Improvements 1, 2, and 3

As expected, in these improvements there is a decrease in the number of days between first consultation and SDC, especially in improvement 3, with a decrease from 52.19 to 37.52 days, on average. However, it is interesting to note that, despite this decrease, the number of days between first consultation and surgery remains similar in all improvements, even when two changes in the input parameters are combined, that is, in improvement 3. The reason behind this rise is the increase of days between SDC and surgery. For instance, there is an increase from 46.57 to 54.78 days, on average, in the case of improvement 3.

Although the parameters of activities that occur before the SDC are being improved, the capacity to perform surgery remains exactly the same as the current situation. Patients go through the first part of their clinical pathway in a shorter time interval, but there is a greater bottleneck in waiting for surgery.

Improvement 4

In improvement 4, the number of days between first consultation and SDC remains exactly the same as in the current situation, since no improvement has been made to the input parameters of the activities that take place in this first part of the pathway. In other words, the waiting time for diagnosis and decision on the next steps – performing the surgery or initiating neoadjuvant treatments – remains the same as the current situation. On the other hand, there is a great decrease in the number of days between SDC and surgery, from 46.57 to 11.01 days, on average.

In the case of this improvement proposal improvement, patients take the same amount of time to reach SDC, but there is an increased capacity to perform surgeries. Thereby, the waiting time for its realization is reduced significantly.

Improvement 5, 6, and 7

When actions to improve the parameters of activities that take place along the entire pathways are proposed, the results seem to be more positive. In improvements 5, 6, and 7, there is a decrease in the number of days between first consultation and SDC, as was seen in improvements 1, 2, and 3, respectively, since the same changes were made in the activities that occur before the SDC. However, in improvements 5, 6, and 7, the number of days between first consultation and surgery also decreases, as a consequence of the reduction in the waiting time for the surgery.

Through these improvement proposals, it seems that for patients to travel their pathway in a significantly shorter time interval, there is a need for improvement input parameters of activities that occur throughout this entire process. Therefore, it is crucial to reach a balance between the improvement actions implemented, so that there are no bottlenecks, since, as previously noted, the disappearance of bottlenecks in an initial part of the circuit can cause greater bottlenecks in further parts, when the capacity to perform these later activities remains untouched.

Combining Performance with Value

After obtaining the outcomes of all the improvement proposals presented in Table 6.1, it is important to make a decision about which one generates more value from the point of view of the stakeholders, remembering that the breast cancer patients' pathway must be aligned with the delivery of VBHC. In other words, it is time to put into practice the methodological approach developed, combining pathways modeling with value modeling. In this part, it was verified that some of the physicians considered that the involvement of administrative staff members is more beneficial in what concerns the decisions that must be made regarding the choice of the improvement actions.

Through the software used to build the multicriteria decision models, whose value functions and weight coefficients were presented in the previous chapter, it is possible to create a performance table for the several improvement alternatives (options). Figure 6.1 presents a table in which, for each improvement proposal, the values or performance levels associated with each of the five evaluation criteria are inserted: "Access to diagnosis", "Access to surgery", "Quality of life", "Efficiency in performing exams", and "Speed in obtaining exam results".

Table of performances

Options	Access to diag	Access to surg	QoL	Efficiency	Speed
Imp 1	48.41	47.69	L5	1	6
Imp 2	41.52	53.47	L3	0	10
Imp 3	37.52	54.78	L3	0	6
Imp 4	52.19	11.01	L4	1	10
Imp 5	48.41	11.01	L4	1	6
Imp 6	41.52	15.64	L3	0	10
Imp 7	37.52	15.65	L3	0	6

Figure 6.1. Table of performances of the proposed improvement alternatives in the five evaluation criteria.

By using the M-MACBETH software, the performance of each option is converted into a score, which corresponds to the sum of the scores associated with each criterion, considering the weight coefficients previously calculated. Thereby, a table is obtained that presents the overall score for each of the seven improvement options.

In this study, as two individual multicriteria decision models were built from the point of view of two DMs, belonging to different categories at IPO-Lisboa, two tables are obtained with the overall scores of each improvement proposals, either from the perspective of a physician (Figure 6.2) or from the perspective of an administrative staff member (Figure 6.3).

Table of scores

Options	Overall	Access to diag	Access to surg	QoL	Efficiency	Speed
Imp 1	18.60	20.43	-7.53	0.00	0.00	100.00
Imp 2	39.29	55.01	-23.72	64.00	100.00	0.00
Imp 3	60.46	82.61	-27.38	64.00	100.00	100.00
Imp 4	55.96	8.71	220.31	36.00	0.00	0.00
Imp 5	73.89	20.43	220.31	36.00	0.00	100.00
Imp 6	80.13	55.01	180.50	64.00	100.00	0.00
Imp 7	102.02	82.61	180.41	64.00	100.00	100.00
Target	100.00	100.00	100.00	100.00	100.00	100.00
Current State	0.00	0.00	0.00	0.00	0.00	0.00
Weights :		0.2500	0.2000	0.2700	0.1300	0.1500

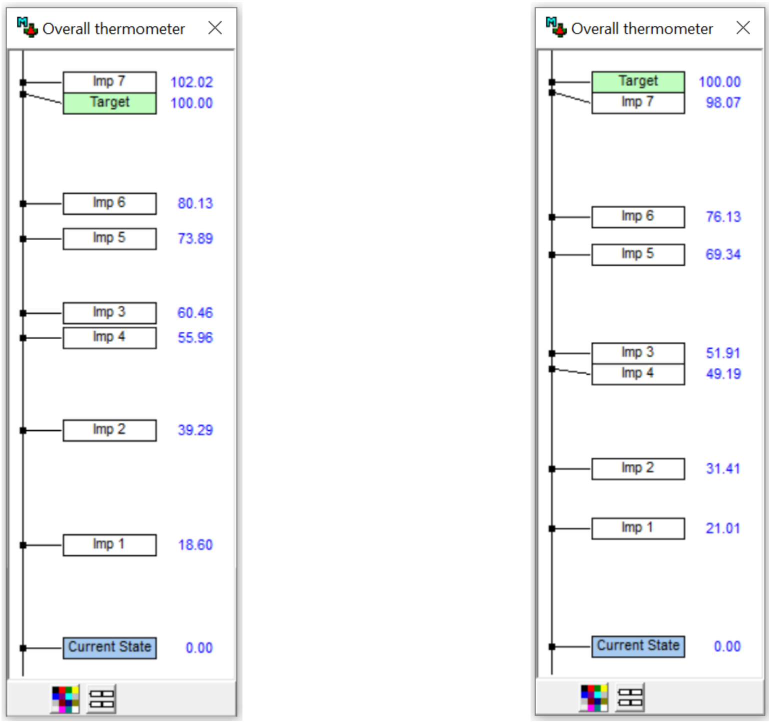
Figure 6.2. Table of scores of the proposed improvement alternatives, obtained in the M-MACBETH software, when the qualitative judgements were provided by a physician.

Table of scores

Options	Overall	Access to diag	Access to surg	QoL	Efficiency	Speed
Imp 1	21.01	29.00	-11.03	0.00	0.00	100.00
Imp 2	31.41	63.49	-34.73	69.00	100.00	0.00
Imp 3	51.91	85.89	-40.10	69.00	100.00	100.00
Imp 4	49.19	12.36	146.17	31.00	0.00	0.00
Imp 5	69.34	29.00	146.17	31.00	0.00	100.00
Imp 6	76.13	63.49	130.89	69.00	100.00	0.00
Imp 7	98.07	85.89	130.86	69.00	100.00	100.00
Target	100.00	100.00	100.00	100.00	100.00	100.00
Current State	0.00	0.00	0.00	0.00	0.00	0.00
Weights :		0.3100	0.2700	0.1900	0.0800	0.1500

Figure 6.3. Table of scores of the proposed improvement alternatives, obtained in the M-MACBETH software, when the qualitative judgements were provided by an administrative staff member.

Figure 6.4 presents the overall thermometers of the proposed improvement alternatives, obtained in the M-MACBETH software, in each individual decision model, allowing a better visualization of the scores obtained since they are ordered on a scale.



(a) (b)

Figure 6.4. The overall thermometer of the proposed improvement alternatives, obtained in the M-MACBETH software, when the qualitative judgements were provided by a physician (a) and by an administrative staff member (b).

It is possible to observe that, as the two multicriteria decision models built based on the qualitative judgements of the two DMs are different, the overall scores calculated for each improvement proposal are also different in both cases. Nevertheless, it can be seen that when ordered by their overall score in a decreasing way, the sequence of the seven improvements is the same in the two cases, and a consensus has been reached. The only difference is that option 7 owns a score greater than 100 (and therefore, higher than the score of the “target” level) when the decision model built from the physician’s perspective is applied. From the administrative staff member's perspective, the overall score of this option is lower than 100, although it is very close to this value (98.07). Thus, it is observed that, from the two DMs' point of view, the sequence of the improvement, from the one that generates the most value to the one that generates the least value, is the following: Improvement 7; Improvement 6; Improvement 5; Improvement 3; Improvement 4; Improvement 2; Improvement 1.

The results obtained allow to understand which actions are the most attractive to be taken, promoting the discussion, or even negotiation between the different DMs involved about the next step of the decision-making process.

Clearly, improvement 7 is the one with the highest overall score, and therefore, it is the most attractive to implement. However, this is also the improvement that requires a greater number of actions so that it can be put into practice once it presents changes in the input parameters of the three main points of the pathway, where problems are detected currently. Also, it is important to bear in mind that there may be constraints regarding the number of actions that can be taken simultaneously.

Through this decision model, it is possible to answer the question: "What is the most attractive option, if one has the possibility to make only two changes to the input parameters of the activities considered?". Here, the intention is to find out which improvement has a higher overall score when there is a constraint in the number of actions that can be taken simultaneously. In this case, option 6 would be the most attractive, that is, doubling the number of MRIs performed per day and increasing the number of surgeries performed per month by 40%. Therefore, an improvement action would be taken in one activity that occurs before the SDC and in another that occurs after the SDC.

Furthermore, it is also observed that, if it were only possible to put into practice one of the improvement actions, the most attractive option would be improvement 4, as among improvements 1, 2, and 4, this is the one with the highest overall score. Interestingly, in this improvement, none of the parameters of the activities that occur before the SDC would be modified, and only the number of surgeries performed would be increased.

It is also important to note that a more detail analysis of the results can be made in future applications, performing, for instance, a sensitivity analysis by changing the weights of the considered criteria, as well as through the creation of more improvement proposals.

6.2. Workshop with Health Stakeholders

All of the outcomes obtained by the integrated approach were presented to the stakeholders involved in the study, through a workshop. Both physicians and administrative staff members exhibited a high level of confidence in the results. The participants had already comprehended how the simulation model worked at the time of its initial validation. However, this time, they were able to observe the impact caused by small changes in the system that is so familiar to them.

Furthermore, there was the opportunity to present the functioning of the simulation model and its results to other stakeholders who were not involved in the construction and validation of the model, namely physicians from IPO-Lisboa and some medical students.

This workshop allows to promote discussion and reflection about the different perspectives of improvement and analyze the feasibility of implementing the improvement actions. The feedback regarding the use of these types of tools to assess the impact of changes in pathways was very positive. Also, the health stakeholders mentioned that this is an interesting methodological approach, and it can and should be applied to analyze pathways of other pathologies.

6.2.1. Analyzing the Feasibility of Implementing the Improvement Actions

The combination of the simulation model with the multicriteria evaluation model allows for understanding which improvements are most attractive from the stakeholders' point of view. However, to complement the decision-making process, it is essential to realize how the suggested actions can be implemented and how feasible they are. Figure 6.5 presents the relationships between actions to be taken (causes) in order to achieve improvements in the breast cancer pathways at IPO-Lisboa (effects).

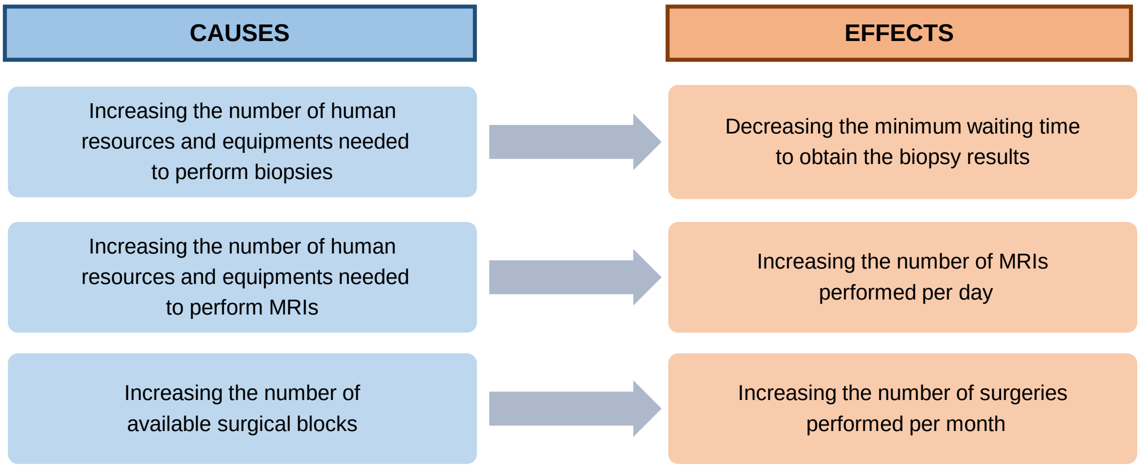


Figure 6.5. Relationships between actions to be taken (causes) in order to achieve improvements in the breast cancer pathways at IPO-Lisboa (effects).

During workshops where the results of the models developed were shown, physicians and administrative staff members have reported that the decrease in the minimum waiting time for obtaining biopsy results and the increase in the number of MRIs performed per day can be achieved by increasing the number of human resources or equipments. However, increasing the number of equipments is often a solution associated with expensive costs, and therefore, the best solution is to perform better management of human resources. This can be done through incentive systems, increasing the productivity of existing human resources, or hiring new professionals. Both of these solutions entail costs for the institution. Nevertheless, it was pointed out by administrative staff members that the best strategy is always to increase the productivity of existing human resources since the intake of new professionals is associated with training programs, once many times these new resources may not possess the required level of expertise.

On the other hand, through the decision model, it was possible to analyze that the increase in the number of surgeries performed is the operation that must be executed first if there is a constraint of put into practice only one action. To this end, it was determined by the stakeholders involved in the study that there is a need to increase the number of blocks available for breast cancer patients. Although they can bring negative consequences for other IPO-Lisboa pathways or include expensive costs, there are three different ways to achieve this increase in the number of surgeries performed:

(1) decreasing the number of blocks assigned to non-priority patients of other pathways;
(2) improving the management and planning of activities performed at the hospital;
(3) increasing the number of rooms of the operating theater.

The first possibility is to increase the number of blocks assigned to breast cancer patients by decreasing the number of blocks assigned to non-priority patients of other oncological pathways. The operating theater is a service that integrates several pathways, dealing with multiple pathologies. Therefore, there is a crossing of processes and a sharing of resources. This measure, although positive for breast cancer pathways, has the consequence of increasing surgery waiting times for patients of other pathologies, resulting in bottlenecks in other oncological pathways.

Secondly, a possible solution may correspond to the execution of better management and planning of the activities carried out in the hospital. For example, when rearranging surgery schedules, the objective is to increase the number of surgeries performed and decrease cancellations. It is important to highlight that the systems responsible for healthcare delivery are often unpredictable, and surgeries may be canceled due to delays in previous operations. So, by imagining that, with adjustments in the start times of surgeries, one extra surgery is performed and not canceled, after one year, 260 extra surgeries will be executed, which may be currently being canceled because some schedules do not take into account possible delays and unforeseen circumstances. Thus, it is necessary to invest and apply better planning tools, which can deal with monetary costs and time-consuming actions.

Finally, to increase the number of rooms in the operating theater, remodeling the institution's infrastructures needs to be carried out. This measure is the one that has the most immediate effect, but it is also the one with more expensive costs.

Table 6.2 summarizes how the improvement actions can be implemented and what are the costs associated with them.

Table 6.2. Summary of measures to implement improvement actions and the costs associated with them.

Improvement Actions	How to implement improvements actions	Costs associated with improvement actions
Increasing the number of equipments	Acquiring new equipments	Expensive monetary costs
Increasing the number of human resources	Creating and/or applying incentive systems	Monetary costs
	Hiring new professionals	Monetary costs and training programs
Increasing the number of available surgical blocks	Decreasing the number of blocks assigned to non-priority patients of other pathways	Increasing surgery waiting times for patients of other pathologies
	Improving the management and planning of activities performed at the hospital	Monetary costs and time-consuming actions
	Increasing the number of rooms of the operating theater	Expensive monetary costs

During the realization of this study, changes in the hospital's infrastructures were already happening. Hence, this increase in the number of rooms was being put into practice, forecasting a major improvement in the services provided by the hospital, adding value to them.

6.3. Feedback from the Participants

Through the results obtained, it is possible to observe that the use of this socio-technical approach is able to respond to the problem that DMs have at hand, that is, to realize how it is possible to improve breast cancer pathways when aligned with the delivery of VBHC.

Moreover, the methodological approach combines the use of two different techniques, thus, during the conduction of the study, feedback was obtained from the stakeholders involved.

Regarding modeling pathways, the different participants highlighted that the simulation model can detect and/or confirm the existing problems of the clinical pathways. Furthermore, they realized clearly that this approach may and should have applicability in the different institution's oncological pathways, and not only in the case of breast cancer. Through the model, it is then possible to answer the question "what if", which is often asked by these professionals, to understand in advance the impact caused by possible improvement measures.

Concerning value modeling, the DMs stressed the usefulness of building models to allow an organized visualization of the criteria (or fundamental points of view) that need to be considered when trying to understand how value is generated by IPO-Lisboa activities. Despite being a time-consuming method, due to the high number of questions asked to the DMs and several interviews, the use of this approach promotes the interaction between different teams so that their points of view are heard and taken into account in the complex decision-making processes.

Thus, the implementation of the methodological approach was approved by the stakeholders involved in the study, who consider it to be very useful so that the existing clinical pathways at IPO-Lisboa may reach better results.

7. Discussion

Hospitals are complex systems, where their professionals deal daily with situations of pressure given the unpredictable environment and the high patients' expectations regarding the quality of the healthcare delivery.

In the case of IPO-Lisboa, there is then an attempt to find ways to continuously improve the clinical pathways of this institution, adding value to them. Therefore, it is necessary to improve the value of the activities that cancer patients undergo throughout their pathways, keeping in mind that these are patients who travel their journeys over a long period of time, dealing with situations of stress and anxiety. For both them and healthcare professionals, it is not just the final result that must be taken into account when trying to improve the hospital pathway. Intermediate activities are also part of this process. Thus, by adding value to the hospital's activities, it becomes possible to add value to the care delivered to patients.

On the other hand, some resistance may arise from healthcare professionals regarding the implementation of improvement actions. Consequently, it is necessary to find strategies and use approaches that involve actively multidisciplinary teams that are part of these complex systems. In this way, it becomes possible to include different points of view, which are important in the decision-making processes.

In this project, the proposed methodological approach created combines different methods, which have not only a technical component but also a social one. Thus, and taking into account data from the literature to understand which techniques were most suitable for solving the problem, the DES method was combined with the MACBETH method (an MCDA approach). Through this combination, it was possible to model the breast cancer patients' hospital pathways, as well as to model how value is generated by the IPO-Lisboa activities. With the implementation of this proposed methodology, although some limitations were recognized, several advantages resulting from its use were identified.

7.1. Positive Points of the Methodological Approach

The methodological approach developed allowed, when modeling clinical pathways, to identify the main bottlenecks and to analyze the main aspects that need to be enhanced. Also, it was possible to assess the impact of alternative changes in the parameters of the activities to improve this process. Thus, the construction of a simulation model, although not being familiar to healthcare professionals, left them very enthusiastic, as it presented itself as a tool with high potential to analyze the impact of hypothetical organizational changes in the pathways traveled by patients.

It is important to highlight that sometimes the data necessary to populate the simulation model were not available in an electronic format, and therefore, it was collected with a lower level of detail during interviews with healthcare professionals. At first sight, this fact could be seen as a limitation since there was a possibility that these data did not correspond exactly to reality, as they are the result of the perspectives and experiences of the hospital team members. However, after building the model, it was validated by the stakeholders involved, showing that even simplified, it had a high capacity to mimic the real system. Moreover, the fact of this tool has been implemented in a dynamic and interactive software that allowed the graphic visualization of its functioning, through an animation of the patients' flow in the several activities, contributed to their engagement.

By using the methodology, it was possible not only to gather improvement proposals but also to discover which ones have added more value to the activities of the institution, that is, which ones have presented themselves as being more attractive from the point of view of the stakeholders involved in the decision-making process. Thus, the importance of the strong social component allied with the technical component must be emphasized, which allows the information collected to be more complete, that there is a greater diversity of points of view, and that a higher level of acceptance is reached, as the perspectives of the different stakeholders are considered to make a higher quality decision.

During the value modeling task, a value tree was structured, which captures the fundamental points of view that must be considered when trying to evaluate how it is possible to generate additional value to the IPO-Lisboa activities. Thus, the information collected during several interviews, in which the objectives, values, preferences, and concerns of the different stakeholders were identified, is organized in a visually intuitive way, facilitating its understanding.

Furthermore, for building the multicriteria decision model, it must be highlighted the need to collect several qualitative judgements from the stakeholders involved, which is a time-consuming task. Thus, by using a web-based platform to collect this data, the participants were able to answer questions posed at their own pace and when it was most convenient for them. Subsequently, meetings were held for the DMs to be able to adjust and validate the decision model so that it adequately reflected their perspectives without spending large amounts of time on its construction.

When the simulation model and the multicriteria decision model were combined, it was promoted discussions and reflections regarding the different points of view, as well as it was analyzed how it is possible to implement the improvement actions, understanding how feasible their execution is.

In a nutshell, the use of the developed methodological approach allowed to complete the objectives of the proposed work, building a tool to assist the DMs of IPO-Lisboa in decision-making processes that focus on improving clinical pathways, being aligned with the delivery of VBHC.

7.2. Limitations and Points to Improve

It was noted that there was a lack of familiarity on the part of some health stakeholders regarding the use of simulation models and multicriteria analysis. Thus, there were some initial doubts and hesitations concerning the implementation of the methodological approach. However, it was verified that all participants possessed a strong enthusiasm to learn, an aspect that allows overcoming this limitation.

In this study, only the clinical pathways of breast cancer patients were considered. Nevertheless, many of the activities that make up this journey are points where pathways of other pathologies intersect. Therefore, this analysis can be considered as a piece of the puzzle that is the healthcare delivery system of IPO-Lisboa, which presents different clinical pathways with transversal activities that share resources among themselves. Consequently, when some questions were asked to the stakeholders, such as how it would be possible to implement actions to improve these pathways, they sometimes had some difficulty in providing an answer, mainly the administrative staff members. The reason behind this issue is the fact that the allocation of some resources needs to take into account the overall activities of the hospital, and not just those that are provided to breast cancer patients. Thus, there is a limitation of the simulation model considering the clinical pathways of a single pathology.

Regarding the multicriteria decision model, only two individual models were built, which ended up presenting similar responses when ordering improvement proposals according to their attractiveness (there being a consensus). Therefore, the involvement of a small number of participants in the construction of these models, although belonging to two different categories (one physician and one administrative staff member), was a limitation. This can be countered by creating a larger number of individual models that would allow for considering a greater diversity of points of view. Moreover, the development of a group model would also allow the DMs to work together more directly.

However, the methodological approach developed was validated by the different participants involved in the study, showing its potential for being expanded to other pathways of IPO-Lisboa. Also, they can be crossed with each other, and a larger number of DMs can be involved in the value modeling process so that the above-mentioned limitations can be overcome.

8. Conclusions and Future Work

The purpose of this thesis was to develop tools capable of assisting the stakeholders of IPO-Lisboa in complex decision-making processes. In this way, a methodological approach was created, which combines pathways modeling with value modeling. For that, it became necessary to develop a simulation model using the DES method, and a multicriteria decision model applying the MACBETH method. These two models were integrated, proving to be a powerful tool to promote discussions and reflections on the different perspectives of the stakeholders involved in the decision-making processes. Moreover, by using this approach, it is possible to discover which actions are most attractive to be taken from different points of view of different and reaching consensus, when the goal is to improve hospital processes, specifically the pathways of breast cancer patients.

It is important to underline that this is a socio-technical approach. The strong social component, combined with the technical one, was the main advantage of the methodology created. At each step of this approach, and for constructing the simulation and decision models, the opinions of the stakeholders involved in the study were heard and taken into account, turning this procedure more inclusive and engaging. Moreover, all the models developed during this project were validated by the different participants, who emphasized a particular interest in applying simulation models capable of analyzing the impact of changes in parameters of the activities that constitute the clinical pathways. Also, through their different perspectives, it was possible to understand how value is generated by the IPO-Lisboa activities, remembering that this is an essential concern of the health professionals, as this is a hospital with a patient-centered attitude. Thus, when adding value to the clinical pathways' activities, value is also added to the care delivered to patients.

The novel approach developed constitutes a contribution to the literature since there is a gap in combining simulation methods with MCDA, which must be seen as an integral part of problem-solving methodologies. In the case study, through the simulation model, it was possible to discover the main bottlenecks existing in the breast cancer patients' pathways, from their first consultation to the surgery. Moreover, this model enabled the investigation of the impact caused by hypothetical changes in this system. By combining this model with the multicriteria decision model, it was possible to determine that value is added to this process when different improvement actions are integrated, namely the increase of surgeries performed per month, the increase of MRIs performed per day, and the decrease of the minimum waiting time to obtain biopsy results. Subsequently, and as in a complex hospital system there are monetary constraints and intersections between different pathways, it becomes necessary to analyze how feasible the implementation of these actions is. Once this approach possesses a strong social component, with the participation of health stakeholders is also possible to promote insights concerning these issues.

Concerning future work, it is possible to highlight the particular interest in integrating clinical pathways of different pathologies in simulation models. As discussed previously, some services and activities are transversal points between different hospital pathways, and therefore, these activities share resources with each other. Thus, the model of breast cancer patients' pathways can be seen as the first piece of the great puzzle that is an oncological hospital, which contains circuits of different pathologies that work simultaneously. Consequently, when crossing different pathways, it becomes possible to simulate a system closer to reality. Nevertheless, it is important to keep these models simplified so that the collection of the necessary data to populate them is performed in a timely manner, and the analysis of the results is not too complex.

Furthermore, the collaborative approach can be improved through the participation of a greater number of stakeholders. In addition to individual decision models, such as those built in this study, group decision models can also be developed, allowing a greater sharing of knowledge and opinions, in order to make higher quality decisions with a higher degree of acceptance. Also, it is important to bear in mind that conflict may arise when a large number of participants are involved. Besides decision conferences, other techniques can be used. For example, the Delphi method is a good one to elicit judgements, due to being an anonymous and iterative tool to improve group communication and eliminate the influence of stronger personalities, thereby being suitable to handle conflict management [86].

The improvement of complex hospital processes is an area in proliferation, and the development of tools and approaches capable of helping stakeholders involved in decision-making processes is essential. In a world subject to constant and unpredictable changes, it is crucial to adopt quick and effective measures capable of improving and adding value to the hospital pathways, which are journeys taken every day by a wide range of patients.

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Appendix A – Types of Treatment used in Breast Cancer

Table A.1. Main types of treatment used in breast cancer and their description.

Treatment	Description
Surgery	Surgery can be divided into two major groups: conservative surgery, when the cancerous lump is removed, and mastectomy when the whole breast is removed, and it may involve further breast reconstruction. However, in the last decades, breast conservation has become the main objective of the performed surgeries, replacing mastectomy, which was the previous standard [35][36]. Breast reconstruction can be done immediately with breast removal or afterward. However, studies report that immediate reconstruction is preferable since, in this way, the patient does not experience the fact that she has effectively lost one of the breasts. Studies have also shown that, in early-stage cases, conservative surgery followed by radiotherapy is as effective as mastectomy. The amount of tissue removed in a conservative surgery depends on the type of cancer, the size of the tumor and where it is located, the amount of tissue that is around the tumor and needs to be removed, and the size of the breasts. Furthermore, a small amount of healthy tissue around the tumor is also removed and tested to know if more tissue needs to be removed or not. After this type of surgery, the patient is submitted to radiotherapy to destroy the remaining cancer cells [35]. Regarding mastectomy, this is a surgery in which there is the total removal of one or both breasts. It can be accompanied by the removal of lymph nodes from the axilla when there is evidence that cancer has spread to the lymph nodes. A procedure called sentinel lymph node biopsy should be performed, as these are the first nodes affected by the spread of breast cancer. In this way, when these cells are analyzed, it is possible to know if the removal of these nodes is also needed [39][40].
Radiotherapy	This is a type of treatment in which controlled doses of radiation allow the death of the remaining cancer cells after surgery or chemotherapy cycles. Each radiotherapy session lasts only a few minutes, and the treatment is done 3 to 5 weeks. Irritation of the breast skin, fatigue, or lymphoedema can be highlighted as its side effects [35].
Chemotherapy	Chemotherapy is a treatment in which anti-cancer drugs are used to kill cancer cells. A chemotherapy cycle corresponds to a session done every 2/4 weeks. This treatment can be divided into adjuvant chemotherapy when it is performed after surgery to kill the remaining cancer cells, and neo-adjuvant chemotherapy, when it is performed before surgery if it is necessary to reduce the size of the tumor firstly. The type of medication used depends on the type of cancer and how far it has spread. Infections, loss of appetite, feeling and being sick, tiredness, and hair loss are some of the side effects. Also, this treatment stops the production of estrogens [35].
Endocrine Therapy	This is a type of treatment that allows the decrease of the levels of estrogens and progesterone, or that stops its effects. Endocrine therapy depends on the stage and grade of cancer, age, whether the patient has already gone through menopause, and what other types of treatment the patient is subject to. As radiotherapy, this therapy is typically used after surgery or chemotherapy, or before that, allowing the shrinkage of the tumor and making the removal easier [35][36]. It is possible to highlight some of the offered treatments to patients who experience this therapy: (1) **Tamoxifen:** used both in women who are already going through menopause and those who have not yet experienced it. Stops estrogen from binding to estrogen-receptor-positive cancer cells. (2) **Aromatase inhibitors:** used when a woman has already experienced menopause, and estrogen is no longer produced in the ovaries. (3) **Ovarian ablation or suppression:** used in women who have not yet gone through menopause, and estrogen is still produced in the ovaries. This technique stops the ovaries from working, using the drug gooseling, which is a luteinizing hormone-releasing hormone agonist (LHRHa) and administered through injection once a month. After stopping this treatment, menstrual cycles return to normal, unless a woman is already close to menopause, leading to induced menopause.

Treatment	Description
Target Therapies	These therapies change the way that cells work, helping cancer to stop growing and spreading. However, not all cancers can be treated with these therapies. This is used when cancer is stimulated by a protein called human epidermal growth factor 2 (HER2). Shivering, diarrhea, feeling and being sick, headache, cough, and skin rash are some of the main side effects [35].
Bisphosphonates	Bisphosphonates are medicines used when patients have already gone through menopause, and recent studies show that this is a way to reduce the risk of breast cancer spreading to the bones. These drugs (zoledronic acid or sodium clodronate) are administered at the same time as chemotherapy is performed [41].

Appendix B – EORTC QLQ-C30 Questionnaire and BR23 Module

Table B.1. Description of the EORTC QLQ-C30 questionnaire and the BR23 module.

Subscales		Abbreviation	Number of items
EORTC QLQ-C30 (15 multiitem scales or QoL domains)			
Global health status		GH	2
Functioning Scales	Physical functioning	PF	5
	Role functioning	RF	2
	Emotional functioning	EF	4
	Cognitive functioning	CF	2
	Social functioning	SF	2
Symptoms Scales	Fatigue symptom	FS	3
	Nausea/vomiting	NV	2
	Pain	P	2
Dyspnea		DS	1
Insomnia		I	1
Appetite loss		A	1
Constipation		C	1
Diarrhea		D	1
Financial difficulties		F	1
BR23 Module (8 multiitem scales or QoL domains)			
Functioning Scales	Body image	BI	4
	Sexual functioning	SF	2
	Sexual enjoyment	S	1
	Future perspective	FP	1
Symptoms Scales	Systemic therapy side effects	SE	7
	Breast symptoms	BS	4
	Arm symptoms	AS	3
	Upset by hair loss	U	1

Appendix C – The MACBETH Linear Programming Formulation

The basic MACBETH scale suggested by M-MACBETH for a matrix of judgements is obtained by linear programming. Let:

- C_k $(k = 0, \ldots, 6)$ be the seven MACBETH categories of difference in attractiveness: "null" (C_0), "very weak" (C_1), "weak" (C_2), "moderate" (C_3), "strong" (C_4), "very strong" (C_5), and "extreme" (C_6);
- X be a finite set of performance levels;
- x^+ and x^- be the most and least preferred levels of X, respectively;
- x and y be two elements of X such that x is at least as attractive as y;
- $(x, y) \in C_k (k = 0, \ldots, 6)$ be a MACBETH judgement of the difference in attractiveness between x and y expressed by the single category C_k;
- $(x, y) \in C_i \cup \ldots \cup C_s (i, s = 1, \ldots, 6 \; with \; i < s)$ be a MACBETH judgement of the difference in attractiveness between x and y expressed by a subset of categories from C_i to C_s, in cases of judgement hesitation or disagreement.

The "basic MACBETH scale" is obtained by solving the following linear program, where $u(x)$ is the score assigned to performance level x:

Minimize $[u(x^+) - u(x^-)]$

Subject to:

(1) $u(x^-) = 0$ (arbitrary assignment),

(2) $\forall (x, y) \in C_0 : u(x) - u(y) = 0$,

(3) $\forall (x, y) \in C_i \cup \ldots \cup C_s$ with $i, s \in \{1,2,3,4,5,6\}$ and $i \leq s : u(x) - u(y) \geq i$,

(4) $\forall (x, y) \in C_i \cup \ldots \cup C_s$ and $\forall (w, z) \in C_{i'} \cup \ldots \cup C_{s'}$ with $i, s, i', s' \in \{1,2,3,4,5,6\}$, $i \leq s, i' \leq s'$, and $i > s' : u(x) - u(y) \geq u(w) - u(z) + i - s'$.

When the linear program in infeasible, the set of judgements is inconsistent. When it is feasible, the optimal solution may not be unique. If multiple solutions exist, there is more than one possible score for at least one performance level $x \in X \backslash \{x^-, x^+\}$, in which case their average is taken to ensure the uniqueness of the basic MACBETH scale [12][69].

Appendix D – Simulation Input Parameters

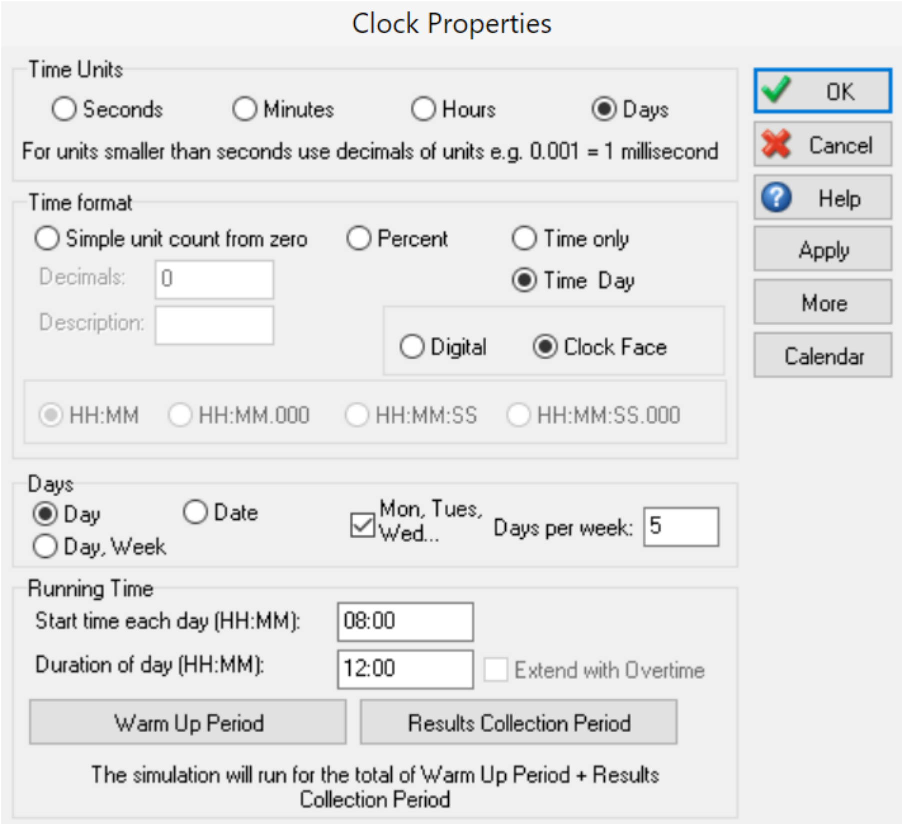


Figure D.1. Clock properties of the simulation model developed using SIMUL8.

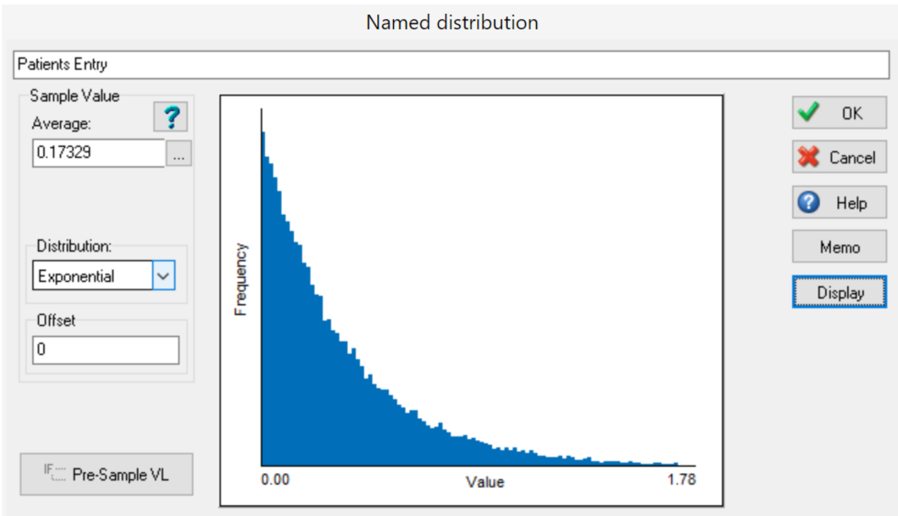


Figure D.2. Distribution associated with the patients' entry at IPO-Lisboa, that is, the work entry point of the simulation model.

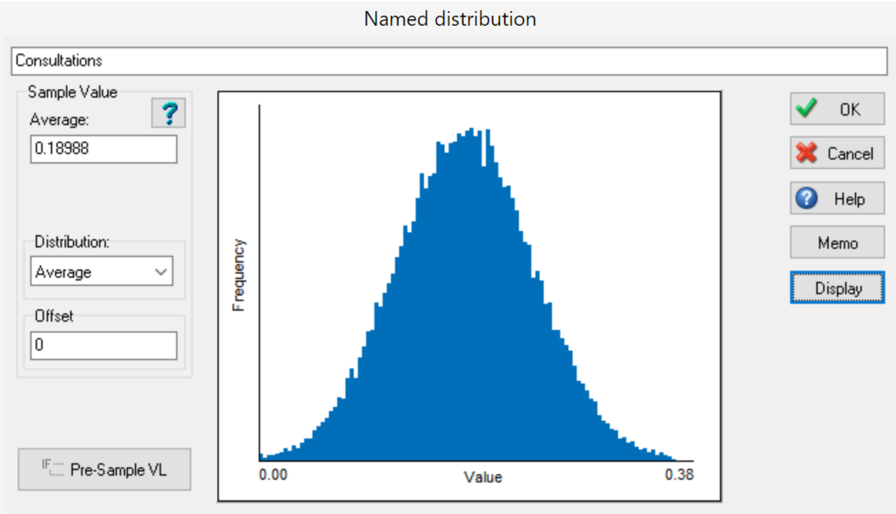


Figure D.3. Distribution associated with the performance of consultations at the MBC. In the simulation model, it was associated with the following activities: "First Consultation", "Subsequent Consultation", and "Surgical Decision Consultation".

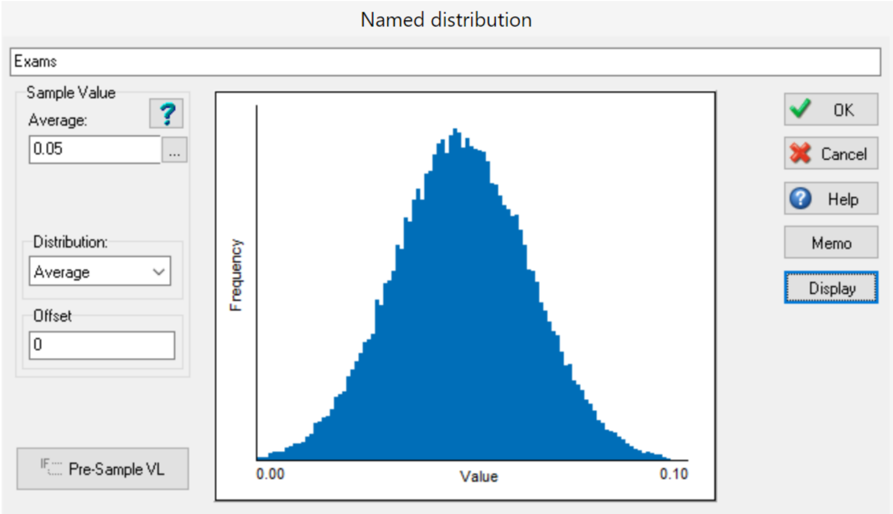


Figure D.4. Distribution associated with the performance of some exams at the radiology service and the nuclear medicine service. In the simulation model, it was associated with the following activities: "Biopsy", "CT", and "Bone Scintigraphy".

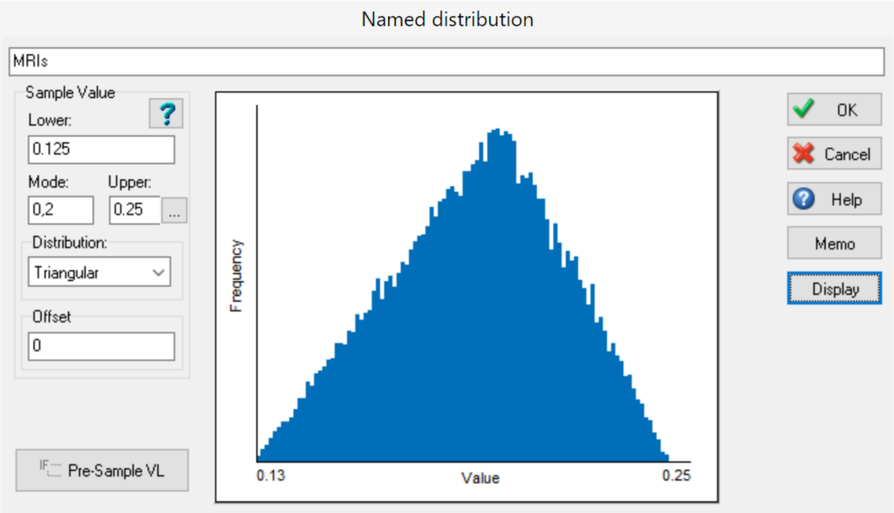
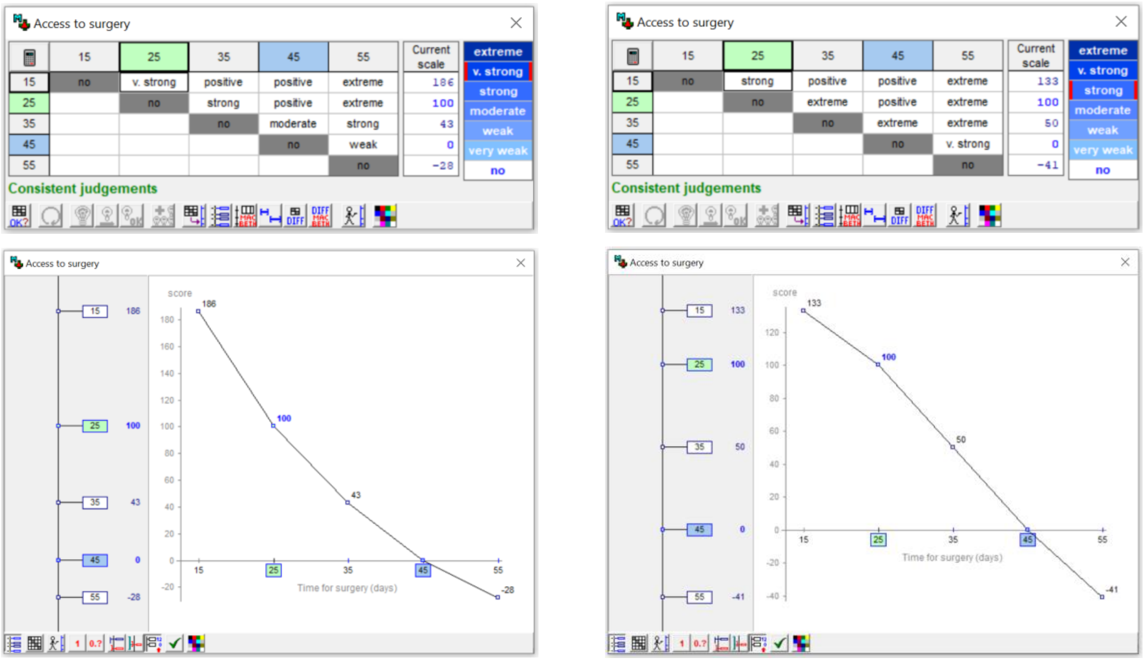


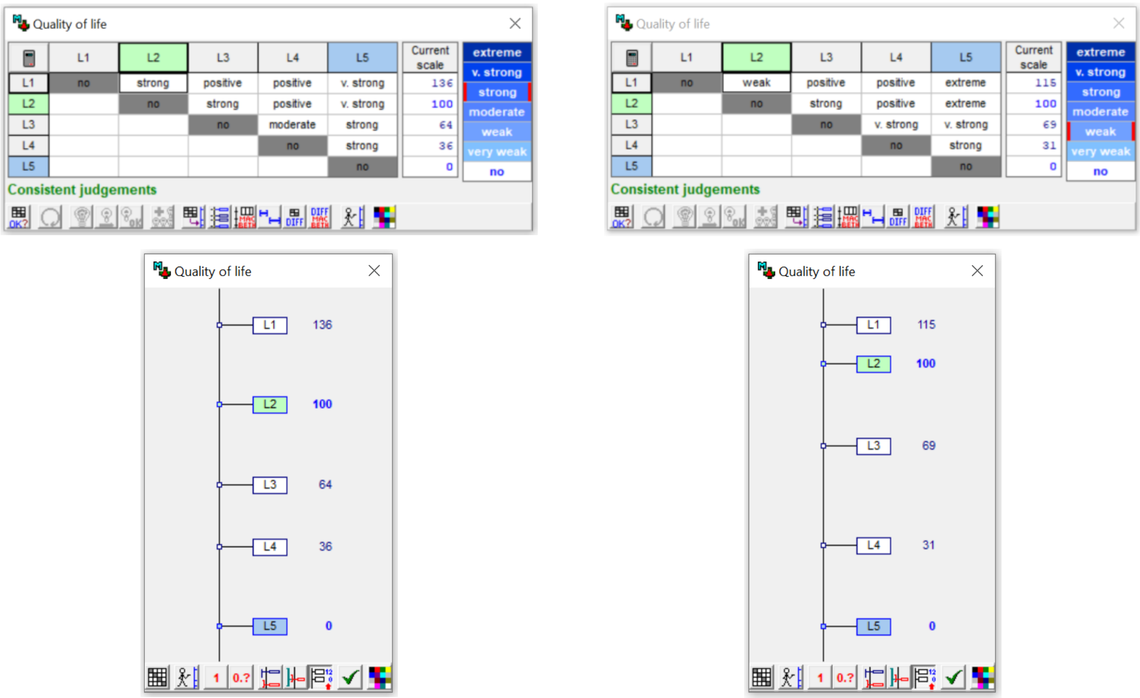
Figure D.5. Distribution associated with the performance of MRIs at the radiology service. In the simulation model, it was associated with the activity named "MRI".

Appendix E – Value Judgements Matrices and Value Functions



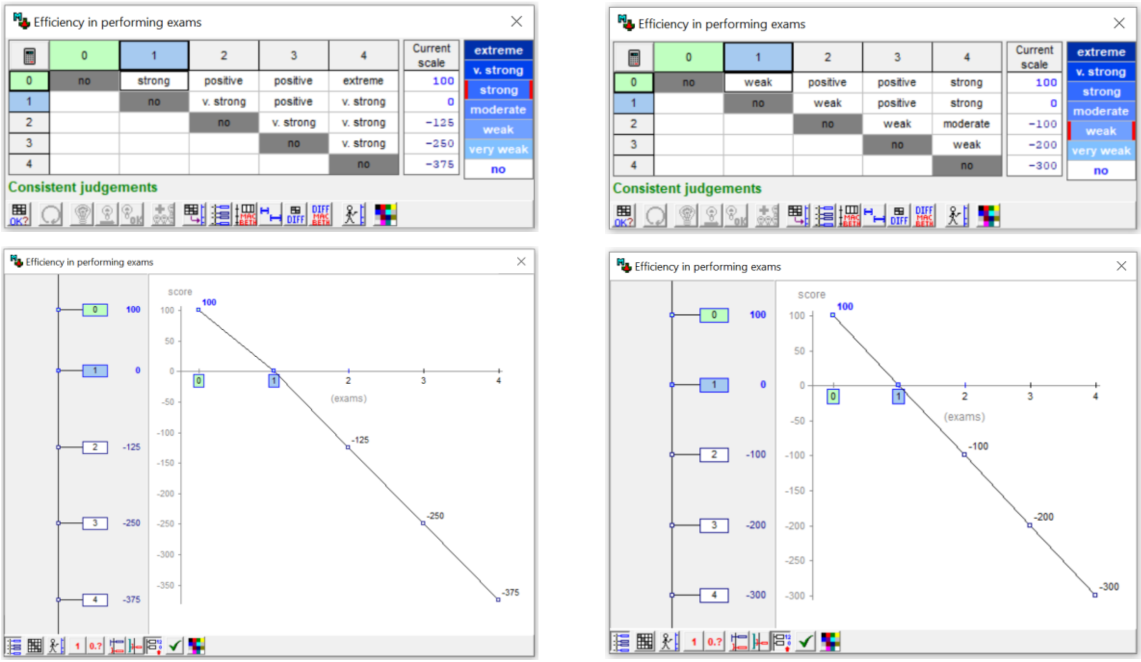
(a) (b)

Figure E.1. Resulting value judgements matrix (above) and respective value function (below) for the "Access to surgery" criterion when the judgements were collected from a physician (a) and an administrative staff member (b).



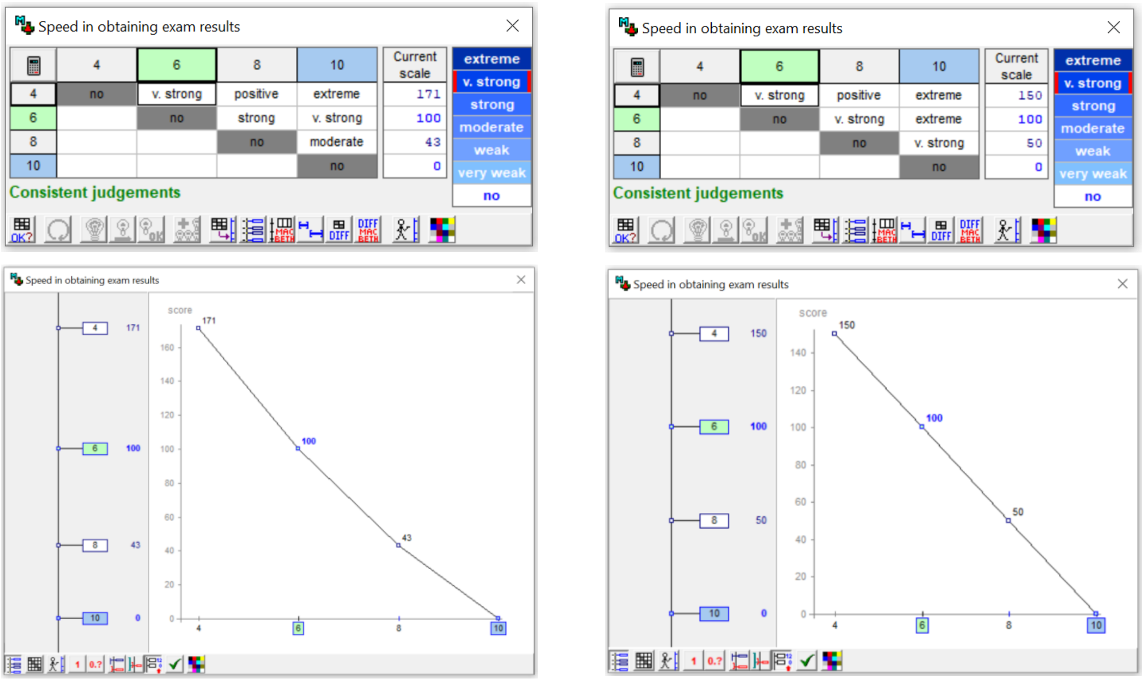
(a) (b)

Figure E.2. Resulting value judgements matrix (above) and respective value function (below) for the "Quality of life" criterion when the judgements were collected from a physician (a) and an administrative staff member (b).



(a) (b)

Figure E.3. Resulting value judgements matrix (above) and respective value function (below) for the "Efficiency in performing exams" criterion when the judgements were collected from a physician (a) and an administrative staff member (b).



(a) (b)

Figure E.4. Resulting value judgements matrix (above) and respective value function (below) for the "Speed in obtaining exam results criterion" when the judgements were collected from a physician (a) and an administrative staff member