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# Quality and access performance assessment of the Portuguese public hospitals:

A multicriteria framework

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## Biomedical Engineering

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# Declaration

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

# Preface

The work presented in this dissertation has been performed at Instituto Superior Técnico (Lisboa, Protugal), under the supervision of Professor Ana Sara Silva Rodrigues da Costa, within the frame of the hSNS FCT – Research Project (PTDC/EGEOGE/30546/2017): Portuguese public hospital performance assessment using a multicriteria decision analysis framework.

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Firstly, I would like to thank a lot to my parents, as education comes from birth till the day we are, every time learning and growing as a human being, conscious, responsible and never giving up. Perseverance and resilience were the most important lessons I attended at home and this turned possible to finish this hard step today.

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Last but not less important, I want to thank my family (and to the relatives who have already passed away), my friends and my godfather who were always asking me for my dissertation and boosting me not to give up.

# Abstract

Health is a basic human right. Every world citizen should have access to health services, wherever and whenever needed. We are fortunate to live in a country where this right is recognized and promoted. This is possible through the National Health Service, one of the oldest worldwide. However, it has been facing some difficulties to meet the needs of its citizens, being pushed to a threshold in costs containment, compromising the quality of care delivered. This issue is one of the most challenging in the century we are living, so this study concerns the performance assessment of the Portuguese public hospitals through a multicriteria approach, where the ELECTRE TRI-nC method is used to build a model. The data for the case study was gathered and handled from a reliable source, establishing the actions (hospitals and hospital centers) to be assessed. The criteria are chosen, based on that benchmarking, the literature review and according to the judgement of the Decision Maker. The criteria weights are determined through the SRF procedure and the required parameters, as well as the categories and the corresponding reference actions, defined through interactions with the Decision Maker. Then, the model was executed using the *MCDA-ULaval* software. The results provided the assignment of each hospital to a category or an interval of categories, revealing that the majority of the Portuguese hospitals is below average. Finally, the model was tested in its stability and robustness, proving it is a reliable tool to be useful in future research.

**Keywords:** Health care, Hospitals, Quality, Access, Multiple Criteria Decision Aiding, ELECTRE TRI-nC.

# Resumo

A Saúde é um direito humano básico. Todos devem ter acesso a serviços médicos, onde e quando precisam. Somos sem dúvida bastante privilegiados por viver num país que reconhece e promove esse direito. Tal é possível através do Serviço Nacional de Saúde, um dos mais antigos do mundo. Porém, este tem enfrentado dificuldades em satisfazer as necessidades da sua população, sendo pressionado por contenção de custos, o que compromete a sua qualidade. Este problema é um dos mais desafiantes do século em que vivemos, pelo que o presente estudo avalia o desempenho dos hospitais públicos portugueses recorrendo a uma abordagem multicritério, onde o método ELECTRE TRI-nC é usado para construir um modelo. Os dados recolhidos para o caso de estudo são provenientes de fonte fiável, sendo estabelecidas as ações (hospitais e centros hospitalares) para serem avaliados. Os critérios são escolhidos a partir desse *benchmarking* e da revisão de literatura, assim como de acordo com a perspetiva do decisor. Os respetivos pesos são determinados através do procedimento SRF e os parâmetros, categorias e correspondentes ações de referência são definidos em interação com o decisor. Seguidamente, o modelo foi executado usando o *software MCDA-ULaval*. Os resultados obtidos correspondem à associação de cada hospital a uma categoria ou intervalo de categorias, revelando que a maioria dos hospitais públicos portugueses se encontra abaixo da média. Por fim, foi efetuada uma análise de estabilidade e de robustez, provando que o modelo criado é robusto, podendo ser útil em investigações futuras.

**Palavras-chave:** Cuidados de Saúde, Hospitais, Qualidade, Acesso, Análise de Decisão Multicritério, ELECTRE TRI-nC.

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# Nomenclature

| | |
|---|---|
| $a$ | Action |
| $g$ | Criterion |
| $C$ | Category |
| $b$ | Reference action |
| $w$ | Criteria weight |
| $\lambda$ | Credibility level |
| $v$ | Veto threshold |
| $p$ | Preference threshold |
| $q$ | Indifference threshold |

# Glossary

| | |
|---|---|
| **AHRQ** | American Agency for Healthcare Research and Quality |
| **DA** | Decision Aiding |
| **DEA** | Data Envelopment Analysis |
| **DM** | Decision Maker |
| **EU** | European Union |
| **FHU** | Family Health Unit |
| **GDP** | Gross Domestic Product |
| **HCG** | Health Center Group |
| **HCQI** | Health Care Quality Indicators |
| **HRA** | Health Regulatory Agency |
| **IMF** | International Monetary Fund |
| **IOM** | Institute of Medicine |
| **MCDA** | Multiple Criteria Decision Analysis |
| **MoU** | Memorandum of Understanding |
| **NHS** | National Health Service |
| **OECD** | Organization for Economic Co-operation and Development |
| **PFI** | Private Finance Initiative |
| **PHCU** | Personalized Health Care Unit |
| **PHS** | Portuguese Health System |
| **PPP** | Public-Private Partnerships |
| **RHA** | Regional Health Administration |
| **SDGs** | Sustainable Development Goals |
| **SDR** | Standardized Death Rate |
| **SRF** | Simon Roy Figueira procedure |
| **WHO** | World Health Organization |

# 1. Introduction

## 1.1. Motivation

Health is the most important “asset” we have. It has “no cost” but costs a lot. As in the Portuguese Constitution, where is stated that everyone has the right to health protection but also the duty to defend and to promote it, health care provisioning is one of the most important rights for the human being and so we are really lucky to live in a country where this right is recognized and promoted. This is possible through the SNS (from the Portuguese abbreviation *Serviço Nacional de Saúde*) which stands for the National Health Service, created in 1976 and is one of the oldest worldwide. However, it has faced some difficulties to meet the needs of its citizens. In 2019, the health care expenditure in Portugal reached 9.5% of the Gross Domestic Product (GDP), more than the average of the OECD (with 9.0%), according to PORDATA [1] and OECD Statistics [2]. When almost 10% of the GDP was being spent in the health care sector per year, it was being pushed to a threshold in order to contain costs seeking innovative and better ways to improve efficiency, without compromising the quality of care delivered. Hospitals in Portugal are funding within contracts that do not completely take into account the maximization of the health care provisioning quality.

This issue is one of the most challenging ones in the century we are living in now, so this dissertation takes place on the analysis and support for decisions in the health care sector. It is extremely relevant to assess the quality of the Portuguese public hospitals, considering benchmarks to be handled and computed in order to study and so to improve the performance of the health care providers in the country we live in. Therefore, the quality assessment is possible to be done through an approach with many criteria (MCDA, Multicriteria Decision Analysis), using the ELECTRE TRI-nC method, which requires several criteria to best judge quality. Thus, we hope that this dissertation will be able to represent the Portuguese health care providers (in this case, the public ones) and consequently the status of the SNS.

## 1.2. Objectives

In order to pursue an analysis of the health care provisioning, under quality and access dimensions, mainly considering the health care providers, the SNS itself, and therefore propose a method which uses relevant criteria and includes the Decision Maker’s preferences to reach personalized weights. Those consequently make it possible to assess the performance based on composite indicators, using a multicriteria model. Thus, a variety of objectives widely considered the analysis to be pursued may be described afterwards:

- Acknowledge the context of health in Portugal in a wide range of fields, such as social, economic and political, taking into account the dimensions of quality and access to health care provisioning;
- Build a model for assessing the overall quality and access of the Portuguese public hospitals;
- Propose a robustness analysis methodology to be applied to the model;
- Apply the designed model to a case study in the Portuguese health care sector and imply possible recommendations for health care managers and health care policymakers.

## 1.3. Work methodology

The aforementioned objectives can be achieved through a work procedure which includes a plan, from the problem description, where one identifies what is supposed to be analyzed, throughout a wide range of research and application steps, to the multicriteria model then applied to the case study, from whose results further recommendations come. The work methodology is then described below:

- Identify the problem and identify its background - the health care sector and its circumstances;
- Review the suitable literature notwithstanding a concrete theoretical foundation;
- Formulate a model to be applied to the aforementioned dilemma, according to the established foundations;
- Collect the required data to be used in the case study;
- Apply the defined model to the collected data and obtain reliable results;
- Discuss the results obtained from the operationalization of the model, based on the considered parameters and robustness analyses;
- Conclude relevant recommendations from the application of the work methodology.

## 1.4. Structure of the dissertation

This dissertation presents a structure of seven chapters, which pursue the aforementioned goals through the defined work methodology presented in this Chapter 1. Afterwards, Chapter 2 analyzes the context of the problem, considering the main issue and its circumstances about the health care sector firstly globally and then in Portugal, studying the SNS and Portuguese health care providers. Chapter 3 corresponds to the literature review to give support to the proposed methodology and model built in the next chapters. Moreover, it will allow establishing a concrete definition of quality in the health care services provisioning as well as the way to measure it, considering the construction of composite indicators to be included in the assessment. Then, in Chapter 4 the methodology used to build the model is presented, the ELECTRE TRI-nC. Chapter 5 embraces the case study, detailing the overview of the methodology appliance, then presenting the Decision Maker (DM), the data sample gathered and handled from a reliable source (ACSS benchmarking), the selection of the assessment indicators and consecutively definition of the criteria, as well as the selection of the actions (hospitals and hospital

centers) to be assessed in this MCDA approach with the respective performance table for the year of 2019. Then, Chapter 6 includes the definition of the variables to be inserted in the model in an interaction with the DM. This sixth chapter starts with the calculation of the criteria weights through the SRF procedure in the DecSpace platform, then the modeling parameters are defined (method and criterion parameters, as well as the veto threshold) and the categories and respective reference actions established. Besides that, the model built in *MCDA-ULaval* software is executed, so the method ELECTRE TRI-nC is carried out, obtaining the assignment results: each action assigned to a category or an interval of categories. Finally, this chapter also includes the stability and robustness analyses to test if the model created is reliable. So, in the last chapter, Chapter 7, conclusions of this dissertation are drawn, some limitations of the approach pointed out and recommendations for future research are also considered.

# 2. Problem definition

This chapter includes the definition of the problem and the respective context. Firstly, the health sector in a worldwide perspective will be shortly described and then there will be a specific description of the Portuguese Health System as well as its changes throughout the past years.

## 2.1. Background – the health sector

Health is one of the basic human rights, which means that every world citizen should have access to the health services needed, wherever and whenever they need, with no financial hardship [3]. Better health is essential to human well-being and happiness, which implies that there is an important contribution to progress in the economic sector, as well as providing some possibilities to increase worldwide human life expectancy. They become more productive and tend to save more. However, many factors influence the health status and the capability a country has to provide high-quality health services for its inhabitants [3].

The provision of health care should be effective, equitable and safe widely across populations, throughout the continuum of care and along the life course, with a simultaneous waste reduction. As defined in the Sustainable Development Goals (SDGs), universal health coverage aims to ensure health safety and universal access to health care services to worldwide citizens, enhancing progress towards more efficient and equitable economies and societies [3].

Universal health coverage is a job half done if excluding quality on its provisioning, being extremely important to keep the health care with the preference and needs of the populations being effectively served. In fact, high-quality health care is not a warranty for people who live in developed countries, as these can afford to provide any care for their citizens, but somehow this is not being conducted in terms of being effectively provided. Poor-quality health care is harmful and wastes important resources (scarce in some cases) which may be invested in other drivers of economic and social improvement to provide better lives for populations.

Globally considered, many aspects of the quality of health care have been improved which means much progress in this sector. For instance, the survival rates of cancer patients and the mortality caused by cardiovascular diseases have shown better values [4,5]. However, those are a few examples of what health care good news is concerned about. Meanwhile, in developed countries, one in 10 patients suffers from the adverse effects of medical treatments and seven in 100 hospitalized patients expect to take an infection during the stay (while this figure is even worse for developing countries, where one in 10 patients undergoes those conditions), which could be easily prevented with better use of antimicrobials and improved hygiene [6,7]. Moreover, worldwide costs associated with medication errors have been determined to be 42€ billion each year [8]. So, as an undoubted truth, beyond the effects on populations' lives, low-quality health care wastes money and time, which implies that if the quality is part of the universal health coverage then this is striving for better and longer lives as well as an economic necessity. In fact, this is affordable for developed countries but still not for developing ones, where the

lack of quality even worsens the unaffordability for covering all the associated costs. Nearly 15% of the expenditure in hospitals of developed countries is used to correct avoidable mistakes. Low-quality health care leads to vast economic and social expenses, related to patient harm, caused by a disability for a long stay, duplicate services, lost productivity, preventable hospital admissions and readmissions, amounting to trillions of € every year [9]. Nevertheless, up to 20% of the expenditure in the health sector is involved in processes that generate few improvements in the health care provided, which could be avoided and used more effectively [6].

As aforementioned, rather than a plus in the sector, achieving quality is a must. For some, this may be ambitious, but this should be the goal, whose effort implies leadership, management, planning and effective investment. For instance, meanwhile in Uganda, one designed a model of health care services involving its inhabitants, improving a range of indicators, such as 33% of child mortality reduction [10]. In Costa Rica, unbelievable upgrades were done in primary care due to a planned and allocation strategy [11]. Thus, this is possible to carry on and even more affordable for countries in which resources are vaster but wrongly allocated and ineffectively invested.

Globally thinking, the health care provided to the world citizens is effectively done, if with quality. Quality involves many indicators to be defined and for this purpose, a sustainable and planned method should be carried out and should be outlined in similarity across every country. Along with access and financial protection, quality comes as a clearly defined priority of the SDGs for universal health coverage.

## 2.2. Context – the health care in Portugal

The Portuguese Health System (PHS) is composed of coexisting systems: (1) the National Health Service (NHS), regulating, providing management, financing and provisioning health care, (2) the Health Subsystems with special social health insurance schemes, dealing through occupation-based categorization used in the public sector and for specific groups, namely military and banking, as well as by (3) the voluntary and private sector health insurance [12].

The PHS was designed in 1971, being firstly recognized the right to health to all Portuguese citizens and afterwards, social movements of the 1974 Revolution demanded conditions to make this happen and applied for every single inhabitant, leading to the Portuguese Constitution of 1976 [13]. In fact, Portugal has been facing changes throughout the past decades, with social and economic impacts. Since the military coup of April 25$^{th}$ in 1974, which freed the Portuguese political regime from a dictatorial to a democratic one, the country has seen remarkable developments, such as the integration in the European Community in 1986 and the Euro Zone in 1999.

Before the revolution of 1974, health care was provisioned for the employed citizens and to their direct dependents through a fund of social security and sickness protection, which were financed by regular contributions from both employers and employees. After this period, which began in 1946 with the enaction of the first social security law in Portugal and had its end in 1974, then a process of restructuring of the health care services was implemented, being established in 1979 the National Health Service (known in Portuguese as *Serviço Nacional de Saúde, SNS*), a universal tax-financed health care system [12,14]. At that time, this “universal, comprehensive and free-of-charge National Health

Service" brought together already existing hospitals and other health care facilities, which were being under the operation of religious charities, known as *Misericórdias,* and the social welfare system [14]. This establishment was in line with the basic principle of the right to health for every citizen, defined in the new and democratic Portuguese Constitution of 1976 [12]. Therefore, many conditions were being created to encompass all health care related to the avoidance of diseases and the diagnostic and treatment procedures of patients and individuals under rehabilitation processes. The NHS was established as part of the Secretariat of State for Health in the Ministry of Social Affairs, organized on three articulated levels: central, regional and local, each one with its specific dimension and characteristics, ensuring the application of the law that enacted the right to health protection [15].

Since the creation of the NHS, Portuguese health care underwent numerous changes, such as the application of user charges, although some exemptions were also established to ensure that every citizen was able to access health care services regardless of the social and economic strata to which they belong. Some features kept unchanged from the previous system, such as health subsystems, remaining to provide a large portion of the Portuguese population, both public (civil employees) and private corporates or individuals (insurance and banking enterprises or post-office services, for instance) [12]. Then, in spite of being publicly financed and provisioned and the NHS aggregated most of health care facilities performing in Portugal, private supply has been active, *i. e.,* some laboratory tests, imaging, rehabilitation centers and clinics were apart from public funding [12]. The NHS came under a regionalized schema (Regional Health Administration, Inter-Hospital Commissions, and Local Commissions) pretending to improve the community health services [16,17,18,19]. This structure was then changed in 1990, when five Regional Health Administrations (RHA) were established with the scope generalized in 1993 with geographical borders defined (nevertheless, this law was never implemented), enacting that in each Portuguese region, regardless if in the south, center or north of the country, should be an RHA [20,21]. The demand for health care protection and universal coverage had grown intending to be provisioned with quality and quickly, thus the legislation mentioned to be more concerned and pointed to the need for resources management and allocation clearly done as close as possible to the citizens in need for care services. This was the lead point to create regions of health care administration, managed by each demand and competencies. The RHAs are distinct entities focused on administrative and financial managing with its own singular autonomy and assets, deciding how to perform the respective functions of coordination and organization as well as planning, technical support, assessment of the process within the health care institutions and allocation of resources (human and capital ones) [21]. The case of the Portuguese islands, the Autonomous Regions of Madeira and Azores are peculiarly different due to the fact there are special geographical conditions and administration under a specific political regime with the respective regulatory system considering a distinct operation of the health care services provisioning affected to their policies and under the judgement of their own regional' government [21].

Also in 1990, when a restructuration of the NHS took place through the enaction of the Health Basis Law (known in Portuguese as *Lei de Bases da Saúde*), its goals regarding the universality of the health care provision ensuring the target population to be covered by the promised care protection were redefined in order to distribute equitably and guarantee the necessary provision all over the country [20].

This included the goal of being free of charge for every citizen in need depending on the respective financial and social conditions, as well as being equity in terms of access in order to minimize any effects from geographical, economic, social or educational inequalities. Some measures also enacted in the law were to implement a regionalized coordination and a participatory and decentralized management. The targeted users of the NHS should be the Portuguese inhabitants (*i.e.* national citizens with Portuguese nationality or foreign individuals with residence authorization in Portugal or even those who follow the required conditions of stateless citizenship). Furthermore, special measures were taken into account such as health protection coverage to certain risk groups, namely newborns, young citizens, drug dependents, women with declared pregnancy, employees whose occupation so justify and handicapped individuals.

By 1996, some agencies were established for Outsourcing of the Health Services in order to ensure that the available resources were being well applied, defining metrics, planning the processes and assessing the results in budget-defined programs [22]. Meanwhile, the Health Regulatory Agency was established, whose defined purpose was to guarantee the general interests of each citizen in particular and of the whole citizens in general [23].

In the decades of the 1980s and 1990s, the promised geographically coverage of the public health care provisioning was relatively well accomplished, with an increase, for instance, in the number of medical appointments in primary care, accounting to 36.4% between the years of 1985 and 2001 [24]. The responsibility is taken by the Portuguese Government on what both the individual and collective protection to health was concerned truly presented a significant efficiency.

At the beginning of the 21$^{st}$ century, the NHS turned into a mixed system, established by an integration amongst the sectors, public and private, provisioning primary, secondary and long-term health care [12]. Health reforms were then carried on aligning and improving the claimed efficiency within the universal health coverage of the NHS health care provided. Moreover, many public hospitals became private enterprises just administered with public capital following a newly defined management model for privatization of the already existing public hospitals. Besides that, innovative reforms took place and established the creation of new hospitals in the NHS funded by both public service and concession to the management of hospital facilities and private capital through a Private Finance Initiative (PFI) to construct and maintain the hospital facilities: the Public-Private Partnerships (PPP), such as the instance of the hospital facilities in Braga, Loures, Vila Franca de Xira and Cascais [25]. The main health care achievement category of the NHS is Primary Health Care, whose reforms brought many organizational reformulations. By the way, Family Health Units (FHUs) were established in 2006 with self-oriented teams composed of multi-disciplinary health professionals with specific work procedures and own methodologies which implied some autonomy to apply operationally and technically their knowledge and experience. This was subjected to a defined contract system involving employment with decentralized diagnostic processes and some advantages to the workforce to achieve higher productivity, quality and effectiveness. Besides that, Health Center Groups (HCGs) appeared as administrative entities, controlling the FHUs and the former health care units (named Personalized Health Care Units, PHCUs), where the symmetric dispersion of provisioned care was just in theory, as it is possible to be seen in Figure 2.1, disclosing many inequalities regarding geographical isolated areas

in terms of access to health care services with potential impacts on the Portuguese health equity of universal coverage [26].

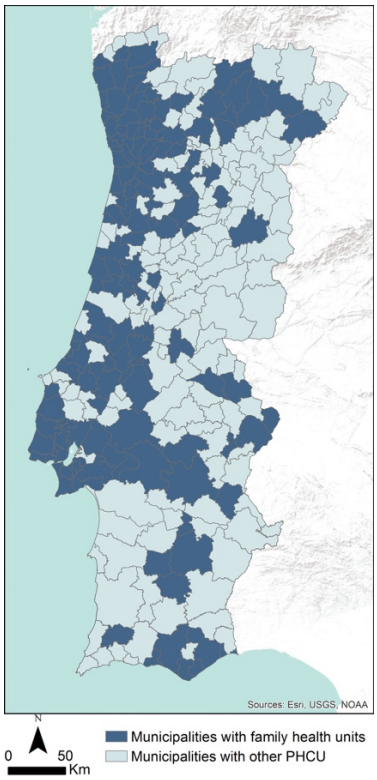


Figure 2.1: Asymmetric distribution of health care provisioning in Portugal (Mainland), through FHUs and PHCUs [26].

Meanwhile, many countries underwent a serious financial crisis in 2008 and there was no exception for Portugal, leading to severe impacts in the following years in the health sector, amongst others. After a soft but relatively stable economic growth of the gross domestic product (GDP) counted to 0.8% between the years 2001-2010, Portugal started to experience an economic recession in 2009 [27]. Along with an increase in unemployment and a dramatic public debt, this Portuguese economic turmoil hampered the country to access to the international financial markets, turning the conditions even worse to re-finance the debt. This context pushed Portugal to ask for financial support from the European Union (EU), the International Monetary Fund (IMF) and the European Central Bank [28]. Then, after the financial crisis, in order to ensure cost restraint, some measures were applied, including the health sector, through the Economic and Financial Adjustment Programme. This programme was signed amongst the three aforementioned international institutions and the Portuguese government in 2011, defining the Memorandum of Understanding (MoU) [28]. This agreement made possible a loan of €78 million, intending to cost containing and ensure better conditions in the NHS. The MoU established many policy measures for the following period, 2011 to 2014, which included austerity requirements, decrease of public expenditure, increase of the taxes to reduce budged issues, restructuring and stabilization of the financial sector with new reforms in goods, services, housing, sanitation, transports and education

[28]. In fact, 34 measures were applied through the MoU as far as the health sector was concerned, in order to massively reduce costs and improve overall efficiency on a permanent basis [29,30].

Meanwhile, almost all of the implementation carried on the expenditure in the health care resulted from the effects of price, some from the reduction of quantities and just a small proportion was due to the financial responsibility from the government to its citizens. This was possible through a decrease of the general health worker salaries, reduction in the expenditure on public pharmaceutical products, implementation of clinical guidelines in medical practice, as well as through reestablishment of prices related to private enterprises whose contract had been made with the NHS [12].

In fact, the health policies as well as their overseeing, assessment and implementation are at the responsible of the Portuguese Government, through the Ministry of Health. The Ministry of Health is organized as it is shown in the schema presented in Figure 2.2.

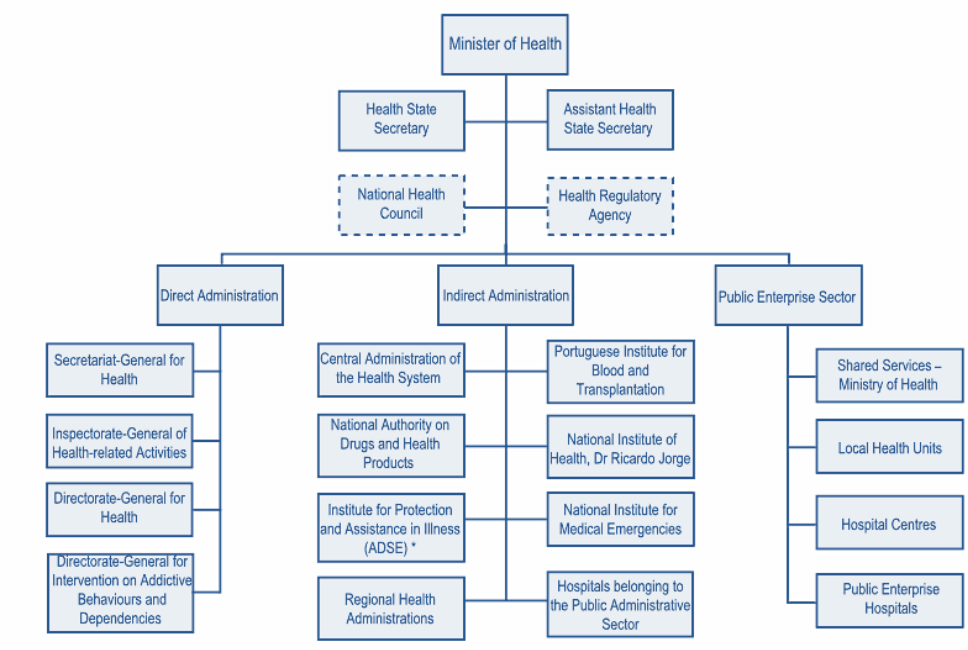


Figure 2.2: Organizational schema of the Portuguese Ministry of Health [12].

The main role of the Ministry of Health is to manage, regulate and plan the NHS, as well as to audit private health care providers, regardless of whether they are part of the NHS. The processes of making the health policies are at the responsible of the government and, usually, the rule administration goes to institutional partners to be consulted. The policy measures plan for evaluation and assessment is not well detailed indeed. The task of implementation is carried out by RHAs and, in fact, the Ministry of Health does some evaluation and inspection, as well as the Inspectorate-General of Health-related Activities and the Court of Auditors, however, the assessment of the policies is a non-systematic process. The responsibility for the first level of control, under the supervision of the Minister of Health, is carried out by the Health State Secretary and by the Assistant Health State Secretary [12].

As one can see in the Figure 2.2, the Ministry of Health embraces many institutions: the National Health Council (a consultative body); the Health Regulatory Agency (HRA) which is independent in its determinations; some directly administrated bodies (the Secretariat-General for Health, the

Inspectorate-General of Health-related Activities, the Directorate-General for Health and the Directorate-General for Intervention on Addictive Behaviors and Dependencies); some indirectly administrated (the Central Administration of the Health System, the National Authority on Drugs and Health Products, the Institute for Protection and Assistance in Illness – ADSE, the RHAs, the Portuguese Institute for Blood and Transplantation, the National Institute of Health Dr. Ricardo Jorge, the National Institute for Medical Emergencies and the Hospitals belonging to the Public Administrative Sector); and some having a different status (the case of the Public Enterprise Sector: Shared Services of the Ministry of Health, Local Health Units, Hospital Centers and Public Enterprise Hospitals) [12].

As referred, two of the bodies do not undergo the Ministry's administration. Both are independent: the National Health Council is in charge of the recommendations and advice on what measures to incite the implementation of health policies are concerned; and Health Regulatory Agency which is responsible for the supervision of the health sector, including the regulation of health care institutions on the operating requirements, patient's rights, quality of the health care provisioned, enforcement of the competition of the health care sector, as well as equality of the health care access by the citizens [12].

The Ministry of Health run hierarchically several central services which directly undergo the government's administration. The Secretariat-General for Health provides support to some other services, bodies and institutions, which are not integrated within the NHS, considering information, public relations, legal advice and internal resources. This entity also gives technical and administrative support to the Ministry, giving assistance to several government offices, coordinating the work of their staff. By its side, the Inspectorate-General of Health-related activities establishes the disciplinary of the health sector, being responsible for the audits and supervision, in the NHS services and institutions, as well as in the private ones. The Directorate-General of Health coordinates, regulates, creates plans and supervises health promotions, as well as the disease prevention and health care activities, services and institutions, independently they belong to the NHS. This entity also performs public health programs, epidemiological surveillance, health studies and statistics. The Directorate-general for Intervention on Addictive Behaviors and Dependencies implies the decrease in the consumption of legal and illegal drugs, preventing and conceiving treatments for the addictive behaviors as well as the reduction of the dependencies [12].

Some other entities undergo the indirect administration of the government, as one can see in Figure 2.2. The Central Administration of the Health System implements the health policies, regulates and plans simultaneously with the RHAs in health service contracting, as well as being responsible for the management of equipment, facilities, financial and human resources, information and systems' technology of the NHS. Another entity is the Portuguese Institute for Blood and Transplantation, being in charge of donated human blood analysis, storing, processing and provisioning as well as of its components, organs, tissues and even cells. Also regulates the quality and safety regarding those aforementioned core functions and establishes some control on the pharmaceuticals used for transfusions and gives certainty that a stock of safe blood and its components exists and is available in case is needed. Furthermore, the National Authority on Drugs and Health Products (as known as *INFARMED*) has on its responsibility the health products sector and pharmaceuticals following the standards of the general public health safety. So, this entity guarantees all the health care workers and

patients have safe access to efficient health provisioning with high-quality pharmaceuticals and secure and certified health products being applied. The National Institute of Health, Dr. Ricardo Jorge (as we know as *INSA*, *Instituto Nacional de Saúde Doutor Ricardo Jorge*) is the main reference for the Portuguese health system concerning laboratory and epidemiological analysis, including the national observatory and laboratory reference in the health sector, performing health research at the Ministry of Health and providing evidence for policies in the public health sector for its six departments: Health Promotion and Chronic Diseases, Nutrition and Food, Environmental Health, Genetics, Epidemiology, and Infectious Diseases. Those core departments perform cross-disciplinary programmes in problem areas of public health, such as health monitoring, laboratory quality assessments and research and development (R&D). Moreover, another institution that is also very known is the Institute for Protection and Assistance in Illness (*Instituto de Protecção e Assistência na Doença*, *ADSE*), conceiving effective access to health care coverage which means social protection for public administration workers and respective families. This entity is a health subsystem for civil servants under the indirect control of both the Ministry of Finance and Ministry of Health. Following but not less important, another well-known entity which is the National Institute for Medical Emergencies (*Instituto Nacional de Emergência Médica*, *INEM*), being in charge of the Integrated System of Medical Emergency, providing immediate assistance to severely ill patients or injured citizens, delineating and assessing the activities related to this core function. The RHAs (Regional Health Administrations) are responsible for the national health policies in the respective region and regulate all levels of health care there, including strategic management and supervision of public health as well as direct and centralized management of the NHS primary care. The NHS, besides being financed by the Ministry of Health, has its regional structure established in 1993, including five health administrations: *Algarve*, *Alentejo*, *Vale do Tejo*, *Lisboa*, *Centro* and *Norte*. The Ministry of Health runs the principles through which, in accordance with the directives established in regional plans, the RHAs perform their intervention. RHAs are in charge of the development of a long-term care network, coordination of the health care provision in each region, establishment of protocols with private entities, supervision of hospitals and management of the primary care. Moreover, RHAs are even responsible for the agreements with private non-profit-making bodies and religious charities (as known as *Misericórdias*) and with governmental bodies. Last but not the least, hospitals belonging to the Public Administrative Sector are a reduced part of the public hospitals, which were not taken into the conversion for Public Enterprises (as known as *Entidades Públicas Empresariais*, *EPE*), *i.e.* public entities without the status of “enterprise”, so are still being regulated by civil rules [12].

A third sector is the Public Enterprise, where a well-known entity is being managed, Shared Services of the Ministry of Health (*SPMS*, *Serviços Partilhados do Ministério da Saúde*). This entity gives specific shared health-related support: logistical, financial, informational, communicational, systems and human resources, as well as supplementary actions to organizations that are part of the whole NHS and also to entities which belong to the Ministry of Health, in the case they intend to provide activities specifically focused on the health field. Furthermore, Local Health Units, established in 1999, allow a better connection between primary care and the hospitals, through the integration of distinct levels of care. Actually, eight Local Health Units exist in the continental country: *Santiago do Cacém*, *Beja*, *Portalegre* (those three in the South), *Castelo Branco*, *Guarda* (those two in the Center), *Bragança*, *Viana do*

*Castelo* and *Matosinhos* (those three in the North). Amongst the public hospitals, few remain as individual entities, but in the major, they have the status of “enterprises”. Hospital Centers include hospitals that are regulated as Public Enterprises and were established to provide an increment of efficiency, allowing better communication between institutions that provide hospital care in the same district. Hospitals and Hospital Centers are both Public Enterprises, which means that their management has some autonomy and accountability in comparison with the hospitals belonging to the Public Administrative Sector [12].

Regarding health status and how those aforementioned entities are regulating and managing the health sector in Portugal and how successful all the measures are being taken throughout the past years, it is time to perform some detailed analysis. In fact, Portugal has shown good news, with progress in both increasing the average life expectancy at birth and reduction of the mortality rates during the last four decades. In 1965, the universal immunization programme contributed to the distribution and universalization of the health care services provided to Portuguese citizens and afterwards, this was boosted by the implementation of the NHS, with general progress in the global living conditions. In 2014, life expectancy in Portugal amounted to 81.3 years, relatively higher than the average value for the EU in the same year (80.9 years) [31]. It was also undoubtedly noted that life expectancy was different between women and men, where women were expected to live longer than men (6.4 years), being this value slightly lower in the EU (5.5 years) [31].

Over the last forty years, many indicators were created to define and assess the population health, being made more sensitive and accurate. Thus, this became increasingly more useful throughout the time passed in order to define health plans as targeted as possible and needed. Those indicators, established to ensure an accurate health assessment were brought into a deepening level of detail in comparison with the traditional ones early created, such as the mortality rate under a certain age and the potential years of life loft when in premature death. Through well-established indicators, it turns to be possible to identify the death cause and then avoid afterwards for dozens, hundreds or even thousands of patients, know if the services were timely provisioned and as needed, as well as the healthy behaviors those patients had or had not throughout their lifetime. Then, it is possible to achieve which are the health gains using indicators for a health care assessment.

The number of inhabitants in Portugal amounted to approximately 10 million in 2016 and two-thirds of them resided in urban areas, which is absolutely distinct from what had been seen before the year 1974, when just nearly one-third of the 8.8 million Portuguese citizens were living in urban areas [32]. There has been an urbanization process throughout the last decades, aligned to a growth of the Portuguese population during some phases and with distinct rhythms, also revealing some decreases at certain periods but with no relevancy. Along with these changes, some social conditions showed better rates, such as the literacy rate (increased from 74.3% to 94.8% in the period 1970-2011), the percentage of residences with public water provision (increased from 47% to 99% in the period 1970-2011), the percentage of the Portuguese citizens with access to urban waste collecting system (increased from 34% to 81% in the period 1970-2011), or even the percentage of the population with access to showers (increased from 32% to 98% in the period 1970-2011) [32].

In spite of being noted many improvements in Portuguese social conditions, not all facts were so positive. In fact, there were three interventions of the IMF, the first two in the aftermath of the dictatorial to democratic regime transition (in the years of 1977 and 1978, as well as in 1983-1985) and the third one in 2011, already mentioned in this chapter [33].

By the way, now in terms of demographic conditions, one of the major issues of Portuguese health on the overall assessment is the increased ageing, due to the demographically inverted evolution. The Portuguese population above 65 years old has been growing (from 9.8% in 1974 to 20.7% in 2015) and the young age group, which comprises the citizens between 0 and 14 years old, has been shrinking (from 27.7% in 1974 to 14.1% in 2015), as one can see in Figure 2.3 [32].

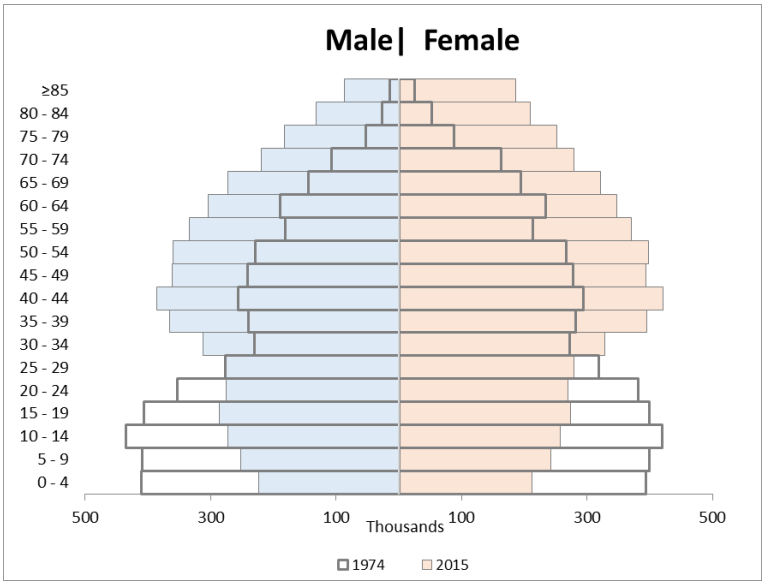


Figure 2.3: Inverted pyramid showing the ageing of the Portuguese population, in years old (adapted from INE, 2016).

This inverted pyramid is in part due to a decrease in fertility rates. In fact, during this period, from 1974 to 2015, the registered number of live births per woman in fertile age reduced more than 50%, from 2.7 to 1.3 and since the year 1983 this indicator has been under the required value (which is 2.1) needed to ensure the replacement of the Portuguese population for the next generations. This was registered almost similarly in the whole country (93%), *i.e.*, almost all municipalities underwent this drop in the birth rate. By the way, aligned with the aforementioned indicator, there has also been a change in the average of the mother's age at the first birth of her child, increasing from 24 years old in 1974 to 30.2 years old in 2015 [32].

Furthermore, there is a discrepancy on where the elder groups reside in Continental Portugal, being located in a higher percentage in peripheral areas of the center-east and northeast side, as one may see in Figure 2.4, which therefore creates some issues regarding the access to the health care services and some inequalities in terms of its provisioning for this part of the population, affecting the overall health indicators.

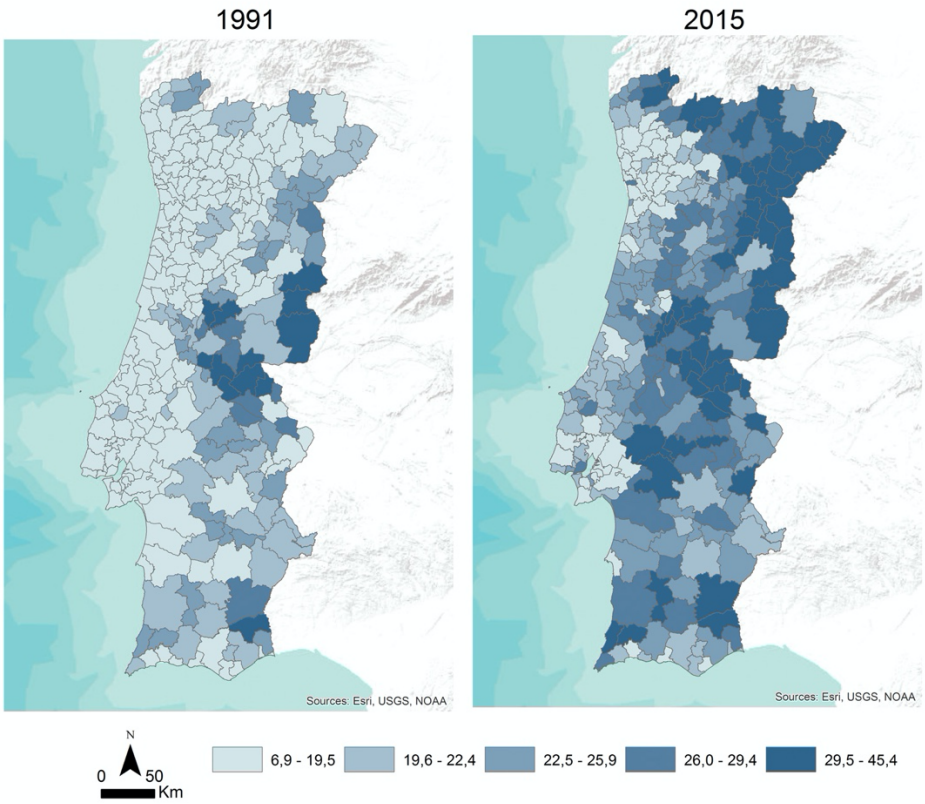


Figure 2.4: Distribution of the Portuguese population, in percentage, with 65 years old or above, in comparison between the years 1991 and 2015 (adapted from INE, 2017).

Another relevant fact is the increase of the life expectancy of the Portuguese population throughout the past four decades, from 13.1 years in the overall average of this indicator at birth (revealing a rise of 13.2 years for men and 13.0 years for women). Nevertheless, there is still a difference between the life expectancy at birth of both genders (6.6 years in 1974 to 6.4 in 2017) [34].

Some strategies carried out through development programs, such as the Mother-Child Health Program or the Immunization Programme, as well as preventive and therapeutic systems improvements, aligned with social and economic uplifts which contributed to better conditions in terms of hygiene, minimum sanitation, housing, eating and physical exercise habits, assumed such a relevant impact in the reduction of the maternal mortality rate, as well as in the perinatal, neonatal and infant mortality rates. The promotion of healthy habits and frequent health monitoring, performing the recommended disease prevention actions, has played an important role not only in the overall health improvement of the Portuguese population but also in the inequalities in health status between urbanized and rural regions [35]. In approximately forty years, there was a deep decrease in the mortality rates, by the way, the infant mortality rate dropped from 37.9‰ in 1974 to 2.9‰ in 2015, the neonatal mortality rate dropped from 20.9‰ to 2.0‰ in the aforementioned period, as well as the perinatal mortality rate which decreased from 32.3‰ to 3.7‰ [36]. Furthermore, the maternal mortality rate has also been significatively decreasing throughout the past decades, whose value was 47.7 women deaths per 100,000 neonates in 1974, in the sequence of complications during their pregnancy period [32]. However, these issues are actually much rare, so this indicator almost tends to 0 nowadays. In fact,

there is hardly any recorded maternal death during their pregnancy period due to complications and this is owing to health care established measures within the scope of the NHS, such as the high number of child births accompanied by many specialized medical professionals, the aforementioned program Mother-Child Health or even due to fewer issues caused by abortions, especially since the enaction of the decriminalization law for the abortion in 2007.

The health care in Portugal has undertaken several satisfactory changes, nevertheless, the scenery could be better without the increased incidence of some types of diseases in adult age, such as cancer, metabolic diseases, endocrine dysfunctions and nutritional disorders related to a wrongly assumed lifestyle or even unhealthy habits some people are conducive to follow. In fact, nearly 40 years ago, the most prevalent diseases were related to the circulatory system and external causes and undoubtedly were the major causes of death in Portugal, however since this past the rise of other causes of death till actually led to some health issues nowadays, such as the case of diabetes for instance [36]. Considering an analysis by age group and gender, in 1974 the neonatal and infant mortality was in most of the registered cases due to pneumonia and other respiratory issues, the deaths of young patients (mainly children above 5 years old and young adults till 25 years old) were due to transport accidents and the major causes of death for patients above 25 years old were cerebrovascular diseases. Four decades and a half passed since those registered values and actually (almost, because of the data is regarding the year of 2018), the neonatal deaths are due to complications that happened during the perinatal period of pregnancy, the infant mortality is mainly due to congenital malformations, the child and young adults' deaths are mainly caused by transport accidents as it was also in 1974, while the death causes for people above 25 years old till 59 years old may be filtered by gender in this case as it is distinct (for men and for women the major cause is ischemic heart disease and breast cancer, respectively), and finally, for the age group of 60 years old onwards, the major cause continues to be the same for both genders and similar as in 1974, which is cerebrovascular diseases [36].

By the way, in terms of mortality, 45% of deaths in 1974 were population under 70 years old, nevertheless, in 2017 this value was much different, 22%. In an absolute perspective, 45% of all deaths in 1974 was 43,750 deaths and 22% in 2017 was 23,251 deaths. This means that there was a drop in the Years of Potential Life Lost, *i.e.*, per 100,000 citizens for men the value was 14,089 years lost in 1974 and then 4,057 years lost in 2017, as well as per 100,000 citizens for women the value was 8,188 years lost in 1974 and then 1,851 years lost in 2017. This is the number of years summed up from every death that occurred under the age of 70 years old, considering every difference between the reference age (70 years old) and the age at which the patients have dead [34]. Most years of Years of Potential Life Lost per 100,000 citizens for men were due to accidents or circulatory system-related diseases till 1974, while for women this was due to respiratory issues followed by circulatory complications. Otherwise, in 2017, there is almost no difference between the genres while considering the causes for the Years of Potential Life Lost: cancer complications as the most impactful followed by circulatory system diseases [12].

Many health indicators have shown improvements throughout the last decades and the proof is that values are decreasing. Moreover, in some cases, Portugal presents better figures on what health status is concerned when in comparison with other countries of the EU (for instance, the EU-15, which

comprises the following group of countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom). In fact, Portugal has undergone a deep decrease in the Maternal Mortality rate of 83%, from 1974 to 2017, as well as in the Perinatal Mortality (84%), Neonatal Mortality (87%) and also the Infant Mortality (92%). Considering the countries of the EU-15 group, it is possible to analyze that Portugal is one of those countries that has been achieving a better and favorable epidemiological transition for the infant period of age as one can see in Figure 2.5 [34].

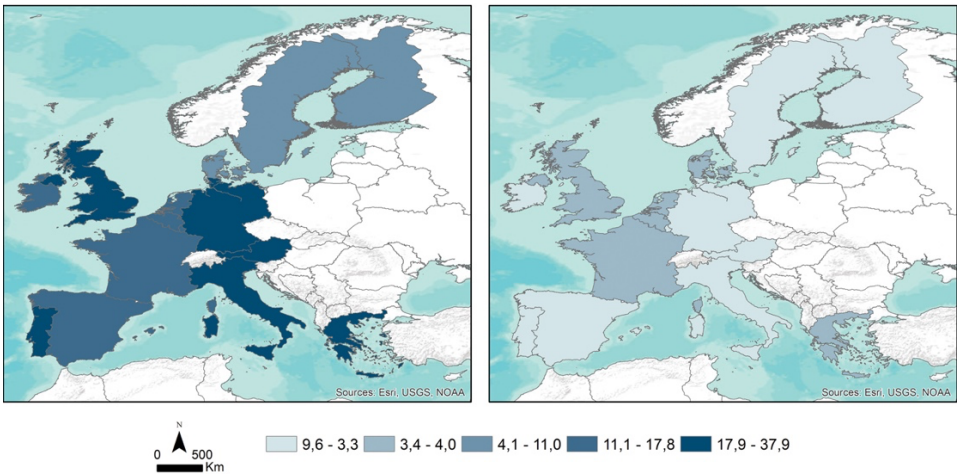


Figure 2.5: Distribution of the Infant Mortality rate (%) considering the EU-15 countries, in 1974 (on the left) and 2017 (on the right) [34].

The gains in health due to those changes are visible in the increase of life expectancy at birth, amounting to 12.7 years for almost four decades and a half. This made also possible a higher change in the life expectancy at birth for Portugal amongst the EU-15 countries, being the first one of those countries with better improvement (in relative terms *i.e.* %) in this indicator, as one can see in Figure 2.6 [34].

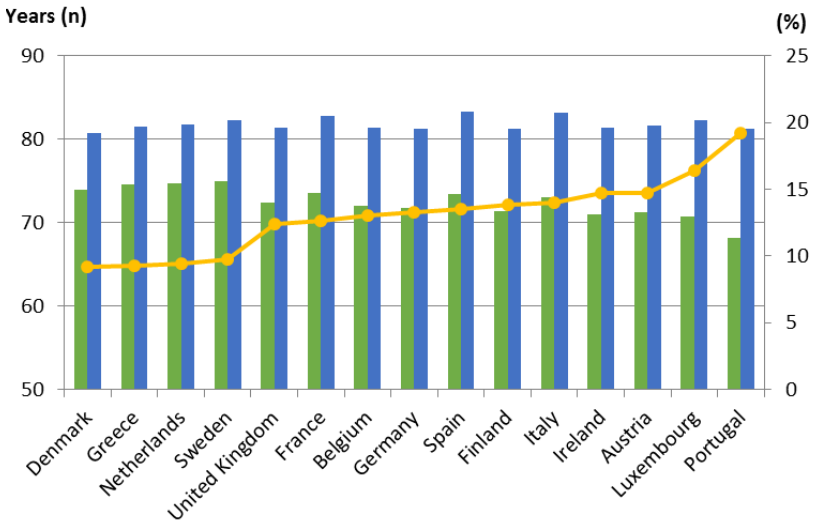


Figure 2.6: Life expectancy at birth for the EU-15 countries, in years, registered in 1974 (green) and 2017 (blue) with the respective variation in percentage (yellow) between 1974 and 2017 [34].

One of the most researched death causes is cancer. In fact, malignant tumors are the main cause of death under the age of 65 years old, which has been increasing throughout the time passed. As one can see in Table 2.1, in 1974 for instance, malignant neoplasms in Portugal accounted for 151.20 for SDR (Standardized Death Rate) which meant 151.20 deaths per 100,000 inhabitants [34]. This value is strictly lower than the one for the same year in the overall average of the EU-15 countries, which was 199.80 deaths per 100,000 inhabitants [36]. Those differences in the SDR showed that Portugal was in fact in better patterns for health on what the oncology field was concerned. However, since 1974 this scenery worsened and then, in 2017, after an irrelevant short growth of the number of deaths (by 0.22%) caused by malignant neoplasms, there were 151.53 deaths per 100,000 inhabitants [34]. Nevertheless, in the EU-15 countries, this value decreased by 21.30%, from 1974 to 2017. Then the difference between the SDR by the aforementioned cause of the EU-15 and Portugal was undoubtedly shorter as the values were respectively 157.22 and 151.53 deaths per 100,000, in 2017. Portugal is, by the way, one of the countries with a lower mortality rate in this cause in spite of the values are truly worrying [36].

Furthermore, there has been an increase in the consumption of tobacco, during the last decades, which implied more diseases of the respiratory system and also oncology complications [34]. This harmful consumption contributed to a huge rise in the number of deaths caused by respiratory-related cancers, such as lungs, bronchus and trachea malignant issues. In Portugal, as one can see in Table 2.1, there were registered 11.50 deaths per 100,000 inhabitants in 1974 due to those issues, nevertheless this value deeply changed and then in 2017, the SDR by trachea, bronchus and lung cancer was 24.63 deaths per 100,000 inhabitants, which meant an increment by 114.17% [34]. This is significatively worrisome for Portugal health status actually as this has been worsening throughout the last years. For the EU-15 countries group, the SDR by those respiratory system-related malignant complications has been almost unchanged since 1974, when there were registered 34.70 deaths per 100,000 inhabitants (in fact, a higher value than in Portugal in 1974, which was 11.50) [36]. Then, in 2017, the SDR by those causes for EU-15 countries group was 34.42 deaths per 100,000 (this meant a decrease by 1% of the number of deaths by those causes between 1974 and 2017 for the EU-15 countries), turning the situation of Portugal on this scenery hard to be better amongst the EU-15 group [36].

Moreover, also presented in Table 2.1, liver diseases showed higher mortality rates in 1974 both in Portugal and in the EU-15 group, respectively 34.90 and 21.50 deaths per 100,000 inhabitants, which has been decreasing till 2017, when those values were respectively 8.53 and 9.12 deaths per 100,000 inhabitants, meaning a reduction of 75.60% and 57.90% between the years of 1974 and 2017 [34,36]. One of the factors strictly related to this cause of death is the consumption of alcohol that has truly been decreased: from 1974 to 2017 the alcohol consumption fell by 43% in the EU-15 (in absolute terms, the registered value was 18.30 L/person/year in 1974 and then 10.30 L/person/year in 2017) [36].

By the way, another cause of death that also disturbs the health status of the Portuguese population is diabetes, as can be seen in Table 2.1. The SDR by diabetes in 1974 amounted to 10.20 deaths per 100,000 inhabitants in Portugal, less than in the EU-15 group (17.90 deaths per 100,000 inhabitants) [34,36]. This scenery worsened for Portugal, as in 2017 the registered SDR by diabetes was almost twice as in 1974, then amounting to 19.83 deaths per 100,000 inhabitants, in contrary to what has been

happening to the overall EU-15 countries group (which decreased by 38.20% from 1974 to 2017) [34,36].

The major causes of death in 1974 (cerebrovascular and ischemic heart diseases), with registered SDR of 299.30 and 100.50 deaths per 100,000 inhabitants in Portugal, respectively, has been decreasing throughout the past decades, as observed in Table 2.1 [34]. Then, in 2017, those values were 53.43 and 37.93, which meant a variation of -82.20% and -62.30%, respectively [34]. Likewise, in the EU-15 group in 1974, those diseases showed high values also, more than 100 deaths per 100,000 inhabitants both of them and afterwards, decades passed between 1974 and 2017, when a decrease of 75.80% and 67.10% happened, respectively, for the cerebrovascular and ischemic heart diseases in the EU-15 group of countries [36]. Furthermore, the difference between the SDR for both issues in Portugal and the EU-group was absolutely higher in 1974, as for cerebrovascular diseases the SDR difference was 160.20 deaths per 100,000 inhabitants (more in Portugal than in the EU-15 group) and for ischemic heart diseases, the SDR difference was 66.60 deaths per 100,000 inhabitants (more in the EU-15 group than in Portugal) [34,36]. Those differences have been balanced throughout the time and, in fact, in 2017, the SDR difference for cerebrovascular diseases was just 19.70 deaths per 100,000 inhabitants (more in Portugal than in the EU-15 group) and the SDR difference for ischemic heart diseases was just 17.00 deaths per 100,000 inhabitants (more in the EU-15 group than in Portugal).

Worse than undesirable was also the number of deaths for inhabitants under 65 years old in 1974, as easily noted analyzing Table 2.1. In this year, the SDR by all causes (for people between 0 and 64 years old) was 450.50 deaths per 100,000 inhabitants in Portugal and 352.90 deaths per 100,000 inhabitants in the EU-15 group [34,36]. Those values were undoubtedly worrisome, which also affected the overall life expectancy, which had been improved. By the way, in 2017, Portugal registered 166.43 and the EU-15 group 161.02 deaths per 100,000 inhabitants due to all causes (0-64 years old citizens), meaning really satisfactory news for the overall health status [34,36].

Table 2.1: Analysis of health indicators for Portugal and the EU-15 group of countries, including a comparison between the years of 1974 and 2017, as well as the respective health gains [34,36].

| SDR by cause | 1974 | | | 2017 | | | Variation for Portugal (1974-2017), % | Variation for EU-15 (1974-2017), % |
|---|---|---|---|---|---|---|---|---|
| | Portugal | EU-15 | Difference | Portugal | EU-15 | Difference | | |
| SDR by all causes (under 65 years old) (per 100,000 inhabitants) | 450.50 | 352.90 | 97.60 | 168.43 | 161.02 | 7.41 | -62.61 | -54.37 |
| SDR by malignant neoplasms (per 100,000 inhabitants) | 151.20 | 199.80 | -48.60 | 151.53 | 157.22 | -5.69 | 0.22 | -21.31 |
| SDR by lungs, bronchus and trachea cancer (per 100,000 inhabitants) | 11.50 | 34.70 | -23.20 | 24.63 | 34.42 | -9.79 | 114.17 | -0.80 |
| SDR by liver diseases and cirrhosis (per 100,000 inhabitants) | 34.90 | 21.50 | 13.40 | 8.53 | 9.12 | -0.59 | -75.56 | -57.58 |
| SDR by diabetes (per 100,000 inhabitants) | 10.20 | 17.90 | -7.70 | 19.83 | 11.12 | 8.71 | 94.41 | -37.88 |
| SDR by cerebrovascular diseases (per 100,000 inhabitants) | 299.30 | 139.10 | 160.20 | 53.43 | 33.72 | 19.71 | -82.15 | -75.76 |
| SDR by ischemic heart diseases (per 100,000 inhabitants) | 100.50 | 167.00 | -66.50 | 37.93 | 54.92 | -17.00 | -62.26 | -67.11 |

## 2.3. Summary

This chapter described how is being performed the essential actions in the health sector, in Portugal. Being analyzed some details of the worldwide health care status, the case of our country is even more relevant in an undoubtedly case comparison in order to establish metrics and analyze some progress on the health status for several criteria. Therefore, the way to follow the line, well-established and objective, is the main part of the focus, the organization and the management of the Health System, defining specific assessment to the quality of the health care provided as well as the equal access to Portuguese citizens on what the provisioning of the health care services they need is concerned.

So as one can understand the health care sector in Portugal and the way the resources are being applied, as well as the results the country show in the sector, it is important to describe how everything works and how is being assessed, then a detailed analysis was done in this chapter to study afterwards the literature in Chapter 3.

# 3. Literature review

The concepts of quality and access are intensively used in the health care sector, as being extremely relevant for the establishment of a successful health care services provisioning to the whole population, with adequate standards and well-provided as it is needed. This chapter identifies how both quality and access are defined in the health sector, as well as how they can be measured in order to be assessed. Therefore, this chapter aims to establish a bridge between the concepts and the way those concepts are both applied to define an assessment method to evaluate the Portuguese public hospital afterwards.

## 3.1. Quality in the Health Sector

Standards of health care services and expectations from the citizens, media and civil society with a huge demand for accountability and transparency have led to an emphasis on health concerns. In fact, universal health protection and the need for improvements of patient outcomes in the context of value-based health care created awareness of the gaps in the effectiveness and person-centeredness of the provisioned care. Practice variations in the delivery of the health care services, as well as access to those services without appropriate attention to quality, have been generating barriers to achieving the desired health outcomes. Furthermore, there is still a need to align the performance of private and public health care services in some health markets, where the quality differs from one to another which undoubtedly affects the overall outcomes. Thereby, some concerns regarding the quality of the health care services are related to the trust in the effective preparedness for outbreaks or other sophisticated emergencies, driving towards an increase of the need for commitment and belief in the health care provisioning as a public good by the population [37]. However, in fact, there are still several issues on what the term “quality” is concerned with and what does this means and encompasses.

A definition of quality is complicated to be established and is even more difficult when considering this concept is being applied in the health care dimension. Some authors define, in a generic approach, non-specifically or non-sensitively. Others follow the trends of non-aggregated approaches considering the dimensions in case and the criteria used, which gives an assessment of quality by its own perspective, nevertheless, when all the dimensions are combined it leads to a more complex and accurate evaluation as intended [38]. In fact, being defined in many ways, the concept tended to a non-consensual definition for itself, assuming a nature that is relatively partial and subjective as is depending on the individual and the context. Therefore, the way the meaning of quality is assumed may vary from person to person, depending on their perspectives.

Quality is extremely important for our lives, as we are always pursuing the “best” services or products, intended the ones with more quality in the concrete case (effectively, the quality is not the only criteria that affect the product or service to be the best of the worst amongst others but this is another case). The concept “quality” has been already defined as “to have excellence”, which serves as a differentiator for advantage against the competitors, by the fact this means costs reduction, waste minimization and even a clear reputation [39].

Health care provisioned with quality of services provided is the most common quoted demands of a health policy and, actually, this is undoubtedly focused by the agenda of policymakers at national and international health systems [40,41]. For a national level, the health care quality is an issue for many reasons, from the general public needs of high-quality provisioning to the continued demands on patient better outcomes considering value-based health care, as well as the detection of certain health care quality specific issues [37]. For a European level, the European Commission identifies quality as an essential part of the health system performance, *i.e.* the capability to reach their goals, therefore on the Common Values and Principles in EU Health Systems there were referred that the values of the access to quality health care, equity, solidarity and universality have been widely considered throughout the work of different EU institutions [42]. Furthermore, there is the international level, where the quality of care is given special attention, mainly within the SDGs, by the fact that the goal is to provide universal health protection, without financial risk and with equity in the access to effective and safe, as well as of quality health care services, including affordable medicines and vaccines for every citizen. In fact, two World Health Organization (WHO) reports from 2018 referred to the aforementioned goals, a text guide focused on the global understanding of health quality as an essential part for the universal health provisioning and a handbook for national strategies regarding the issue of quality policies for health care services [37,42].

The European Observatory on Health Systems and Policies mentioned that research on the literature is not so simple to summarize and even more with the passing times [43]. A variety of approaches exists, as well as methods for the improvement of the quality of the health care, targeting hospitals, health care centers and clinics or specific areas, such as maternal, dental, emergency. This evidence has led to a better understanding of how important some specific settings for specific groups of patients are and how the effectiveness may affect the achievement of overall goals [44]. The issue of the individual strategies for particular patients, of minor groups within particular settings, is still actually rarely addressed, without any guidance on how the policymakers should implement their establishments regarding health care policies [45]. In spite of being vast, the literature has not allowed yet a universal consensus on what the concept of “quality of health care” is concerned. Thus, there is still a misunderstanding regarding this term, about its meaning and what should encompass. Depending on the context, paradigms and analysis, the definition may be distinct. Early definitions of quality related to the health care sector had been almost particularly generated by health practitioners and health researchers. Nevertheless, throughout the times, the importance given to the preferences and perspectives of the patients as well as public and specific key individuals has grown and started to become more relevant [43].

## 3.2. Different Perspectives for Health Care Quality and Access

In 1980, Avedis Donabedian had already mentioned, in "*Explorations in quality assessment and monitoring: the definition of quality and approaches to its assessment*", that improving and assessing quality implies a well understanding of what this encompasses. Donabedian defined "quality" as a term used to the achievable desired objectives using the possible allowed means. The definition reflects that the term is not so specific and may be used in several other sectors by many different people, as "quality" is then a term used to refer to a set of positive features within a variety of circumstances, for instance, a hospital process or doctors proficiency, but also when referring to clothes, cars, household appliances or food. By this fact the term has then a widespread use, leading to the undesired issue regarding the correct definition of quality used by policymakers and health practitioners, about attributes of the health systems and services. According to Donabedian, there is still a definition for the quality of care. The quality of care is then defined as the expected care to be maximized in the measurement of a patient's welfare, having taken into account the gains and losses inherent to the whole process [46]. This definition is particularly well-established and interesting due to the fact that not only details that quality of care includes the whole process of care in all its parts but also specifies that the goal is the highest possible patient's welfare during the process and at the end of it, as well as focusing on the gains and considering the losses which are expected during the process of care. Patient's welfare undoubtedly refers to the individual health status: physical, physiological and psychological levels, being even in line with the approach that considers relatively relevant patient's perspectives [47].

Ten years later, in 1990, a reference for the research in this field, Institute of Medicine (IOM) in the United States of America, in *"Medicare: a strategy for quality"*, defined that quality of care is the level to which the health care provisioning for the population raises the possibility of achieving the desired health outcomes, being in accordance with the actual proficiency knowledge. At first sight, the definition by IOM focuses on health outcomes that are more directed than the "patient welfare" in Donabedian's definition. Nevertheless, IOM considers the desired health outcomes, specifying that this goal is supposed to take into account patient's satisfaction as well as their well-being next to quality-of-life measurements and health status [48]. This definition is still more complete than Donabedian's, leading to an inspiring understanding by many other worldwide researchers. In comparison with many other definitions before the 21$^{st}$ Century (including the definition by Donabedian), almost all referring to medical care, the IOM's definition establish its focus on health services (as health care involves services, preventive, restorative, rehabilitative, acute and chronic care, which are provisioned to the population by many different providers in several different settings) and on population (rather than on patients), highlighting the relation between quality, prevention and health promotion. Moreover, the quality of care, according to IOM's definition, is not static, being in continuous change. The concept is dynamic, in fact, as the definitions point out to the actual proficiency knowledge to establish the concept of quality. Then, the definition reinforced the relevance of evidence-based health care as well as strengthened that health care providers can only be assessed against the actual knowledge. Thus, a service that was considered

a high-quality one at a certain time may be classified as a poor-quality service some years later, taking into account recent researches and newer knowledge.

Afterwards, in 1997, the European Council in *"The development and implementation of quality improvement systems in health care"* established a new definition for quality of care: the level to which a treatment increments the probability of reaching the desired outcomes and reduces the chances of undesired issues for the patient, considering the actual proficiency knowledge [49]. This definition was published as part of the European Council's recommendations on the systems directed for the improvement of quality for the EU countries and is the first one to consider patient safety. Therefore, based on this, quality of care is not only focused on the desired and positive outcomes (which is also referred to by the IOM definition) but also on the decrease of the chances of achieving undesired results.

Then, in 2010, the European Commission in *"Quality of health care: policy actions at EU level"* noted that a "good quality" provisioned care should be safe and effective, as well as synchronized with the patients' preferences. This definition was published in a reflection paper for the European Council, referring that other dimensions of quality of care, namely efficiency, equity and access are considered as part of a wider analysis and are not directly addressed inside the definition of "quality of care", in spite of being related to the concept. Nevertheless, those attributes are also extremely relevant to the health care systems in order to avail of the benefits of the "good-quality" health care provisioned [50].

Recently, in 2018, WHO in *"Handbook for national quality policy and strategy"* stated that a health service, in order to prove quality in its provisioning, should be effective, safe and responsive. Thus, three dimensions determine the quality of the health care according to WHO: effectiveness (evidence-based health care services to the population in need), safety (with no harm for whom the care is being provisioned) and patient-centeredness (considering each one's preferences, values and needs). Those dimensions, encompassed in the definition of WHO, already noted eight years before (by the European Commission), may allow conceding a service as a poor or a good one, however, to realize the benefits of a quality care, the health services should be timely, integrated, efficient and equitable. Then, there is a distinction between the three core dimensions of quality and other attributes belonging to good health care [37].

Several different definitions specify distinct attributes that are related to quality, as aforementioned. Effectiveness, safety and patient-centeredness are undoubtedly considered as core dimensions of quality of care. Nevertheless, there are some definitions including timeliness, efficiency, access, equity and appropriateness as additional attributes. Somehow, taking into account many attributes turn the conceptual analysis embarrassing and in fact blurs the distinction between the overall health care performance and the quality of care. In order to simplify and to solve this misunderstanding, it may be simple to organize the concepts, classifying them into dimensions of quality, subdimensions that contribute to the core dimensions and other dimensions of health care performance (as seen in Table 3.1, Table 3.2 and Table 3.3).

Table 3.1: Core dimensions of quality of care according to some selected definitions.

| Definitions of quality | Core dimensions of quality of care | | |
|---|---|---|---|
| | Effectiveness | Safety | Patient-centeredness |
| **Donabedian (1980)** [44] | | | |
| **IOM (1990)** [46] | x | | |
| **European Council (1997)** [47] | x | x | Responsiveness |
| **IOM (2001)** [49] | x | x | x |
| **OECD (2006)** [50] | x | x | Responsiveness |
| **WHO (2006b)** [51] | x | x | x |
| **EC (2010)** [48] | x | x | Responsiveness |
| **EC (2014)** [52] | x | x | x |
| **WHO (2016)** [53] | x | x | x |
| **WHO (2018)** [35] | x | x | x |

Table 3.2: Subdimensions of quality of care according to some selected definitions.

| Definitions of quality | Subdimensions of quality of care | | | | | |
|---|---|---|---|---|---|---|
| | Health improvement | Appropriateness | Acceptability | Timeliness | Satisfaction | Other |
| **Donabedian (1980)** [44] | | | | | | Patient welfare |
| **IOM (1990)** [46] | x | | | | x | |
| **European Council (1997)** [47] | x | x | | | x | Assessment of care |
| **IOM (2001)** [49] | | | | x | | |
| **OECD (2006)** [50] | | | | | | |
| **WHO (2006b)** [51] | | | x | | | |
| **EC (2010)** [48] | | | | | | Patient's preferences |
| **EC (2014)** [52] | | x | | | | |
| **WHO (2016)** [53] | | | | x | | Integration |
| **WHO (2018)** [35] | | | | x | | Integration |

Table 3.3: Other dimensions of health care performance according to some selected definitions.

| Definitions of quality | Other dimensions of health care performance | | |
|---|---|---|---|
| | Access | Efficiency | Equity |
| Donabedian (1980) [44] | | | |
| IOM (1990) [46] | | | |
| European Council (1997) [47] | x | x | |
| IOM (2001) [49] | | x | x |
| OECD (2006) [50] | | | |
| WHO (2006b) [51] | x | x | x |
| EC (2010) [48] | | x | x |
| EC (2014) [52] | | x | x |
| WHO (2016) [53] | | x | x |
| WHO (2018) [35] | | x | x |

The aforementioned classifications were firstly based on the work carried out within the OECD HCQI (Health Care Quality Indicators) project, in 2006. This project aimed to develop indicators for worldwide standardization of health care quality. Three dimensions of effectiveness, patient-centeredness and safety were defined in the project as being the main established dimensions of the quality of health care provisioned, referring that other attributes, such as the ones mentioned above, could be mapped within them. For instance, continuity and acceptability could be accommodated into patient-centeredness, whereas appropriateness could be within effectiveness. Efficiency, equity and accessibility were also defined as essential goals of health care provisioning, when related to the quality of the health systems. Nevertheless, the HCQI project mentioned that the IOM definition established in 1990 was coherent when referring to safety, responsiveness and effectiveness as being the only attributes of health care that directly increase the probability to achieve the desired health outcomes [52]. According to several definitions already considered, quality of health care was established, in fact, for specific contexts. For instance, the European Council intended to guide the systems involved in the improvement of the overall quality, in 1997. Therefore, it is undoubtedly reasonable that the definition also includes the assessment of the health care process as an element of quality, along with patient satisfaction, efficiency, efficacy, effectiveness and accessibility [49]. In “Crossing the Quality Chasm”, published in 2001 by the IOM, being a report specifically targeted to the achievement goals of a standard health care provisioning: patient-centeredness, equity, safety, effectiveness, timeliness and efficiency, led the general adoption by several organizations in the United States and outside of it [51]. Those six dimensions of quality, clearly taken by the IOM as performance expectations, *i.e.*, a list of characteristics which allows reaching the defined goals when considered and improved was afterwards adapted in 2006 by the WHO as the main dimensions of quality in processes of strategic management in health care systems, where the

attribute “timeliness” was converted into “accessibility” in order to take into account geographic availability and progress of health care provisioning [53]. Quality versus other attributes of performance, also related to quality, was then established and did not have a simple consensus. Then, the European Commission’s Expert Panel broadened the term quality and its meaning, which included the dimensions of efficiency, equity and appropriateness in its focus for the future of EU standard quality of health care in 2014 [54]. In the same way, the WHO defined timeliness (which was originally mentioned by the IOM in 2001) instead of accessibility (used in 2006 by the WHO) and included integration in the health care provisioning as a dimension in the high-quality level, simultaneously with the approach done in 2013 by the Council for the Health Care of Canada [56]. Also, in the HCQI framework, it may be found that patient-centeredness is part of the referred integrated health care, which was afterwards published in 2015 by the OECD [57].

Besides the aforementioned entities, such as the IOM, the OECD and the WHO, the American Agency for Healthcare Research and Quality (AHRQ) has also developed some work in order to validate indicators to assess the performance of the health care quality provisioned by the health care providers. Based on the IOM, the indicators are stronger when assessing processes and mainly when they measure the outcomes, nevertheless they are usually used on structural inputs, rather than outcomes, due to the fact it is harder to access data provided by patients as well as outcomes obtained from multiple medical care episodes and less capable integration or databases built with poor information. For the AHRQ, the quality assessment involves a more rigorous and systematic approach that is quantifiable for the measurements obtained, turning this more reliable and, therefore, more valid. Thus, the reality is strictly represented by comparisons between different cases and distinct entities analyzed.

The inconsistency and lack of consensus in the definition of quality in health care contribute to the misunderstanding in the concept of quality in this sector. This has some influence on the health care policies and adopted strategies taken to improve it. Moreover, this misunderstanding in the distinction between the quality of health care and attributes of health care performance had been generated from the confusion of the distinction between the mid and the final goals of the health care systems and between the levels at which quality is assessed.

During the last twenty years, there has been considerable development on health systems assessment frameworks, which includes, explicit or implicitly, quality as a major health care goal but they are distinguished in how quality is defined and what is its influence on the overall health system goals. An interesting and well-understood framework was established by the WHO: terms in blocks [53]. This framework depicts in blocks the terms “information”, “health workforce”, “service delivery”, "medical products, vaccines and technologies”, “leadership/governance” and “financing” as system building blocks. “Quality” is there defined as an intermediate goal of the health systems, along with “coverage”, “safety” and “access”. Thus, achieving those goals, it will make possible to reach better health system outcomes and improvements, considering then the terms “improved level and equity of health provisioning”, “responsiveness”, “financial protection/fairness in financing” and “improved efficiency”.

By the way and considering the Donabedian’s definition for quality, which considers in general terms “the capability to achieve desired goals through allowed means”, when combined with the framework of building blocks by the WHO, quality of a health system is then defined as the “ability to achieve goals

(intermediate and overall) using allowed means" [46,53]. The Donabedian's perspective clarified that it was essential to differentiate the distinct levels when evaluating the quality of the health care: the care received by the community, the care received by the patient, the care setting and individual practitioners; while others have considered different levels where developments on policies regarding quality assessment are taken into account: the macro-level (the health system), meso-level (organizational) and the micro-level (clinical) [59].

In fact, there are distinct definitions of quality depending on the level at which quality is assessed. The exact definition of levels seemed to be not so essential, however, due to the aforementioned reason, Donabedian's tiers were then condensed into two conceptual levels. The first one is the level of the health services, including chronic, acute, palliative and preventive care [60]. At this level, the consensus is that quality of care is the degree to which both individuals and populations are provisioned with safe, people-centered and effective health care services [37]. The second one is the level of the health care system entirely, which is considered as with high-quality when achieved an overall target for efficiency, financial protection, responsiveness and improved health. Several definitions of health care quality consider those attributes amongst the aforementioned quality dimensions [37]. But this is a broad definition set for health care system which may be ambiguous in the context of quality improvement, i.*e.* it is indeed essential to consider efficiency and access in the health systems however there may be some confusion regarding the focus of the quality improvement plans leading to distractions from the strategies that definitely makes possible increments on safety, patient-centeredness and effectiveness of provisioned health care. In order to clarify and establish a conceptual notion, WHO proposed the term "health care quality" for the first level, the one of health care services, and "health system performance" for the health care system level as long as, according to an international trend, this defines the capability the health systems present to reach intermediate and outcomes.

Health system performance assessments though frameworks defined by the EU and by the OECD took into account as a core dimension the quality of the health care at the "health care quality" level, along with other attributes of performance (population health, efficiency and accessibility, for instance) [54,57]. This means that health system performance is nothing more than a term used for health system quality considering the definition of the term by Donabedian and the health care service quality is one of the main components there.

The achievement of health system goals and their quality are strictly related, as seen in Figure 3, a framework for the health system performance. As noted, four intermediate goals established by the building blocks model, as defined by the WHO, are joined into two: quality (also considering safety) and access (also including coverage). Therefore, population health status and outcomes, as well as health system patient-centeredness and responsiveness, are objected to vary on the extent to which citizens have access to the provisioned health care and depend on the quality of the service (if the service provided is safe and effective, for instance). The amount of resources spent on the health care branch, non-material or financial, needed to reach expected outcomes define the efficiency of that system [61].

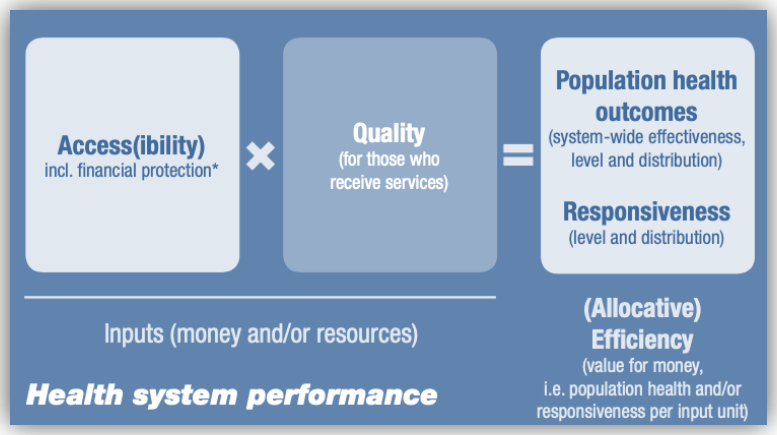


Figure 3.1: The framework relation between health system performance and quality of the health care services [61].

In the literature, it can be found studies focused on the assessment of the Portuguese health care providers, providing values for the efficiency scores for the year 2016 as Pereira et al. [62] and the category interval assignments for the years 2017 and 2018 as Rocha et al. [63] assessing quality and access of Portuguese public hospitals. It is possible to note that some hospitals and hospital centers in Portugal obtained better performances than others, in one article than in another, depending on the method used and the indicators involved on the assessment. Some Portuguese health care providers (considered as DMU, Decision Making Units [62] and as Actions [63]) were not assessed unless here in our dissertation.

Póvoa do Varzim/Vila do Conde Hospital Center, EPE, Tâmega e Sousa Hospital Center, EPE, Leiria Hospital Center, EPE, Entre Douro e Vouga Hospital Center, EPE, Baixo Vouga Hospital Center, EPE, Santarém Hospital Center, EPE, Setúbal Hospital Center, EPE, Vila Nova de Gaia/Espinho Hospital Center, EPE, Espírito Santo de Évora Hospital, EPE, Garcia de Orta Hospital, EPE, Tondela-Viseu Hospital Center, EPE, Trás-os-Montes e Alto Douro Hospital Center, EPE, São João Hospital Center, EPE, Porto Hospital Center, EPE, and Lisboa Central Hospital Center, EPE were the efficient portuguese health care providers in 2016 according to Pereira et. al [62] (the authors used Data Envelopment Analysis, DEA).

Then, considering the year 2017, Póvoa do Varzim/Vila do Conde Hospital Center EPE, Entre Douro e Vouga Hospital Center EPE and Setúbal Hospital Center EPE were assigned to the better categories (maximum), *i.e.,* $C_4$ (good performance) or $C_5$ (very good performance), according to Rocha et al. [63], considering a classification based on categories assignment (from the worst performance, $C_1$, to the best, $C_5$). Póvoa do Varzim/Vila do Conde Hospital Center EPE, was assessed as a $C_5$ (maximum), being the action with the highest performance in the year 2017. Cova da Beira Hospital Center EPE and Coimbra Hospital Center EPE, were assigned to the worst category interval, *i.e.,* $[C_1, C_1]$ (the worst performance as minimum and maximum) in 2017 [63].

For the following year, 2018, Póvoa do Varzim/Vila do Conde Hospital Center EPE, Médio Ave Hospital Center EPE, Tâmega e Sousa Hospital Center EPE, Barreiro/Montijo Hospital Center EPE and Tondela-Viseu Hospital Center EPE were assigned to the better categories (maximum), *i.e.,* $C_4$ or $C_5$ according to Rocha et al. [63]. The action Póvoa do Varzim/Vila do Conde Hospital Center EPE was assessed as a $C_5$ (maximum), being the action with the highest performance in the year 2018. Médio Tejo Hospital Center EPE, Espírito Santo de Évora Hospital EPE and Lisboa Ocidental Hospital Center EPE, were assigned to the worst category interval, *i.e.,* $[C_1, C_1]$ (the worst performance as minimum and maximum) in 2018 [63].

Those results from the articles aforementioned are difficult to be strictly compared with no inaccuracy as the method used by Pereira et al. [62] was a different one (DEA) with eight indicators and the method used by Rocha et al. [63] was ELECTRE TRI-nC (the one that will be used in our dissertation with similar assessment dimensions but different indicators used for criteria and subcriteria (not just criteria as in our case).

Another study was conducted investigating the impact of access and quality to health care services on the technical efficiency, which is an appropriate topic in this theme, from where some inconclusive inferences were drawn, *i.e.,* no link was detected between technical efficiency and quality of the health care services provisioned by Portuguese public hospitals. However, the impact of the access to health care provisioning on the technical efficiency of the health entities, barely analyzed through a robust method, allowed to associate better clinical safety practices to low levels of technical efficiency, related to high expenditure, so conducting to trade-offs between dimensions [64].

## 3.3. Summary

Thus, several definitions and perspectives on what quality is concerned were referred to in this chapter as well as its dimensions: person-centeredness, safety, accessibility, equity, effectiveness and efficiency. It was essential to explore those different dimensions and how they can be held together in order to conduct a well-performed analysis and assessment of the Portuguese public hospitals afterwards, in the following chapters.

Moreover, quality is an important concept that may be understood and the manner it is measured should be proper (in this case, through composite indicators), generating the need for following investigation and details onwards covering Multiple Criteria Decision Analysis methods, precisely the ELECTRE TRI-nC which will be carried on to conduct the work done in this dissertation.

# 4. Methodology

Almost everyone makes choices and decisions every day. Humans are rational beings and then everything may be analyzed, so our choices are weighted, and the decisions made. This chapter focuses firstly on the utility of the MCDA and then on which the process is defined. Then, the considered MCDA method for the development of this dissertation, ELECTRE TRI-nC, is covered in this chapter.

## 4.1. MCDA

The Multiple Criteria Decision Analysis (MCDA) allows assessing distinct criteria within a decision-making process. Undoubtedly, this process also happens in the enterprise world, companies' environment, government organs and medical centers. When making comprehensive and essential decisions, levels of scale and multiple criteria need to be accounted for.

There is a familiar adage in Portuguese that mentions that life "is settled on of decisions", proposing that there are decisions to be taken regardless of how basic or complex they are essential for our everyday life. Choices have outcomes, some great and some terrible, they likewise have contradictory perspectives or standards that one thinks about when the ideal opportunity for choosing shows up. Concerning that, it was since the earliest reference point that humanity began creating techniques to help them taking the best choices as indicated by their targets. Despite the fact that were discovered more established instances of these methodologies, Benjamin Franklin's methodology called "Moral Algebra" grabbed some focus because of its notorious figure [65]. At whatever point Franklin was attempting to choose his situation on a big deal, would compose on inverse sides of a piece of paper contentions in favor or against that matter. Subsequently, he would battle to gauge the separate loads of every contention and following this assessment he would cross out the contentions on each side of the paper. In the case that two arguments on each side were similarly weighted, he would cross both out, in any case, if there were contentions in each side distinctively weighted, he would cross as many contentions as possible until the equilibrium was reached. Afterward, it would happen that one of the sides would run out of contentions (all crossed out), then, at that point, Franklin would uphold the side where there were still contentions left remaining as the most ideal choice. This technique was unmistakably an early Decision Aiding (DA) approach, where Franklin would take a choice, yet in addition weight his contentions.

One calls upon DA models, as per Roy, when is attempting to acquire some responses, which may help address the stakeholder's inquiries [66]. These components endeavor to explain a choice, or simply prescribe a conduct to expand the consistency between the advancement of the cycle and the partner's objectives and worth framework. Eventually, the subsequent data of the model is assessed mulling over the emotional inclinations of the leader [67]. The DA approach is grounded in three key components, what characters remember when playing out the examination [68]: the actions, which allude to the objects of the decision, the equivalent are called alternatives at whatever point it is not conceivable to consider them together; the consequences or outcomes, that allude to the perspectives, traits or

attributes of each action, that make potential distinctions between them; and the preference systems modelled and demonstrated as inclination frameworks, where each pair of considered actions, assigns one and only one of the three circumstances: incomparability, indifference or preference. Thus, given two potential actions, considering the consequences of each one and their worth framework may: settle on one over another (noteworthy inclination and then preference), or express lack of interest in the decision between the two actions (indifference) or even state that cannot look at the two actions (uniqueness and so incomparable between each other).

At the point when Franklin was dividing contentions as geniuses or cons, was taking at the top of the priority list various perspectives, which can be generally portrayed as criteria and are central for the use of DA models. Bouyssou characterizes a criterion as "a real-valued function on the set A of alternatives, such that it appears meaningful to compare two alternatives X and Y according to a particular point of view" [69]. On the off chance that the user is just utilizing one criterion for the correlation between options, then, at that point, the DA approach is monocriteria. Yet, in the event that it is strange that the Decision Maker (DM) just has one single clear measure like only one criterion to direct the cycle, it is much more uncommon when there is more than one DM [66]. Thusly, in this kind of circumstances, we are in the space fields of multicriteria choice supporting, which as the name recommends more than one single criterion is considered in the process. Every criterion is thought about autonomously from the others and is utilized to assess any possible action as indicated by its score, named performance. The performance of each action is a score ascribed to them which permits to make correlations and set up inclinations between at least one expected action and generating preferences concerning the specific and defined criteria, thought for a specific measure. The scores or degrees can be addressed by a number, a verbal assertion or a pictogram and can be limited by different sorts of scales [66]: subjective/qualitative or ordinal scale, where the difference between two degrees does not have unmistakable importance as far as contrast inclinations. This can occur in a verbal scale, when it is difficult to pronounce that the sets of sequential degrees reflect equivalent inclination contrasts up and down the scale; then again, it can occur in a mathematical scale, when it is difficult to announce that a given distinction between two degrees mirrors an invariant inclination distinction when we move the pair of degrees considered along the scale; and a cardinal or quantitative scale, which is anything but a mathematical scale whose degrees are obviously and quantitatively characterized, such that it offers sense to the shortfall of the amount defined as degree zero and to the presence of a unit permitting us to explain every degree as the expansion of a given number of such units. Hence, the distinction between two scores can get a worth that does not rely upon the two specific degrees considered. Summarizing the definition of scales, there are [70]:

a) Nominal scales (also referred to as a categorical variable scale) are defined as categories or variables which do not have regular arranging or order that has universal application. For instance, red and green are both categories but neither one can be ordered as first or second. However, the nominal data can be assigned to a value (numerical), although those values do not assume true meaning. Therefore, if one assigns a numerical value to calculate the mean or the median, for instance, it would be meaningless.

b) Ordinal scales which may encompass nominal scales, where the rank of the values (ordinal variable) is relevant but the difference between values is meaningfulness. Due to the different nature of the options within the scale, sometimes there is no possibility to know the degree of difference between them. Even when the difference between them is conceivable to be quantified, it does not yield much insight when in comparison with the rank of the values. There is not an objective way to say that one option is x units better than another one. These scales are used to quantify categories without a mathematical assumption such as satisfaction or pain, for instance.

(In fact, both ordinal and nominal scales present descriptive qualities and the difference is the relative position of the labels. However, it is not possible to quantify the difference between ordinal variables, it is just possible to know that one is better or higher than the other; furthermore, there is not an origin on the scales for the aforementioned data sets, so it is not possible to know where the scales start or end.)

c) Interval scales are numerical scales in which the order of the options is known indeed and the difference between the values is meaningful. This scale encompasses the previous ones, nominal and ordinal scales. Also known as an interval variable scale to describe the meaningful nature of the difference between values. In fact, for those scales, we know that one is greater than the other and also exactly how much larger the values are. This is the first scale where one can do true statistical analysis, such as with the temperature, for instance. Like the ordinal scale, the interval scale does not have start or ending points and a true zero, so deeper statistical analysis is not so possible.
d) Ratio scales present a rank of the options, a set value between units and an absolute zero, which means that these scales are like interval ones but with a true zero. On the contrary to the previous scales, the proportion between two units of a ratio scale is meaningful, for instance, analysis on the weight or the age.

In sum, nominal scales have labels, the value and the rank of the options does not matter; ordinal scales have labels, the order matters but the value does not; interval scales have labels, the order and the values matter but there is no true zero; finally, ratio scales have labels, the order and the values matter and are conceivable to be quantified (also the difference between the values) and there is an absolute zero which equals to nothingness.

The nature of the MCDA relies upon the nature of the development of the criteria accordingly to build quality, then Roy decided three conditions concerning the connections of them [66]: thoroughness, which dodges the lack of data; non-redundancy, which implies none of the defined criteria ought to be considered excess; and cohesiveness that refers to the similarity that should be available between a part of every considered criterion while thinking about preferences on them.

DA is a useful instrument, particularly when one needs to address the three MCDA major problematics: ranking, sorting and choice defined by Bernard Roy as the problematic description [68]. For ranking one, we are keen on positioning every one of the other options (alternatives), which means we need to arrange a given arrangement of actions from the best to the most exceedingly terrible considering their significance on a thought about a specific criterion. In sorting, one needs to allot every action to a bunch of categories characterized by standards and components of the alluded category.

Finally, the choice comprises of supporting the DMs in making decisions on a subset of options, as little as could be expected, considered as the best so one can at last pick [71].

Consequently, when characterized DA and subsequently MCDA and the problematics where it is applied, allowing us to distinguish the two key characters, who are liable for building and performing it: the DM, who has been discussed, in whose name or for whom this choice supporting is to be given; and not least important, the analyst who is answerable for giving the choice helping through fostering the models and every one of the computational abilities of the cycle [68]. It is mentioned that the two characters collaborate to empower them to arrive at a choice, by engaging their capacity of understanding the issue, targets and qualities being confronted. The strengthening is accomplished because of getting sorted out and blending complex and clashing data, where the most valuable methodologies result from basic and straightforward applications [72]. The methodology structure can be outlined in four essential phases [67]: organizing (structuring) which comprises in characterizing the choice issue enveloping the picking of the DM; assessing, which comprises ascribing scores and loads to the defined criteria where scores are accomplished making a model of intra-criteria inclinations, generating a performance of the various alternatives for every criterion, while weights are accomplished by elicitation of the scaling constants that mirror the distinction of the allure between them; testing, which comprises in the affectability investigation and vigor of the model, as defined considering sensitivity and robustness analysis; and finally the choice is made, the last advance that closures with a decision of the best options. Meanwhile, it is undoubtedly essential to refer that the analyst ought to especially help the DM, both in getting decisions of significant worth and preference data, as in the understanding of computational outcomes, according to their know-how.

In spite of the fact that DA systems' main objective is to help recognize and give the best choices, it is also allowed to follow the proposal made by the models, as George E. P. Box once said "All models are wrong, but some are useful" [73]; which means that models are portrayals of the real world, by that it is suggested that one should never lose their sense.

The use of MCDA in tackling true issues is immense and covers a wide scope of regions from finance to energy arranging among numerous others [69]. Likewise, in health care, they previously began to be applied, which is extremely consistent since medical services choices are perplexing and include standing up to various perspectives [74]. Even though it is feasible to discover several articles about the assignment of the asset along with clinical medicines, or the decision of the best option for a specific patient since some years ago, as of recently MCDA was then used to make composite indicators to assess hospitals or clinics access and quality. Hence, in this dissertation, it is anything but a model performing an MCDA strategy later to be applied for a specific case whose aim is to survey the quality and access of the Portuguese public hospitals. The picked MCDA method, ELECTRE TRI-nC, is then covered afterwards.

## 4.2. ELECTRE TRI-nC

This method belongs to a family of methods named ELECTRE which stands for *ELimination Et Choix Traduisant la REalité*, performed to manage genuine MCDA circumstances within the real-world applications with its essential specifications: to be included in the model at least three criteria as demanded by the DM the ELECTRE TRI-nC is undoubtedly useful; moreover, when there is a clarified heterogeneity identified within the nature of the scales related with the defined criteria, it turns to be not so easy to characterize one single normal scale that could supplant the previous ones; nonetheless, if actions are assessed either on a feeble span scale like a weak interval one or absolutely ordinal scale, it is recommended to apply ELECTRE TRI-nC method [68].

Those aforementioned scales (ordinal or weak interval scales) are not reasonable for the correlation of differences. Considering given criteria, the case of a loss on it, undoubtedly this can be balanced and then compensated by a gain on a different criterion, however, this procedure may not be satisfactory for the DM. Thusly, previously mentioned circumstances require the utilization of non-compensatory (aggregation) techniques. The presence of little contrasts of preferences may not be considered relevant, thus it is required the expansion of edges, new thresholds for indifference and preference.

It was Bernard Roy and his associates from Paris-Dauphine University who created the ELECTRE methods' family, then the majority of the gathered literature about the ELECTRE family strategies emerges from France, in fact. During the 1960s, Roy made ELECTRE I, which was the principal model of preferences dependent on outranking relations [68].

The ELECTRE strategies to be applied depends on an aggregation of multiple criteria, which permits to assemble at least one outranking relation dependent on the exhibitions of each action on every measure of criteria with the viewpoint of contrasting in a more thorough manner each pair of actions. Moreover, it is also needed another strategy, in order to acquire sufficient outcomes, implying the nature of the case, by arranging, picking or positioning, known as sorting, choosing and ranking, respectively.

There are some ELECTRE methods and variations to confront the three fundamental problematics characterized previously. One of them is the ELECTRE TRI-C method, which is appropriate for MCDA arranging issues where the arrangement of categories is requested and every one of them is characterized through a reference action. Additionally, this method was considered to check a bunch of principal primary prerequisites (homogeneity, similarity, strength, and monotonicity) [75]. In spite of the fact that ELECTRE TRI-C was first evolved it is a particular case of the ELECTRE TRI-nC method, since in this one there is no imperative for the number, $n$, of reference actions as common of every category [76]. Note that an increment of the reference actions for an equivalent category contributes to advancing the meaning of every category and permits to acquire more thin timespans to which each action can be as endorsed to [68]. ELECTRE TRI-nC permits the DM and the analyst in the co-development choice interaction to portray the categories with a significant opportunity in comparison to ELECTRE TRI-C. Nonetheless, it turns possible for the DM to consolidate two sequential categories by keeping the association of the characteristic reference actions of the two combined categories. Therefore, additionally, it allows to segregate a category through making an arranged parcel of the reference

actions, bringing out two new consecutive categories. In this manner, ELECTRE TRI-nC is not just the general method from which the other one comes, this method introduces benefits and includes more capabilities contrasting with the ELECTRE TRI-C [71].

### 4.2.1. Method and notation

An outranking relation is a double relation, $S$, characterized on the arrangement of possible actions, *A*, to such an extent that $a$ is preferred than $b$ ($aSb$) in case there are sufficient contentions to conclude that $a$ is basically comparable to $b$, while there is no fundamental contention to disprove that assertion [77]. This is known as outranking on a binary relation and let $A = \{a_1, a_2, \dots, a_i, \dots, a_m\}$ denote the arrangement of possible actions, which can be completely known or be continuously defined during the decision aiding process. The ELECTRE TRI-nC means to allocate the actions to a bunch of totally ordered categories, characterized as $C = \{C_1, C_2, \dots, C_h, \dots, C_q\}$ being $q \geq 2$. Considering that, it is essential a group of criteria, denoted $G = \{g_1, g_2, \dots, g_j, \dots, g_n\}$ to assess the different actions. To assess an action $a$, for a criterion $g$, it is used $g(a)$. Concerning the arrangement of the reference actions, which characterize the categories, it is denoted $B = \{B_1, B_2, \dots, B_h, \dots, B_q\}$, where $B_h = \{b_{h1}, \dots, b_{hl}, \dots, b_{h|B_h|}\}$ being $r = 1, \dots, m_h$ (which is a sub-group of the reference actions acquainted with portraying category $C_h$ to such an extent that $h = 1, \dots, q$ and $m_h \geq 1$) [76].

Every criterion $g_j$ is viewed as a rule with thresholds or a pseudo-criterion, considering the following two edges: the preference threshold, $p_j$, between the performance of the two compared actions, which is related to the littlest contrast that, when surpassed, the best performing action is viewed as rigorously ideal; and the indifference threshold, $q_j$, between the two compared actions, is related to the largest distinction that is judged viable, with a circumstance of aloofness between the two actions, with various performances [75]. Therefore, $p_j \geq q_j \geq 0$. The motivation behind these limits is to consider the defection of the information from the calculation of the performances, $g_j(a_i)$ for $a_i \in A$, and also some randomness influencing the meaning of the standards [75].

For each criterion and considering the aforementioned thresholds, it is possible to establish the following assumptions [78]: if the action $a$ is strictly preferred over the action $b$ for a criterion $g_j$, with $g_j(a) \geq g_j(b), \forall g_j \in G$ then,

$$g_j(a) - g_j(b) > p_j \tag{4.1}$$

addressing like $aP_jb$, such that $C(aPb)$ denotes its set of criteria; if the action $a$ and $b$ are indifferent to each other for the criterion $g_j$ then,

$$\left|g_j(a) - g_j(b)\right| \leq q_j \tag{4.2}$$

addressing like $aI_jb$, such that $C(aIb)$ denotes its set of criteria; and last but not less relevant, surely where it turns harder, with no adequate reasons to finish up an aloofness circumstance, nor an exacting inclination between the two actions, therefore,

$$q_j < g_j(a) - g_j(b) \leq p_j \tag{4.3}$$

addressing like $aQ_jb$, such that $C(aQb)$ denotes its set of criteria. The last case (Equation 4.3) is wavering among lack of interest or a concluding indifference between the two actions, not being possible to define that $a$ and $b$ are indifferent nor strictly preferred from one another. Therefore, this means that $a$ is weakly preferred over $b$.

With respect to the articulation $p_j \geq q_j \geq 0$, in fact, $q_j$ may be null which means that one action is weakly or strictly preferred over the other one, not being possible to be indifferent. In the case that $p_j$=$q_j$ and not null, the actions are indifferent from each other, or one is strictly preferred over the other one, not being possible to be weakly preferred. Finally, on the off chance that $p_j = 0$, any distinction of performances for one action over another can be considered as critical for an exacting preference on the criterion $g_j$.

As recently expressed, a binary relation for outranking is addressed by $aSb$, which implies that the action $a$ is essentially much as great as $b$, as indicated by a standard criterion $g_j$. For the development of outranking relations, it needs to be taken into count the concordance which legitimizes this development [79]: alludes to the congruity between models that favors $aSb$ to be acknowledged, which means an adequate larger part of criterion should be supportive of this establishment. This may be assessed by the general concordance degree $c_j(a,b), j = 1, \dots, n$ that relates every criterion to a weight $w_j$ to such an extent that $w_j > 0$ with $j = 1, \dots, n$ and $\sum_{j=1}^{n} w_j = 1$ (the amount of all of the weights for every criterion is equal to 1). The general concordance degree is as follows [78]:

$$c_j(a,b) = \sum_{j\in C(a\{P,I,Q\}b)} w_j + \sum_{j\in C(aQb)} w_j\varphi_j =$$
$$= \sum_{j\in C(aPb)} w_j + \sum_{j\in C(aIb)} w_j + \sum_{j\in C(aQb)} w_j + \sum_{j\in C(aQb)} w_j\varphi_j \tag{4.4}$$

where $\varphi_j = \frac{p_j - g_j(b) + g_j(a)}{p_j - q_j} \in [0,1]$ (4.5)

Nonetheless, as well as concordance, it needs to be considered the non-discordance concept. When none of the minority models that go against $aSb$ practices its ability to reject this affirmation, all in all disproving it. The non-discordance is assessed by the general discordance index, which relates every criterion to a rejection power named veto ($v_j$) with the end goal that $v_j > p_j$. The denial impact of veto is displayed utilizing the fractional discordance index $d_j(a,b), j = 1, \dots, n$ and is characterized as [78]:

$$d_j(a,b) = \begin{cases} 0 & \text{if } g_j(a) - g_j(b) \geq -p_j \\ \frac{g_j(a)-(g_j(b)+p_j}{p_j-v_j} & \text{if } -v_j \leq g_j(a) - g_j(b) < -p_j \\ 1 & \text{if } g_j(a) - g_j(b) < v_j \end{cases} \quad (4.6)$$

Last but not less relevant, the credibility degree should be taken into count. Represented by $\sigma_j(a,b)$, it is the level of credibility to think that the action $a$ is essentially much as great as $b$, taking into account the group of criteria $g_j$. To gauge this degree, it is done throughout both aforementioned indexes (general agreement and fractional conflict indexes) as it follows [78]:

$$\sigma_j(a,b) = c_j(a,b) \prod_{j=1}^{n} T_j(a,b) \quad (4.7)$$

$$\text{where } T_j(a,b) = \begin{cases} \frac{1-d_j(a,b)}{1-c_j(a,b)} & \text{if } c_j(a,b) < d_j(a,b) \\ 1 & \text{if } c_j(a,b) \geq d_j(a,b) \end{cases} \quad (4.8)$$

In fact, the aforementioned step of ELECTRE TRI-nC uses the credibility level defined by $\lambda$ (which regularly takes a worth within $[0.5,1[$ and it is fundamentally considered by the DM for the approval of the outranking hypothesis considering all the criteria) [79]. The credibility level can be viewed as a restricted level since it turns a simple relation into a clear outranking one [80]. For the meaning of the accompanying outranking relations, $\lambda$ is contrasted with the categorical credibility indexes of the various actions and to the arrangement of reference ones on every category [78]:

$$\sigma(B_h, a) = \max_{l=1,\dots,|B_h|} \{\sigma(b_{hl}, a)\} \quad (4.9)$$

$$\sigma(a, B_h) = \max_{l=1,\dots,|b_h|} \{\sigma(a, b_{hl})\} \quad (4.10)$$

This turns possible to characterize three possible comprehensive binary relations which are introduced beneath [78]:

- $\lambda$-preference:

$$aP^{\lambda}B_h \Leftrightarrow \sigma(B_h, a) < \lambda \wedge \sigma(a, B_h) \geq \lambda \quad (4.11)$$

- $\lambda$-indifference:

$$aI^{\lambda}B_h \Leftrightarrow \sigma(B_h, a) \geq \lambda \wedge \sigma(a, B_h) \geq \lambda \quad (4.12)$$

- $\lambda$-incomparability:

$$aR^{\lambda}B_h \Leftrightarrow \sigma(B_h, a) < \lambda \wedge \sigma(a, B_h) < \lambda \quad (4.13)$$

In fact, there is a fourth possible relation which is a general one from where the aforementioned come, the $\lambda$-outranking [78]:

$$aS^{\lambda}B_h \Leftrightarrow \sigma(a, B_h) \geq \lambda \tag{4.14}$$

## 4.2.2. Ascending and descending assignment

An essential part of the MCDA method is performing an assignment, where each action is assigned to a category or interval of categories, then it is contrasted with the reference ones thinking about the degree of credibility. Concerning that, the ELECTRE TRI-nC procedure is based on two joint rules: an ascending and a descending one. Those two rules incorporate a selecting function $\rho(a, B_h)$ that permits the decision of one on two continuous categories to be allocated to an action. This selecting function, $\rho$, is [81]:

$$\rho(\mathrm{a}, B_h) = \min\{\sigma(\mathrm{a}, B_h), \sigma(B_h, \mathrm{a})\} \tag{4.15}$$

Clarified that it is of interest depict how the two joint guidelines are characterized to allot at least one potential category to an action [81]:

a) Ascending assignment: pick a credibility level $\lambda$ in the scope of $[0.5,1]$ and consider $h$ from $0$ to the primary value $(k)$, to such an extent that $\sigma(B_k, a) \geq \lambda$, while incrementing $h$. From there, it is chosen an ascending pre-defined category, $C_k$. If $k = 1$, therefore $C_1$ is assigned to the action $a$. Secondly, if $\rho(a, B_{k-1}) < \rho(a, B_k)$ for $1 < k < q + 1$ thus $C_k$ is assigned to the action $a$. On the contrary, if $\rho(a, B_{k-1}) > \rho(a, B_k)$, therefore $C_{k-1}$ is the selected category. For the case that $k = q + 1$, this means that the category to be assigned to the action *a* is $C_1$.
b) Descending assignment: pick a credibility level $\lambda$ in the scope of $[0.5,1]$ and consider $h$ from $(q + 1)$ until the primary value $(t)$, to such an extent that $\sigma(a, B_t) \geq \lambda$, while decreasing $h$. From there, it is chosen a descending pre-defined category, $C_t$. If $q = t$, therefore $C_t$ is assigned to the action $a$. Secondly, if $\rho(a, B_{t+1}) < \rho(a, B_t)$ for $0 < t < q$ thus $C_t$ is assigned to the action $a$. On the contrary, if $\rho(a, B_{t+1}) > \rho(a, B_t)$, therefore $C_{t+1}$ is the selected category. For the case that $t = 0$, this means that the category to be assigned to the action *a* is $C_1$.

By this assignment procedure, each aforementioned principle allows reaching one potential category to each action. Nonetheless, the way those principles act at the same time and independently from each other can bring about two unique prospects for assigned categories. If there is an overlapping of the maximum and the minimum category thus outcomes in the attribution of one single classification, one category only for the action *a* is considered. On the other hand, if the maximum and minimum categories are distinct, therefore this brings about an interval, which is defined as $\Gamma(a)$, being an interval from the minimum to the maximum category considered possible to be assigned to the action $a$.

### 4.2.3. Application, disadvantages and advantages

For some improvement in this dissertation, the use of the ELECTRE TRI-nC was performed with the assistance of *MCDA-ULaval software*, which is a free and open-source application created at the Université Laval, in Quebec (Canada), containing all the ELECTRE family methods to be used in a multi-criteria decision analysis framework [80]. Written in Java, this application calls upon a few outer libraries.

This useful instrument turns possible to build up projects that can manage different informational collections, containing the actions, the standards (criteria and reference actions), tables of performance and configurations for decisions. The fundamental advantages of this apparatus are the chance to consider the criteria, both in nominal or ordinal scales, the chance of consequently defining the weights and getting them normalized, the chance of bringing in and trading information, for instance, pre-characterized performance tables with each of the boundaries characterized, the introduction of the process investigation under outlines, for the consolidation of the scenarios in the reached outcomes and also the chance of conduct a sensitivity analysis for the choice parameters taken into count. Lastly but probably the most relevant advantage of this software is the time saved with the exhibition of all the computational analytics.

Regardless, the ELECTRE TRI-nC presents a few shortcomings, which surely are additionally present in other ELECTRE's. One of them is transitivity. Commonly techniques dependent on outranking relations do not have to fulfill the transitivity property, anyway in case it is decided that preferences ought to be transitive it addresses a shortcoming indeed [79]. Furthermore, one of the disadvantages concerns the disability of not being satisfactory to dole out a performance to a single action, at whatever point it is decided by the DM. On the off chance that every scale for the criteria is quantitative, it is more fitting to utilize different methods.

Surely, there are so many advantages associated with the ELECTRE TRI-nC [79]. It is feasible to order providers into different categories (*>2*). The problem of imperfect information when assembling the defined criteria is considered by adding the preference and indifference thresholds. The existence of qualitative and quantitative scales permits one to think about the first performances with no need for recoding. Another benefit with respect to scales is that they can be heterogeneous, hence there is no compelling reason to standardize data so that one can save performances of the actions for each criterion. It is possible to attribute different weights to different criteria. At least one reference action characterizes each category, but it is possible to be defined by two or more reference actions (which is different when considering the ELECTRE TRI-C, where it is just conceivable one reference action). The ELECTRE TRI-nC is non-compensatory and systematic, which implies that most exceedingly awful performances on specific criteria cannot be efficiently repaid by better ones on different criteria. The ELECTRE methods can show the reasons in favor (concordance) and the reasons against (as non-discordance) in looking at two actions and uses a veto threshold, which builds up the non-compensatory character of the method. The recently introduced benefits, offer help to the ELECTRE TRI-nC in its main goal of allotting actions to comparing ordered categories, considering the picked set of defined criteria. Likewise, note that when evaluating actions, they are contrasted to the reference ones that describe

every category, accordingly, giving the upside of an outright examination instead of a relative correlation [79].

## 4.3. Summary

MCDA method was introduced in this chapter, which as the name proposes call upon multicriteria to take care of decision investigation issues. This method initially recognizes problematics, which are applied to the model intended to reenact circumstances (criteria, reference categories, as aforementioned). Models are tried utilizing sensitivity examines to give vigor to the model, so it can give dependable outcomes that guide in the process. The ELECTRE TRI-nC is an arranging MCDA method, which relegates a bunch of actions to a bunch of requested and pre-characterized classifications (categories), as per the performance of each one in a bunch of standards (criteria). In fact, every category can be characterized by at least one reference action, which comprises a benefit for ordinal issues. This feature is different when considering ELECTRE TRI-C, where just one reference action for every category is conceivable. The method utilizes two joint principles (ascending and descending), every one of them liable for crediting one category to each action, which can bring about one single category or an interval on the off chance that the two principles do not match. In its application, there are two fundamental segments: the development of outranking relations, through contrasting the degree of credibility and the credibility level, determined between each action and the arrangement of reference actions of every category and the abuse of the outranking relations through the two joint principles, which allot each action to category/ies.

Afterwards, the aforementioned method, ELECTRE TRI-nC, will be built up and applied in a contextual analysis, based on a case study.

# 5. Case study

In this chapter, the case study is embraced and the model built to process the ELECTRE TRI-nC method, being detailed an overview of the methodology appliance, then presenting the Decision Maker (DM), the data sample from which the data is gathered and processed for the analysis (ACSS benchmarking, which is a reliable source). Afterwards, the assessment indicators are selected and consecutively the criteria defined, as well as the actions chosen (hospitals and hospital centers) to be assessed in this MCDA approach with the respective performance table presented. Finally, the criteria weights are calculated through a specific procedure (DCM-SRF) and the modeling parameters are presented, *i.e.*, categories, reference actions and thresholds.

## 5.1. Overview

As previously portrayed in Chapter 2, after some changes in the political systems, in 1979, the SNS was carried out. Its framework is essentially founded on the Beveridge model, *i.e.* the primary and secondary health care suppliers are from direct responsibility of the Portuguese Government which is liable for dealing with them both public elements supported transcendently by public charges appropriated by various services including the Ministry of Health.

The NHS is managed to guarantee the right to the wellbeing assurance under the Constitution, in order to give a reasonable and evenhanded consideration to its citizens and it is fairly free to give admittance to every one of the residents, despite the users' expenses being charged relying upon their social and economic states. Somewhat recently, there has been an increment of tension in the framework through various elements: expensive medicines because of the rise on the progressively complex sicknesses and persistent illnesses, an expansion in future and advances innovation and in the technology applied and frequently used, being costly and thusly of restricted admittance. Those circumstances turned high the Portuguese health expenditure, where its worth is for example, per capita, roughly €1983, one of the most expensive in the EU compromising the presence of the SNS [72].

To save the SNS and hence its users, strategy changes have been carried out to lessen costs and the misuse of monetary assets, determined to turn medical care associations more productive and powerful. A portion of the last changes proposed, developed a few clinic consolidations, corporatization of many entities and the consolidation of partnerships with a public-private relation. Hospital centers were created from a horizontal interflow between secondary and local health care providers as well as a vertical consolidation between secondary and primary health care units.

Several changes were carried on the way the health care entities have been financed during the corporatization of the health units. Previously, the assignment of the assets was reviewed meaning that all entities were financed depending on their most recent years expenditure, which main considered fixed sums as per the clinical determination, paying little mind to the expenses caused [83]. Albeit the model anticipated the pay for the genuine expenses of care, the organizations have not concreted and defined exact methods of computing the real expenses, now and again they still do not have a clue, or

in others, the assessed estimation was higher than the genuine worth [84]. Accordingly, the review model was not proficient, as this retrospective model was attributing to suppliers with greater expenses more assets not even being credited liabilities to units or chiefs, moreover existing genuine incoherence in the control of administrations and expenses brought about [85]. On the off chance that there were monetary imperatives, hospitals had less financing than it was supposed to be. Anyway, since the corporatization occurred in 2003, the financing of the entities changed to a prospective model, which means the health care suppliers were, from that second on financed by its movement, considered its degrees of production [84]. The model incorporates an agreement among the Portuguese Government and hospitals, named *contrato-programa*, being haggled between every hospital's Administrative Council and the Ministry of Health. The financial plan ascribed to every entity considers the conveyed medical care administrations. The target of this new financing procedure depends on the advancement of a proficiency gain, given the attribution of a worth considered adequate for every mediation. In this model, the sort, volume and costs of administrations to be executed are fixed preceding their acknowledgment and autonomous of the real expense. Along these lines, the risk of the hospitals relies upon a supportable administration requiring a better use of their assets. This makes a motivating force for a superior administration through the responsibility of the different stakeholders to advance effectiveness, but it ought not to debilitate quality.

However, the Ministry of Health pays for hospitals according to the most effective one in a certain similar gathering, a group of hospitals, through averaging the unitary expenses of that hospital. It is expected that hospitals that have a place in a similar cluster have closely resembling creation innovations. The issue shows up when the idea of proficiency is yet not clear, neither the models carried on for the hospitals grouping accurately reflect both the quality and the conditions of the offered types of provisioning and the management of the entities [86]. This implies that the cycle followed to support hospitals is probably going to deliver wasteful measures.

It is significant that hospital centers bunching incorporates not just the quantity of administrations and their costs, yet additionally mirroring the quality of the health provisioning and the management worked on, which is the focus where this dissertation arises. Along these lines, it is mentioned an itemized learn about the nature of the SNS entities which is conceivable through building an MCDA model. Note that it is essential that this model presents a non-compensatory character to more readily address quality (carrying on the ELECTRE TRI-nC), as certain performances in some criteria do not still compensate weak performances in a different criterion, particularly looking to perilous ones, where for example a weaker patient safety almost bringing about the death of that patient can not be “repaid” by different criteria with high performances [87].

## 5.2. Decision Maker (DM)

In some phases of the procedure carried out in the MCDA approach, the Decision Analysis for the construction of the model implies two key players, the DM and the analyst. The DM, for whom the decision aiding should be taken into count and the one that supports the cycle of the method, is an

expert in the health care sector with know-how in performance assessment, as well as much knowledge in administration, management and health policy-making. Therefore, the analyst, in an interaction with the DM, can keep away from conceivable bias during the study which gives more accurate and trustworthy results.

The DM supported the study in some essential phases: criteria weighting, criterion and method parameters. (*i.e.,* credibility level, preference, indifference and veto thresholds) definition and establishment categories as well as the corresponding reference actions that characterize them.

## 5.3. Data and sample

The case study of this dissertation is focusing on the assessment of the Portuguese public hospitals in terms of their quality, therefore the data gathered should be accurate and trustworthy, which is already supposed to be due to the fact this is handled by a health sector official source, *Administração Central do Sistema de Saúde (ACSS)*, the Portuguese Central Health System Administration. This entity established a benchmarking including the hospitals which belong to the SNS, trying to better succeed in terms of transparency in its tasks and goals (by the fact it is open and freely accessed for the population in general, through a website) as well as in economic and financial status for comparison throughout the years passed. Furthermore, it also allows to statistically analyze the outcomes and data from many health statuses, in a variety of parameters (indicators).

This benchmarking, easily accessed through its website [88], can be exported as an *Excel* file, then gathered and handled being the data sample used afterwards. The data is stored by month and year, for every indicator and the respective value attributed, for each hospital belonging to the SNS. Data for the whole year of 2019 was collected, from January to December.

## 5.4. Criteria

In the process of building a solid and coherent database to be analyzed in this case study, some indicators were taken into count amongst thirty-five from the benchmarking of the ACSS following the work of Pereira, Figueira, and Marques [62]. Those indicators are clustered in six distinct benchmark dimensions, according to ACSS, *viz*.: Access, Care Performance, Safety, Volume and Usage, Productivity and Economic-Financial [88].

Then, our selection process had two stages. In the first stage, high correlated indicators were excluded in a statistical correlation test carried on wiping out some redundancy. Afterwards, some meaningfulness indicators were disregarded as well as indicators without data provided for the year of 2019, the one chosen for the case study analysis. The last arrangement of eight indicators resulting from the sample processing of Pereira et al. [62] is then presented as follows:

- Number of non-urgent first medical appointments performed in adequate time per 100 first medical appointments (quantifies a percentage of the first medical appointments carried out in reasonable time considering the total amount of first medical appointments);

- Number of outpatient surgeries per 100 potential outpatient procedures (counts the percentage of the outpatient surgeries in the whole amount of the outpatient procedures);

- Number of readmissions in thirty days after discharge per 100 inpatients (deals with the percentage of patients readmitted in the first thirty days after the discharge considering the total number of inpatient episodes);

- Number of long-stay inpatients per 100 admissions (is the percentage counting the number of inpatient admissions longer than thirty days considering the total number of inpatient episodes);

- Number of hip surgeries performed in the first forty-eight hours per 100 hip surgeries (corresponds to the percentage of hip surgeries in elderly patients within the first forty-eight hours after the fracture, considering the total number of hip surgeries in elderly patients);

- Annual inpatient occupancy rate (counts the percentage over time of acute admissions considering the total number of acute inpatient beds);

- Average waiting time before surgery (represents the average number of days until the surgery happens considering the total number of scheduled surgeries);

- Operating cost per standard patient (represents in € the operating expenses per standard patient).

The aforementioned selected indicators belong to four dimensions, amongst the referred six benchmark dimensions. The Access pertains to the degree of patient contact with health care providers, in which the first selected indicator is included: the number of non-urgent first medical appointments performed in adequate time per 100 first medical appointments. The Care Performance deals with the quality of the service supplied by the health care providers, including most of the selected indicators: the number of outpatient surgeries per 100 potential outpatient procedures, the number of readmissions in thirty days after discharge per 100 inpatients, the number of long-stay inpatients per 100 admissions and the number of hip surgeries performed in the first forty-eight hours per 100 hip surgeries. Productivity is associated with the rate output/input of the health care providers, including the annual inpatient occupancy rate and the average waiting time before surgery. Finally, the last dimension involved in the selected indicators is the Economic-Financial one, related to the economic and financial aspects of the health care provisioning, where the operating cost per standard patient indicator belongs.

Quality is complex as already mentioned in previous sections, however, Donabedian categorized it into three categories which were related to each other: structural quality, process quality and outcomes [89,90]. Those definitions were vastly used and therefore the dimension *care appropriateness* is associated with quality, whose criteria defines a specification of process quality [91].

Access is also a non-consensual concept, nevertheless, some categories were already defined for access: service availability, organizational barriers, financial barriers, and personal barriers [62, 94]. Therefore, the dimensions *timeliness of services* and *service availability* are associated with the categories of service availability and organizational barriers of access.

One important step of the MCDA is to construct the criteria tree which turns possible to assess the quality domain of the health entities (the actions shown afterwards). It is possible to carry on a bottom-up or a top-down approach, however, the data is limited by the source, the ACSS benchmarking, so that a bottom-up approach is preferable, *i.e.*, the indicators are gathered and selected as a start point for the case study and then the criteria tree is formulated, so the data is handled and processed this way [89]. This is a pseudo-bottom-up approach due to the fact that the indicators are not completely independently chosen, but it is borne in mind which are the most coherent and appropriate indicators and suitable to reflect the quality assessment, according to the literature review. Therefore, the indicators were gathered and selected and afterwards the criteria were defined based on the AHRQ and IOM.

According to Roy, criteria are a tool to assess and compare potential actions in different well-defined points of view. $g(a)$ mentions the performance of the action $a$ on a criterion $g$. As described in Chapter 4, a group of criteria defined to evaluate actions is a family of criteria if it is cohesive, coherent and exhaustive, which means that all the essential points of view are considered for a solid assessment of the actions. The cohesiveness is associated with the aggregation of the DM preferences being accurate with the partial preference taking into count each criterion. If a single criterion is not cohesive and exhaustive at all, then it is disregarded [87].

The family of criteria were defined based on the literature review, as already mentioned. Thus, the family of criteria considered valid and suitable for the assessment in the case study of this dissertation consists of eight criteria, denoted by $g_i$, for $i = 1, \dots, 8$:

- Timeliness of medical appointments ($g_1$): evaluates the accessibility of the health care service provisioning, which is the capability of the system to provide health care to any citizen if required, in a fairly timely manner. It is considered an accessible health care service if it handles adequate resources per patient or in case of demanded care so it should maintain or improve health [92]. It involves the application of fees per medical act to the patients taking into count their affordability to pay, the location and the physical access (distance to the user), dealing with the patients in a reasonable time and presenting low waiting time (timeless) and short waiting lists [93]. The indicator that operationalizes this criterion is to be maximized (Number of non-urgent first medical appointments performed in adequate time per 100 first medical appointments);

- Timeliness of surgeries ($g_2$): evaluates the accessibility to surgery after a fracture in elderly patients, which represents a relevant cause of morbidity and mortality [94]. There is no consensus yet about the perfect time for the surgery to be proceeded after a fracture, nevertheless forty-eight hours is a reasonable waiting time before the hip surgery [95]. The indicator that operationalizes this criterion is to be maximized (Number of hip surgeries performed in the first forty-eight hours per 100 hip surgeries);

- Waiting time before surgery ($g_3$): evaluates the time between the admission of the patients and the surgery episode, considering an average amongst the total of surgical episodes and assesses the health care provider to be accessible when required to surgical procedures, bearing in mind timeliness conditions [94]. The indicator that operationalizes this criterion is to be minimized (Average waiting time before surgery);

- Outpatient surgeries adequacy ($g_4$): evaluates the ability to provide patient-centered health care services based on evidence-based guidelines and scientific knowledge. When focusing on evidence-based standards, the service outcomes result in health improvement (such as increasing life expectancy, pain relief or even better functional capacity), minimizing health risks (*i.e.,* pain, morbidity, mortality) by a reasonable margin enough to consider the surgical intervention worth doing [86]. Major surgeries can proceed as minor procedures based on clinical evidence without pain and any harm to the patient. The indicator that operationalizes this criterion is to be maximized (Number of outpatient surgeries per 100 potential outpatient procedures);

- Large delay of care ($g_5$): evaluates the appropriateness of the health care provision, *i.e.,* whether the health care services are adequate, if one provides a poor resolution to the patient's health issue, leading to an excessive delay of care, which can generate other problems (*i.e.* opportunistic infections acquired during the extended stay or even complicated wounds) [64]. The indicator that operationalizes this criterion is to be minimized (Number of long-stay inpatients per 100 admissions);

- Readmissions ($g_6$): also evaluates the appropriateness of the health care provision in the post-discharge phases, assessing if the therapy was stable at discharge and if the health care provisioned was suitable and accurate for the health issue. The lack of care appropriateness and inadequate post-discharge care are unwanted, due to the fact that they may lead to readmission in the first thirty days after the discharge of the inpatient [64]. The indicator that operationalizes this criterion is to be minimized (Number of readmissions in thirty days after discharge per 100 inpatients);

- Occupancy ($g_7$): evaluates the service availability concerning the occupancy rate of health care providers which is associated with accessibility and also equity. The number of beds available in a health care entity defines the availability to deliver services to inpatients when required. Therefore, beds should be maintained and available to be used, where the ideal value is 85% for the occupancy rate, according to the DM. So, the absolute difference between this ideal value and the real one is used to measure the care service availability [95]. The indicator that operationalizes this criterion is to be minimized (Annual inpatient occupancy rate);

- Technical inefficiency ($g_8$): evaluates the capability of a health care provider to reach objectives concerning the resources expended, bearing in mind the inputs (investment in capital, labor, workers, for instance) to obtain satisfying outputs. Some health care entities focus on best practices and invest in improvements, nevertheless, some are technically efficient just by the fact they divest on access and care appropriateness, without following best practices, in fact just reducing costs with lack of investment. The best achievement objective of health care providers should be economic and financial management of the resources used, but simultaneously the best possible provisioned care being cost-effective [93].

This efficiency analysis includes an overall expense assessment as the individual physicians, physicians' practice, waste of supplies, energy, and equipment usage, for every patient [96]. The indicator that operationalizes this criterion is to be minimized (Operational cost per standard patient).

The aforementioned criteria were distributed over four dimensions in line with the ones from the ACSS benchmarking: timeliness of services, care appropriateness, service availability and economic-financial.

Table 5.1: Dimensions, defined criteria to the case study and the corresponding indicators.

| Dimensions | Criteria | Indicators |
|---|---|---|
| **Timeliness of services** | Timeliness of medical appointments ($g_1$) | Number of non-urgent first medical appointments performed in adequate time per 100 first medical appointments |
| | Timeliness of surgeries ($g_2$) | Number of hip surgeries performed in the first forty-eight hours per 100 hip surgeries |
| | Waiting time before surgery ($g_3$) | Average waiting time before surgery |
| **Care appropriateness** | Outpatient surgeries adequacy ($g_4$) | Number of outpatient surgeries per 100 potential outpatient procedures |
| | Large delay of care ($g_5$) | Number of long-stay inpatients per 100 admissions |
| | Readmissions ($g_6$) | Number of readmissions in thirty days after discharge per 100 inpatients |
| **Service availability** | Occupancy ($g_7$) | Annual inpatient occupancy rate |
| **Economic-financial** | Technical inefficiency ($g_8$) | Operational cost per standard patient |

## 5.5. Actions

Firstly, to select the actions for the case study, the time interval was defined, for the year 2019, from January to December as aforementioned. Although at the time of this case study the data in the ACSS benchmarking website had been already available until the year 2020, it was not available for many

health care entities. Thus, since the data from the year 2020 was far incomplete, one decided that it could be interesting to analyze the previous year 2019 by the fact that it is the most recent year with completed data availability.

Afterwards, the data was handled, and the public secondary health care providers were selected out of the forty-three entities which were included initially in the ACSS benchmarking data. The excluded health care providers were the following:

- all the oncology centers (three), which have specific processes of care directly focused on cancer;

- all the local health units (eight), which are a result of a vertical integration amongst one hospital and many primary health care centers, therefore a comparison between the performance of one local health unit and a public hospital or a hospital center would result in untrustworthy conclusions.

- Cascais Hospital, PPP, and Fernando Fonseca Hospital, EPE, due to lack of data for the criteria analyzed.

This data processing conceived a total of thirty health care providers: nine hospitals and twenty-one hospital centers. According to the ACSS benchmarking data, the health care providers were clustered hierarchically in six distinct groups, from A to F [88]. Nevertheless, for this case study, the sample handling resulted in the exclusion of the health care providers with categories A and F, so the ones analyzed belong to groups B, C, D and E. However, in spite of belonging to different clusters, the previous clustering is disregarded in this dissertation, because it is intended to compare them globally based on the defined criteria for our case study assessment analysis.

The thirty selected health care institutions to be included in the case study (actions), denoted by $a_r$ for $r = 1, \dots, 30$, are the following:

- $a_1$ - Santa Maria Maior Hospital, EPE;

- $a_2$ – Figueira da Foz District Hospital, EPE;

- $a_3$ – Póvoa do Varzim/Vila do Conde Hospital Center, EPE;

- $a_4$ – Médio Ave Hospital Center, EPE;

- $a_5$ – Oeste Hospital Center, EPE;

- $a_6$ – Loures Hospital, PPP;

- $a_7$ – Vila Franca de Xira Hospital, PPP;

- $a_8$ – Tâmega e Sousa Hospital Center, EPE;

- $a_9$ – Leiria Hospital Center, EPE;

- $a_{10}$ – Entre Douro e Vouga Hospital Center, EPE;

- $a_{11}$ – Senhora da Oliveira Hospital, Guimarães, EPE;

- $a_{12}$ – Baixo Vouga Hospital Center, EPE;

- $a_{13}$ – Barreiro/Montijo Hospital Center, EPE;

- $a_{14}$ – Santarém Hospital Center, EPE;

- $a_{15}$ – Setúbal Hospital Center, EPE;

- $a_{16}$ – Médio Tejo Hospital Center, EPE;

- $a_{17}$ – Cova da Beira Hospital Center, EPE;

- $a_{18}$ – Braga Hospital, EPE;

- $a_{19}$ – Vila Nova de Gaia/Espinho Hospital Center, EPE;

- $a_{20}$ – Espírito Santo de Évora Hospital, EPE;

- $a_{21}$ – Garcia de Orta Hospital, EPE;

- $a_{22}$ – Tondela-Viseu Hospital Center, EPE;

- $a_{23}$ – Trás-os-Montes e Alto Douro Hospital Center, EPE;

- $a_{24}$ – Algarve Hospital Center, EPE;

- $a_{25}$ – São João Hospital Center, EPE;

- $a_{26}$ – Porto Hospital Center, EPE;

- $a_{27}$ – Coimbra Hospital Center, EPE;

- $a_{28}$ – Lisboa Ocidental Hospital Center, EPE;

- $a_{29}$ – Lisboa Norte Hospital Center, EPE;

- $a_{30}$ – Lisboa Central Hospital Center, EPE.

Considering the above thirty actions, as well as the criteria already defined and the data set from the ACSS benchmarking, it is possible to build a performance table. Afterwards, the performance values are displayed in Table 5.2 for each action for the year of 2019, for all the eight selected criteria, built with the use of *Microsoft Excel*.

Table 5.2: Performance table for each action by each criterion, for the case study.

| Actions | Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $g_1$ | $g_2$ | $g_3$ | $g_4$ | $g_5$ | $g_6$ | $g_7$ | $g_8$ |
| $a_1$ | 86.37% | 39.25% | 0.49 | 85.19% | 1.76% | 8.10% | 93.32% | 2 872.0 € |
| $a_2$ | 74.04% | 59.17% | 0.82 | 86.23% | 2.92% | 8.67% | 74.89% | 3 184.0 € |
| $a_3$ | 91.21% | 85.60% | 0.58 | 70.73% | 1.03% | 6.10% | 80.33% | 3 708.0 € |
| $a_4$ | 80.54% | 19.60% | 0.81 | 87.13% | 4.42% | 6.65% | 87.13% | 3 928.0 € |
| $a_5$ | 54.80% | 29.38% | 0.90 | 75.11% | 2.75% | 7.86% | 85.85% | 4 311.0 € |
| $a_6$ | 70.55% | 37.23% | 0.38 | 84.58% | 3.29% | 7.89% | 94.49% | 2 854.0 € |
| $a_7$ | 64.42% | 56.18% | 0.31 | 82.41% | 2.46% | 8.11% | 101.71% | 2 888.0 € |
| $a_8$ | 57.88% | 58.50% | 0.63 | 85.35% | 3.38% | 6.49% | 94.93% | 3 173.0 € |
| $a_9$ | 56.61% | 36.79% | 0.71 | 89.76% | 2.71% | 8.57% | 84.96% | 3 294.0 € |
| $a_{10}$ | 73.49% | 16.91% | 0.57 | 84.38% | 2.77% | 7.30% | 92.32% | 3 391.0 € |
| $a_{11}$ | 48.02% | 46.37% | 0.57 | 81.92% | 4.12% | 7.87% | 82.46% | 3 445.0 € |
| $a_{12}$ | 71.69% | 75.08% | 0.44 | 80.31% | 2.84% | 6.72% | 86.34% | 3 511.0 € |
| $a_{13}$ | 86.92% | 27.60% | 1.04 | 76.03% | 4.70% | 7.81% | 83.40% | 3 575.0 € |
| $a_{14}$ | 61.30% | 22.22% | 1.03 | 90.76% | 3.34% | 10.47% | 82.72% | 4 011.0 € |
| $a_{15}$ | 66.08% | 55.67% | 0.97 | 88.69% | 3.30% | 8.54% | 84.61% | 4 103.0 € |
| $a_{16}$ | 76.72% | 21.19% | 0.70 | 82.07% | 3.72% | 9.69% | 91.53% | 4 298.0 € |
| $a_{17}$ | 71.94% | 46.43% | 0.73 | 78.00% | 4.50% | 7.48% | 79.53% | 4 419.0 € |
| $a_{18}$ | 72.38% | 35.71% | 0.34 | 87.22% | 3.39% | 1.19% | 88.50% | 2 639.0 € |
| $a_{19}$ | 51.46% | 53.61% | 0.83 | 81.84% | 3.77% | 7.47% | 87.31% | 3 157.0 € |
| $a_{20}$ | 69.96% | 16.53% | 0.35 | 73.11% | 3.48% | 5.45% | 83.69% | 3 355.0 € |
| $a_{21}$ | 77.15% | 14.68% | 1.16 | 90.69% | 4.88% | 7.26% | 93.17% | 3 374.0 € |
| $a_{22}$ | 76.39% | 28.42% | 1.76 | 92.15% | 4.84% | 8.44% | 89.32% | 3 395.0 € |
| $a_{23}$ | 56.34% | 63.43% | 1.02 | 85.97% | 2.68% | 11.63% | 89.59% | 3 494.0 € |
| $a_{24}$ | 70.63% | 14.33% | 1.38 | 85.77% | 5.95% | 7.45% | 91.47% | 3 990.0 € |
| $a_{25}$ | 51.45% | 59.40% | 1.00 | 73.82% | 4.34% | 8.22% | 87.47% | 2 986.0 € |
| $a_{26}$ | 74.32% | 29.89% | 0.71 | 81.90% | 4.08% | 6.73% | 95.67% | 3 244.0 € |
| $a_{27}$ | 60.66% | 45.04% | 1.36 | 81.36% | 4.42% | 8.79% | 78.34% | 3 347.0 € |
| $a_{28}$ | 69.32% | 32.35% | 1.45 | 77.86% | 5.51% | 6.79% | 79.18% | 3 570.0 € |
| $a_{29}$ | 61.90% | 38.50% | 1.03 | 83.37% | 5.02% | 10.03% | 89.66% | 3 635.0 € |
| $a_{30}$ | 71.18% | 26.55% | 1.42 | 81.91% | 5.65% | 8.35% | 89.08% | 3 782.0 € |

## 5.6. Criteria weighting

In 1994, Jean Simos developed a procedure through which the criteria weights for the outranking problems were then calculated, the Simos' deck of cards procedure. In ELECTRE methods, the interaction between all the defined criteria is represented by the weights obtained and this represents the relative importance from one to each other [77]. In 2002, Roy and Figueira extended the procedure to include interval and ratio scales, creating the Simon Roy Figueira procedure (SRF). This procedure

has been frequently used in ELECTRE family methods for many real-life problems, like the one we are analyzing here in our case study. In the SRF procedure, the different criteria may be hierarchized by the DM, in a certain context, in order to conceive the required information to the analyst to obtain the values of the weights for each of all the defined criteria [97]. So, the weights of the criteria of this case study were acquired through the execution of the SRF procedure, which includes the following steps: initially, the DM collected the required information of the procedure and then supported the calculation of the criteria' weights giving some input to be executed through the *DecSpace* platform[1].

Thus, to obtain the weights of the criteria with the support of the DM, the steps were as follows:

- The DM was provided with a set of cards, corresponding to the number of the well-defined criteria (eight);

- Then, the DM was asked to establish a rank for all the cards (criteria), considering a descending order, which built a hierarchically ranked list of eight cards. The first card was the most important (highest weight) and the last card was the least important (smallest weight). The cards with the same importance (same weight) were grouped in the same position. Based on the position of the corresponding cards in the ranking, the criteria were attributed with ranks (1 was the highest rank, 2 was the second-highest rank and then consecutively till the last one, which was the lowest);

- Thus, the DM was also asked if any consecutive ranks had a bigger difference in terms of importance, *i.e.,* if the difference between two consecutive ranks were bigger. Then, depending on this difference of importance between ranks, the DM could add one or more blank cards between ranks. If no blank cards were added, then the difference between two consecutive ranks was one unit. But, if the difference between two consecutive ranks were bigger than that, so one blank card was added (meant that this difference was two units). Logically, two blank cards added between two consecutive ranks meant a difference of three units and so on;

- Finally, it was essential to know how many times the criteria/criterion in the highest rank were/was more important than the criteria/criterion in the lowest rank, so the DM helped with that, and it resulted in a numerical value, called ratio-z [97].

Table 5.3 displays the ranking of the eight criteria, built by the DM, including blank cards between two consecutive ranks, where Rank 1 is the highest position and Rank 3 is the lowest one.

So, as in Table 5.3, the considered most important criterion was $g_8$ followed by three blank cards which were put between Rank 1 and Rank 2. Consecutively, the criteria $g_1$, $g_2$ and $g_4$ were ranked in an intermediate position. Following those, two blank cards were put and finally in the least important position (Rank 3), the criteria $g_3$, $g_5$, $g_6$ and $g_7$ appear. The value defined for the ratio-z in this case study was 3.

[1] - DecSpace platform, through the website http://app.decspacedev.sysresearch.org.

Table 5.3: Ranking established for all the eight criteria, following the DCM-SRF procedure in the DecSpace platform.

| Ranking | Cards |
|---|---|
| Rank 1 | $g_8$ |
| Blank cards | 3 |
| Rank 2 | $g_1, g_2, g_4$ |
| Blank cards | 2 |
| Rank 3 | $g_3, g_5, g_6, g_7$ |
| Ratio-z | 3 |

Afterwards, considering the aforementioned information retrieved from the DM, the procedure SRF was computed using the DecSpace platform. Thus, the project was created, which is associated with the implementation of the DCM-SRF procedure, including the information collected from the help done by the DM: criteria (eight) in a certain hierarchical rank (with blank cards as in Figure 5.1, and the ratio-z defined). The user of this platform is able to decide the number of decimal places and the weight type (normalized, non-normalized or both). For our project, two was the number of decimal places established and both weight types were selected.

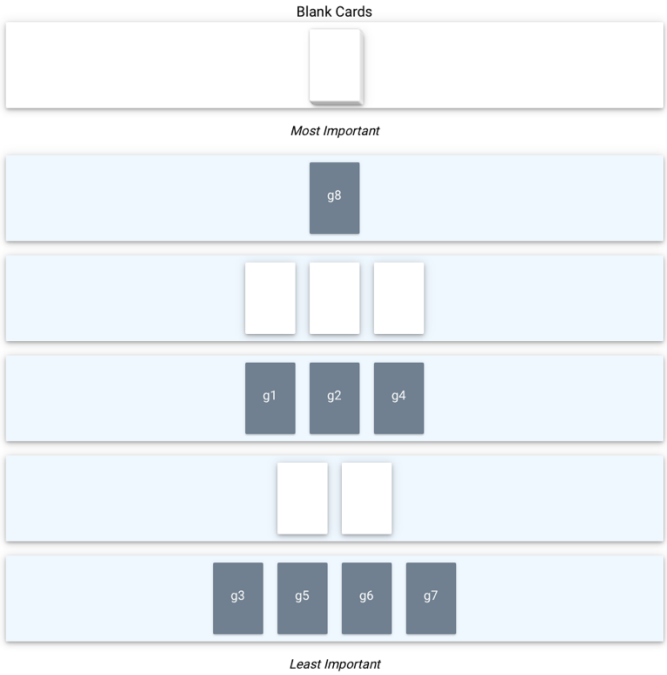


Figure 5.1: Ranking of the cards (criteria and blank cards) defined in the DecSpace platform.

The execution of the DCM-SRF procedure in the platform resulted in the values for the weights of the criteria presented in Table 5.4.

Table 5.4: Weight of each criterion (normalized and non-normalized), calculated through the DCM-SRF procedure.

| Criteria | Non-normalized weight | Normalized weight (%) |
|---|---|---|
| $g_1$ | 1.86 | 14.78 |
| $g_2$ | 1.86 | 14.79 |
| $g_3$ | 1.00 | 7.95 |
| $g_4$ | 1.86 | 14.79 |
| $g_5$ | 1.00 | 7.95 |
| $g_6$ | 1.00 | 7.95 |
| $g_7$ | 1.00 | 7.95 |
| $g_8$ | 3.00 | 23.84 |
| Total | - | 100.00 |

## 5.7. Definition of modeling parameters

For the case study, a set of ordered categories, with the corresponding reference actions that characterize them, was defined. Then, the criteria were, in an interaction with the DM, attributed a performance value to each reference action. The categories were as follows: $C_1$ (very poor performance), $C_2$ (poor performance), $C_3$ (average performance), $C_4$ (good performance), $C_5$ (very good performance).

Thus, the reference values for the performance for all criteria in a certain category were established, presenting the reference actions ($b_1^1$ for the category $C_1$, $b_2^1$ and $b_2^2$ for the $C_2$, $b_3^1$ for the $C_3$, $b_4^1$ and $b_4^2$ for the $C_4$, and $b_5^1$ for the $C_5$) in Table 5.5.

Table 5.5: Criteria performance values of the reference actions for each category.

| Criteria | Categories and reference actions | | | | | | | Direction |
|---|---|---|---|---|---|---|---|---|
| | $C_5$ | $C_4$ | | $C_3$ | $C_2$ | | $C_1$ | |
| | $b_5^1$ | $b_4^1$ | $b_4^2$ | $b_3^1$ | $b_2^1$ | $b_2^2$ | $b_1^1$ | |
| $g_1$ | 90.0 | 85.0 | 80.0 | 70.0 | 60.0 | 55.0 | 50.0 | Maximize |
| $g_2$ | 85.0 | 80.0 | 70.0 | 60.0 | 50.0 | 45.0 | 40.0 | Maximize |
| $g_3$ | 0.4 | 0.5 | 0.6 | 0.8 | 1.0 | 1.1 | 1.2 | Minimize |
| $g_4$ | 90.0 | 88.0 | 86.0 | 85.0 | 82.0 | 80.0 | 75.0 | Maximize |
| $g_5$ | 1.5 | 1.8 | 2.3 | 3.0 | 4.0 | 5.0 | 5.5 | Minimize |
| $g_6$ | 2.0 | 4.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | Minimize |
| $g_7$ | 80.0 | 82.0 | 84.0 | 85.0 | 87.0 | 89.0 | 90.0 | Minimize |
| $g_8$ | 2750.0 | 2800.0 | 2900.0 | 3000.0 | 3300.0 | 3750.0 | 4000.0 | Minimize |

Then, the criterion parameters were also defined: veto threshold ($v_j$), indifference threshold ($q_j$) and preference threshold ($p_j$).

The veto threshold ($v_j$) is related specifically to the criteria and is used to strengthen when there is a "non-agreement" difference favoring one action greater than this value, which will need the DM to refuse any outranking relationship established by other criteria [98]. In Table 5.6, the veto threshold ($v_j$) is defined for every criterion.

Table 5.6: Veto threshold ($v_j$) defined for each criterion.

| Criteria | $v_j$ |
|---|---|
| $g_1$ | 25.0% |
| $g_2$ | 7.0% |
| $g_3$ | 1.0 |
| $g_4$ | 20.0% |
| $g_5$ | 1.0% |
| $g_6$ | 3.0% |
| $g_7$ | 25.0% |
| $g_8$ | 1100.0€ |

The indifference and preference thresholds are necessary to be included in order to deal with imperfect knowledge in the model. There is some arbitrariness in the definition of the criteria, some imprecision in the data set used to build them, some uncertainty of the data parameters as well as the ill-determined databases where some difficulty arises considering the consequences and the outcomes of the selected criteria [99]. The indifference threshold ($q_j$) is the biggest performance difference which is considered compatible with a situation of indifference between two actions with distinct performances and the preference threshold ($p_j$) is the smallest performance difference which is considered relevant when it is exceeded, favoring the action with the highest performance. In Table 5.7, the indifference threshold ($q_j$) and preference threshold ($p_j$) are defined for every criterion.

Table 5.7: Indifference threshold ($q_j$) and preference threshold ($p_j$) for each criterion.

| Criteria | $q_j$ | $p_j$ |
|---|---|---|
| $g_1$ | 2.0% | 4.0% |
| $g_2$ | 1.0% | 2.0% |
| $g_3$ | 0.1 | 0.2 |
| $g_4$ | 2.0% | 4.0% |
| $g_5$ | 0.1% | 0.3% |
| $g_6$ | 0.4% | 1.0% |
| $g_7$ | 3.0% | 6.0% |
| $g_8$ | 120.0€ | 200.0€ |

Finally, the credibility level, $\lambda$, was defined (also known as method parameter or discrimination threshold). This threshold represents the minimum level of trustworthiness in the validity of the outranking relations and is comprised within the range $[0.5,1.0]$, nevertheless, it was narrowed to the range $[0.7,0.8]$ and initially defined that $\lambda = 0.75$.

## 5.8. Summary

In this chapter, the case study under analysis was presented, by modeling using ELECTRE TRI-nC method, gathering and processing the required data set. The eight criteria were defined according to the literature review and the indicators from ACSS benchmarking (which operationalize the criteria) were then associated with them.

From this trustworthy source, ACSS benchmarking, the data was collected and then handled, which resulted in a total of thirty actions (hospitals and hospital centers) selected to be analyzed for the most recent and completed year (2019). Then, the performance values for the actions considered by criterion were obtained, through the help of *Microsoft Excel*, building the performance table.

Then the model was finally built. The criteria tree was established and the performances tables acquired, then it was time to calculate the weights for each criterion. Through the DCM-SRF procedure, executed in the DecSpace software with the support of the DM's expertise in this issue, the criteria weighting was then carried out. Afterwards, the categories and the respective reference actions were established in an interaction with the DM. With one or more reference actions characterizing the categories so the method chosen to be applied was ELECTRE TRI-nC. The model required parameters, *i.e.,* credibility level and criterion parameters (preference, indifference and veto thresholds) were also defined.

# 6. Implementation of the model and analysis of results

In this chapter, the model built is then executed using the ELECTRE TRI-nC method: the modeling elements are executed in the *MCDA-ULaval* software, with the ACSS benchmarking data set. Then, the results are obtained: a category or an interval of categories assigned to each action. Finally, stability and robustness analyses are carried on concerning the execution of the model and then the results are compared and discussed.

## 6.1. Execution of the ELECTRE method and Results

To execute the ELECTRE TRI-nC method, the *MCDA-ULaval v.0.6.16* software was used. One project was created considering the whole family of criteria to assess the thirty considered actions, therefore, to execute this project, the required inputs were: actions (called *alternatives* in *MCDA-ULaval* software), the criteria, the performance table of the actions per criteria, the selection of the method (ELECTRE TRI-nC), the decision configurations (criteria weights, criterion parameters, *i.e.,* indifference, preference and veto thresholds, and the method parameter, *i.e.,* the credibility level) as well as the categories and the respective reference actions with the performance table of those reference actions per criteria.

For the created project in *MCDA-ULaval* software, initially, the actions (or *alternatives*) were inserted, *i.e.*, the health care entities described by the notation. Afterwards, the criteria were introduced, defining the type of measure for each criterion (cardinal or ordinal). For this case, the criteria were cardinal. Then, the performance values from the Table 5.2 for the thirty actions in each criterion was inserted in the software. Consecutively, the applied method was selected (ELECTRE TRI-nC), since more than one reference action were defined for some categories. So, the following step was the decision configuration (Figure 6.1), inserting the weights of the criteria ($k_j$, obtained from the SRF procedure), the criterion parameters (indifference $q_j$, preference $p_j$ and veto $v_j$ thresholds) and the method parameter (the credibility level, $\lambda$).

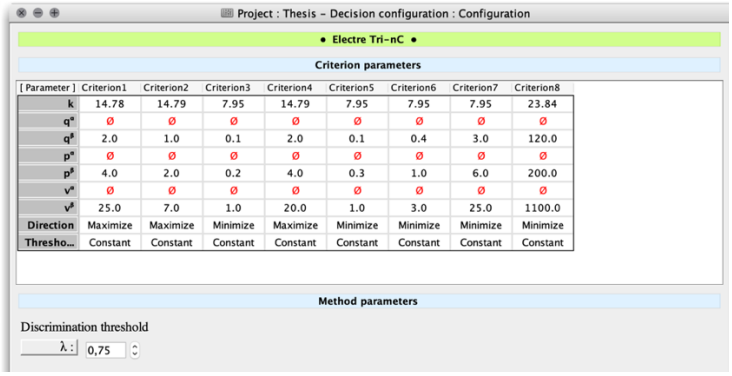


Figure 6.1: Insertion of the weights for the criteria, criterion parameters (indifference, preference and veto thresholds) and method parameter (credibility level) in *MCDA-ULaval* software.

Then, the categories were inserted with the respective reference actions, ordered from the top (very good, $C_5$) to the bottom (very poor, $C_1$) which also happens to the order of the corresponding reference actions, as Figure 6.2 displays.

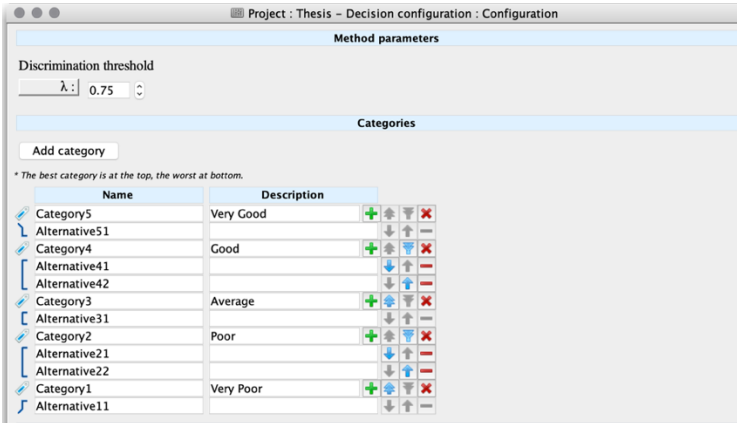


Figure 6.2: Categories and the corresponding reference actions in *MCDA-ULaval* software.

So, the performance values of the reference actions per criteria were inserted (Figure 6.3).

Performance table of the reference alternatives

| [ Alternative ] | Criterion1 | Criterion2 | Criterion3 | Criterion4 | Criterion5 | Criterion6 | Criterion7 | Criterion8 |
|---|---|---|---|---|---|---|---|---|
| Extent | 40,0000... | 45,0000... | 0,80000... | 15,0000... | 53,5000... | 8,00000... | 10,0000... | 1250,00... |
| Alternative11 | 50,0000... | 40,0000... | 1,20000... | 75,0000... | 55,0000... | 10,0000... | 90,0000... | 4000,00... |
| Alternative22 | 55,0000... | 45,0000... | 1,10000... | 80,0000... | 5,00000... | 9,00000... | 89,0000... | 3750,00... |
| Alternative21 | 60,0000... | 50,0000... | 1,00000... | 82,0000... | 4,00000... | 8,00000... | 87,0000... | 3300,00... |
| Alternative31 | 70,0000... | 60,0000... | 0,80000... | 85,0000... | 3,00000... | 7,00000... | 85,0000... | 3000,00... |
| Alternative42 | 80,0000... | 70,0000... | 0,60000... | 86,0000... | 2,29999... | 6,00000... | 84,0000... | 2900,00... |
| Alternative41 | 85,0000... | 80,0000... | 0,50000... | 88,0000... | 1,79999... | 4,00000... | 82,0000 | 2800,00... |
| Alternative51 | 90,0000... | 85,0000... | 0,40000... | 90,0000... | 1,50000... | 2,00000... | 80,0000... | 2750,00... |

Figure 6.3: Performance table of the reference actions per criteria in *MCDA-ULaval* software.

Finally, the project was built and it was possible to be executed. It is recommended to validate the parameters so that the software can check if all the parameters inserted were valid. In case some parameter was wrong, then the *MCDA-ULaval* software would warn about the wrongly inserted parameter to be changed.

Then, with all the configuration validated, the project was executed, obtaining the results displayed in Table 6.1 (each action assigned to a category or an interval of categories).

Table 6.1: Results from the execution of the project (assignment of the actions to a category or an interval of categories).

| Actions | Minimum Category | Maximum Category |
|---|---|---|
| $a_1$ | $C_3$ | $C_3$ |
| $a_2$ | $C_3$ | $C_3$ |
| $a_3$ | $C_3$ | $C_4$ |
| $a_4$ | $C_1$ | $C_2$ |
| $a_5$ | $C_1$ | $C_2$ |
| $a_6$ | $C_2$ | $C_2$ |
| $a_7$ | $C_3$ | $C_3$ |
| $a_8$ | $C_3$ | $C_3$ |
| $a_9$ | $C_2$ | $C_2$ |
| $a_{10}$ | $C_1$ | $C_2$ |
| $a_{11}$ | $C_2$ | $C_2$ |
| $a_{12}$ | $C_3$ | $C_4$ |
| $a_{13}$ | $C_1$ | $C_2$ |
| $a_{14}$ | $C_1$ | $C_2$ |
| $a_{15}$ | $C_2$ | $C_2$ |
| $a_{16}$ | $C_1$ | $C_2$ |
| $a_{17}$ | $C_2$ | $C_2$ |
| $a_{18}$ | $C_2$ | $C_4$ |
| $a_{19}$ | $C_2$ | $C_2$ |
| $a_{20}$ | $C_1$ | $C_2$ |
| $a_{21}$ | $C_1$ | $C_3$ |
| $a_{22}$ | $C_1$ | $C_3$ |
| $a_{23}$ | $C_2$ | $C_3$ |
| $a_{24}$ | $C_1$ | $C_2$ |
| $a_{25}$ | $C_2$ | $C_2$ |
| $a_{26}$ | $C_1$ | $C_2$ |
| $a_{27}$ | $C_2$ | $C_2$ |
| $a_{28}$ | $C_1$ | $C_2$ |
| $a_{29}$ | $C_2$ | $C_2$ |
| $a_{30}$ | $C_1$ | $C_1$ |

Table 6.2: Number of actions (and percentage) per category or interval of categories.

| Categories or interval of categories | Number of actions | Percentage of actions |
|---|---|---|
| $[C_1, C_1]$ | 1 | 3.(3) % |
| $[C_1, C_2]$ | 10 | 33.(3) % |
| $[C_1, C_3]$ | 2 | 6.(6) % |
| $[C_2, C_2]$ | 9 | 30.0 % |
| $[C_2, C_3]$ | 1 | 3.(3) % |
| $[C_2, C_4]$ | 1 | 3.(3) % |
| $[C_3, C_3]$ | 4 | 13.(3) % |
| $[C_3, C_4]$ | 2 | 6.(6) % |

Analysing the results obtained and presented in Tables 6.1 and 6.2, one can note that the minimum category to which the actions were assigned was $C_1$ (very poor performance) and the maximum was an interval of categories $[C_3, C_4]$, between an average and a good performance, which meant some weakness on the performance of the Portuguese hospitals and hospital centers considered in the case study for the standards defined in this dissertation. According to the model here constructed, the category $C_1$ was assigned to the action $a_{30}$ (Lisboa Central Hospital Center, EPE) which is worrisome as this is one of the main health care providers in Portugal. Two of the thirty actions were assigned to the interval of categories $[C_3, C_4]$, $a_3$ (Póvoa do Varzim/Vila do Conde Hospital Center, EPE) and $a_{12}$ (Baixo Vouga Hospital Center, EPE) meaning that those two health care providers had the best overall performance in the analysis done when considering the reference actions associated to the defined categories.

Taking a deep view in Table 6.2, it is possible to verify that 13 actions, 43.(3)% of the actions considered, were assigned to $C_1$ (very poor performance) as the minimum category to which they belong, only 3 actions, 9.(9)% of the actions considered, were assigned to $C_4$ (good performance) as the maximum category to which they belong and no actions were assigned to the category $C_5$ (very good performance).

Moreover, it is noted that 73.(3)% of the actions were either assigned to an interval of categories where the $C_1$ (very poor performance) is the minimum category attributed or assigned to the category $C_2$ (poor performance), *i.e.,* assigned to $[C_1, C_1]$, $[C_1, C_2]$, $[C_1, C_3]$ or $[C_2, C_2]$. So, only 26.(6)% of the actions considered were assigned to an interval of categories where the minimum category was equal to or above $C_2$ and the maximum category was above $C_2$, *i.e.,* assigned to $[C_2, C_3]$, $[C_2, C_4]$, $[C_3, C_3]$ or $[C_3, C_4]$. Note that, no actions were assigned to the $[C_4, C_4]$, which means that the category $C_4$ (good performance) was only the maximum in some cases, not the minimum, which is considerably worrisome.

Considering Figure 6.4 it is easily noted that almost half of the actions (16) were assigned to an interval of categories and logically almost half of the actions (14) were assigned to a single category.

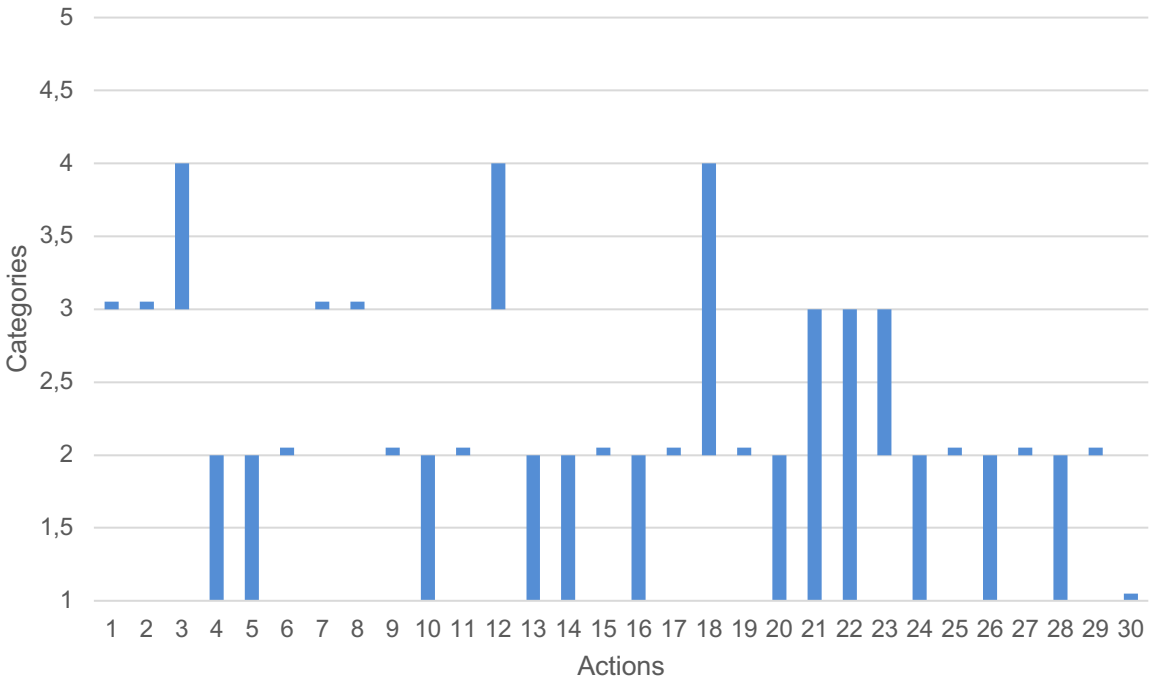


Figure 6.4: Bar chart with the assignment of the actions to a single category or an interval of categories.

## 6.2. Stability and Robustness analyses

The stability analysis included the credibility level, $\lambda$ measuring bounds, which were computed as $[0.7387085,0.758667]$. This represents the interval of values for $\lambda$ where using any value in that interval it is possible to obtain the same results as in Tables 6.1 and 6.2. Thus, further investigation on the impact of the credibility level on the results obtained, then robustness analyses were conducted.

Other stability analyses were undertaken for the weights of each criterion, displayed in Table 6.3. The stability intervals presented in Table 6.3 for the weights of the criteria are relatively short, so the weights chosen are not highly stable, which implies further investigation through robustness analyses.

The robustness analyses consist of the building of one or more scenarios different from the original configuration, which can be done by varying the method and criterion parameters, such as the credibility level and the weights of the criteria.

Table 6.3: Stability analysis for the weights of the criteria.

| Criteria | Weights |
|---|---|
| $g_1$ | [12.8192,16.5008] |
| $g_2$ | [12.2285,17.4325] |
| $g_3$ | [0.0000,9.0445] |
| $g_4$ | [13.3962,17.8705] |
| $g_5$ | [6.5342,10.1371] |
| $g_6$ | [5.3885,11.2017] |
| $g_7$ | [5.3885,12.8382] |
| $g_8$ | [21.2785,25.0050] |

Firstly, considering the variation on the credibility level, initially being $\lambda = 0.75$, then for the robustness analyses the model was executed for $\lambda = 0.70$ and $\lambda = 0.80$, obtained the results displayed in Table 6.4.

Considering the results obtained for the robustness analyses, where $\lambda = 0.70$ and $\lambda = 0.80$, instead of $\lambda = 0.75$, it is possible to note that there were more changes in the categories assigned to actions when decreasing the value for $\lambda$ (five changes, corresponding to 16.(6)% of the intervals of categories) in comparison with the increase of this discrimination threshold (two changes, corresponding to 6.(6)% of the intervals of categories). Moreover, when decreasing the value for $\lambda$, the assignment of the categories to the actions tends to attribute worst performances, *i.e.*, shortens the interval of categories attributed with the maximum reduced. For instance, the actions whose assignments changed with the decrease of the credibility level were previously assigned to an interval of categories $[C_1, C_2]$ or $[C_1, C_3]$, however, with the variation of the credibility level then they were assigned to an interval of categories $[C_1, C_1]$ or $[C_1, C_2]$, worsening the maximum performances attributed. On the other hand, when increasing the value for $\lambda$, the assignment of the categories to the actions tends to attribute better performances, for instance, the two intervals of categories changed from $[C_1, C_2]$ and $[C_2, C_2]$ to $[C_1, C_3]$ and $[C_2, C_3]$.

Table 6.4: Robustness analyses for the credibility level, $\lambda$.

| Actions | $\lambda = 0.70$ | | $\lambda = 0.75$ | | $\lambda = 0.80$ | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum |
| $a_1$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_2$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_3$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_4$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_5$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_6$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_7$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_8$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_9$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_3$ |
| $a_{10}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_3$ |
| $a_{11}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{12}$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_{13}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{14}$ | $C_1$ | $C_1$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{15}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{16}$ | $C_1$ | $C_1$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{17}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{18}$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ |
| $a_{19}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{20}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{21}$ | $C_1$ | $C_2$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ |
| $a_{22}$ | $C_1$ | $C_1$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ |
| $a_{23}$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ |
| $a_{24}$ | $C_1$ | $C_1$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{25}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{26}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{27}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{28}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{29}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{30}$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |

Table 6.5: Exploitation of the robustness analyses for the credibility level, $\lambda$.

| Categories or interval of categories | Percentage of actions for $\lambda = 0.70$ | Percentage of actions for $\lambda = 0.75$ | Percentage of actions for $\lambda = 0.80$ |
|---|---|---|---|
| $[C_1, C_1]$ | 16.(6) % | 3.(3) % | 3.(3) % |
| $[C_1, C_2]$ | 26.(6) % | 33.(3) % | 33.(3) % |
| $[C_1, C_3]$ | 0.0 (%) | 6.(6) % | 10.0 % |
| $[C_2, C_2]$ | 26.(6) % | 30.0 % | 23.(3) % |
| $[C_2, C_3]$ | 6.(6) % | 3.(3) % | 3.(3) % |
| $[C_2, C_4]$ | 3.(3) % | 3.(3) % | 3.(3) % |
| $[C_3, C_3]$ | 13.(3) % | 13.(3) % | 16.(6) % |
| $[C_3, C_4]$ | 6.(6) % | 6.(6) % | 6.(6) % |

Secondly, some scenarios were considered regarding variations on the criteria weights, through changing the number of blank cards or the ratio-z in the DCM-SRF procedure (building new projects in the *DecSpace* platform). For these robustness analyses, four scenarios were considered: “no blank cards added”, “more blank cards added”, “ratio-z equal to 2”, and “ratio-z equal to 4”.

In the “no blank cards added” scenario, no blank cards were placed between the hierarchized levels considered for the actions, as in Table 6.6.

Table 6.6: Ranking established in the scenario “no blank cards added”.

| Ranking | Cards |
|---|---|
| Rank 1 | $g_8$ |
| Blank cards | 0 |
| Rank 2 | $g_1, g_2, g_4$ |
| Blank cards | 0 |
| Rank 3 | $g_3, g_5, g_6, g_7$ |
| Ratio-z | 3 |

In the “more blank cards added” scenario, one more blank card was added to the original ranking, so between Rank 1 and Rank 2 four blank cards were then placed, and between Rank 2 and Rank 3 three blank cards were put, as in Table 6.7.

Table 6.7: Ranking established in the scenario “more blank cards added”.

| Ranking | Cards |
|---|---|
| Rank 1 | $g_8$ |
| Blank cards | 4 |
| Rank 2 | $g_1, g_2, g_4$ |
| Blank cards | 3 |
| Rank 3 | $g_3, g_5, g_6, g_7$ |
| Ratio-z | 3 |

In the “ratio-z equal to 2” scenario, ratio-$z = 2$, and then for the “ratio-z equal to 4” scenario, the ratio-$z = 4$.

The scenarios “no blank cards added” and “more blank cards added” led to slight changes in the weights of the criteria, as verified in Table 6.8.

Table 6.8: Normalized weight of each criterion, calculated through the DCM-SRF procedure, for the scenarios “no blank cards added” and “more blank cards added”.

| Criteria | Weights in the original setting | Weights in the scenario “no blank cards added” | Weights in the scenario “more blank cards added” |
|---|---|---|---|
| $g_1$ | 14.78 | 15.38 | 14.92 |
| $g_2$ | 14.79 | 15.39 | 14.92 |
| $g_3$ | 7.95 | 7.69 | 7.89 |
| $g_4$ | 14.79 | 15.39 | 14.92 |
| $g_5$ | 7.95 | 7.69 | 7.89 |
| $g_6$ | 7.95 | 7.69 | 7.89 |
| $g_7$ | 7.95 | 7.69 | 7.89 |
| $g_8$ | 23.84 | 23.08 | 23.68 |
| Total | 100.00 | 100.00 | 100.00 |

In both scenarios ratio-$z = 2$ and ratio-$z = 4$, the criteria weights changed, where the first resulted in a decrease of the difference in criteria weights and for the second the discrepancy of the criteria weights incremented as one can see in Table 6.9, in comparison with the original configuration (ratio-$z = 3$).

Table 6.9: Normalized weight of each criterion, calculated through the DCM-SRF procedure, for the scenarios ratio-$z = 2$ and ratio-$z = 4$.

| Criteria | Weights in the original setting (ratio-$z = 3$) | Weights in the scenario ratio-$z = 2$ | Weights in the scenario ratio-$z = 4$ |
|---|---|---|---|
| $g_1$ | 14.78 | 13.89 | 15.4 |
| $g_2$ | 14.79 | 13.9 | 15.41 |
| $g_3$ | 7.95 | 9.72 | 6.72 |
| $g_4$ | 14.79 | 13.9 | 15.41 |
| $g_5$ | 7.95 | 9.72 | 6.72 |
| $g_6$ | 7.95 | 9.72 | 6.72 |
| $g_7$ | 7.95 | 9.72 | 6.72 |
| $g_8$ | 23.84 | 19.43 | 26.9 |
| Total | 100.00 | 100.00 | 100.00 |

The results obtained in *MCDA-ULaval* software modifying the weights of the criteria for the robustness analyses on the scenarios “no blank cards added” (Figure 6.5) and “more blank cards added” (Figure 6.6), are the same as the results of Tables 6.1 and 6.2, with the same category interval assignments to the actions (in fact, there were no changes at all).

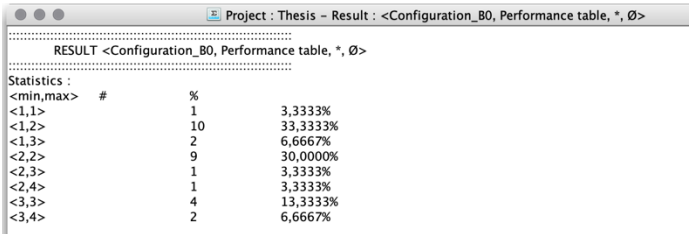


Figure 6.5: Assignment results for the robustness analysis in *MCDA-ULAVAL* software, considering the scenario “no blank cards added”.

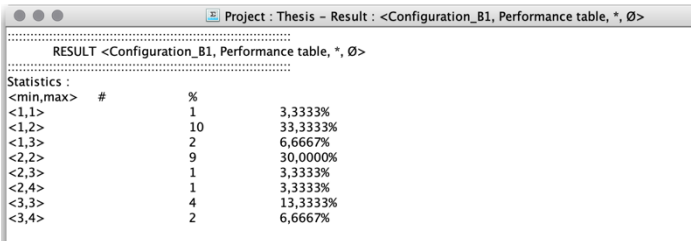


Figure 6.6: Assignment results for the robustness analysis in *MCDA-ULAVAL* software, considering the scenario “more blank cards added”.

The results obtained in *MCDA-ULaval* software modifying the weights of the criteria for the robustness analyses on the scenarios related with the variation on the ratio-z differ in some category interval assignments in comparison with Table 6.1, as one can see in Table 6.10 (where the grey cells highlight different assignments).

Table 6.10: Robustness analyses for the scenarios ratio-$z = 2$ and ratio-$z = 4$, in comparison with the original configuration (ratio-$z = 3$).

| Actions | Scenario ratio-$z = 2$ | | Original configuration (ratio-$z = 3$) | | Scenario ratio-$z = 4$ | |
|---|---|---|---|---|---|---|
| | Minimum Category | Maximum Category | Minimum Category | Maximum Category | Minimum Category | Maximum Category |
| $a_1$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_2$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_3$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_4$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_5$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_6$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_7$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_8$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_9$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{10}$ | $C_1$ | $C_3$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{11}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{12}$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_{13}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{14}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_1$ |
| $a_{15}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{16}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{17}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{18}$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ |
| $a_{19}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{20}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{21}$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ |
| $a_{22}$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ |
| $a_{23}$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ |
| $a_{24}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{25}$ | $C_2$ | $C_3$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{26}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{27}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{28}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{29}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{30}$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |

Table 6.11: Exploitation of the robustness analyses for the scenarios related with the variation of the ratio-z.

| Categories or interval of categories | Percentage of actions for the scenario ratio-$z = 2$ | Percentage of actions for the original configuration (ratio-$z = 3$) | Percentage of actions for the scenario ratio-$z = 4$ |
|---|---|---|---|
| $[C_1, C_1]$ | 6.(6) % | 3.(3) % | 6.(6) % |
| $[C_1, C_2]$ | 30.0 % | 33.(3) % | 33.(3) % |
| $[C_1, C_3]$ | 10.0 % | 6.(6) % | 6.(6)% |
| $[C_2, C_2]$ | 23.(3) % | 30.0 % | 26.(6) % |
| $[C_2, C_3]$ | 6.(6) % | 3.(3) % | 3.(3) % |
| $[C_2, C_4]$ | 3.(3) % | 3.(3) % | 3.(3) % |
| $[C_3, C_3]$ | 13.(3) % | 13.(3) % | 13.(3) % |
| $[C_3, C_4]$ | 6.(6) % | 6.(6) % | 6.(6) % |

As observed in Tables 6.10 and 6.11, it is possible to note that the assignment results slightly changed for these two scenarios, where there were two alterations in the category interval assignments for both scenarios ratio-$z = 2$ and ratio-$z = 4$, highlighted in grey colour in Table 6.10. The aforementioned changes were almost all for the maximum category assigned to the actions, leading to slight changes in the percentage of actions in each interval of categories, worsening the situation where the number of actions assigned to the single category $C_1$ was twice as in the original configuration (6.(6)% instead of 3.(3)%). Moreover, it is possible to note that there were no changes in the results of the assignments for the intervals of categories above $[C_2, C_3]$.

Table 6.12: Changes in the assignment results obtained for all the single scenarios considered in the robustness analyses.

| Scenarios | $\lambda = 0.7$ | $\lambda = 0.8$ | "no blank cards added" | "more blank cards added" | ratio-$z = 2$ | ratio-$z = 4$ |
|---|---|---|---|---|---|---|
| **Percentage of changes** | 16.(6)% | 6.(6)% | 0.0% | 0.0% | 6.(6)% | 6.(6)% |

To summarize, there were more changes, in spite of being few, when decreasing the credibility level or changing the value for the ratio-z, in comparison with the other scenarios. In fact, the scenarios related to the blank cards of the DCM-SRF procedure did not suffer any variations in the assignments obtained.

Here were already analyzed the following scenarios (where the credibility level did not change and afterwards the value for the ratio-z did not change):

- $\lambda = 0.75$ and ratio-$z = 3$ (original configuration)
- $\lambda = 0.75$ and ratio-$z = 2$ (maintaining the credibility level)
- $\lambda = 0.75$ and ratio-$z = 4$ (maintaining the credibility level)
- $\lambda = 0.70$ and ratio-$z = 3$ (maintaining the value for the ratio-z)
- $\lambda = 0.80$ and ratio-$z = 3$ (maintaining the value for the ratio-z)

There, further robustness analyses were conducted, creating new scenarios. Now considering a variation of the credibility level simultaneously with a variation of the value for the ratio-z:

- $\lambda = 0.70$ and ratio-$z = 2$
- $\lambda = 0.70$ and ratio-$z = 3$
- $\lambda = 0.70$ and ratio-$z = 4$
- $\lambda = 0.80$ and ratio-$z = 2$
- $\lambda = 0.80$ and ratio-$z = 3$
- $\lambda = 0.80$ and ratio-$z = 4$

Table 6.13: Robustness analyses for the scenarios considering a variation of the credibility level ($\lambda = 0.70$ instead of $\lambda = 0.75$) simultaneously with a variation of the value for the ratio-z in comparison with the original configuration.

| Actions | Original configuration ($\lambda = 0.75$ and and ratio-$z = 3$) | | Scenario "$\lambda = 0.70$ and ratio-$z = 2$" | | Scenario "$\lambda = 0.70$ and ratio-$z = 3$" | | Scenario "$\lambda = 0.70$ and ratio-$z = 4$" | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum |
| $a_1$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_2$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_3$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_4$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_5$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_6$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_7$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_8$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_9$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{10}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{11}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{12}$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_{13}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{14}$ | $C_1$ | $C_2$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |
| $a_{15}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{16}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |
| $a_{17}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{18}$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ |
| $a_{19}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{20}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{21}$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_2$ | $C_1$ | $C_3$ |
| $a_{22}$ | $C_1$ | $C_3$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_3$ |
| $a_{23}$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ |
| $a_{24}$ | $C_1$ | $C_2$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_2$ |
| $a_{25}$ | $C_2$ | $C_2$ | $C_2$ | $C_3$ | $C_2$ | $C_2$ | $C_2$ | $C_3$ |
| $a_{26}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_1$ |
| $a_{27}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{28}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_1$ |
| $a_{29}$ | $C_2$ | $C_2$ | $C_1$ | $C_1$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{30}$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |

Table 6.14: Exploitation of the robustness analyses for the scenarios related with the variation of credibility level ($\lambda = 0.70$ instead of $\lambda = 0.75$) simultaneously with the variation of the value for the ratio-z.

| Categories or interval of categories | Percentage of actions for the original configuration (ratio-$z = 3$) | Percentage of actions for the scenario "$\lambda = 0.70$ and ratio-$z = 2$" | Percentage of actions for the scenario ""$\lambda = 0.70$ and ratio-$z = 3$" | Percentage of actions for the scenario ""$\lambda = 0.70$ and ratio-$z = 4$" |
|---|---|---|---|---|
| $[C_1, C_1]$ | 3.(3) % | 16.(6) % | 16.(6) % | 16.(6) % |
| $[C_1, C_2]$ | 33.(3) % | 26.(6) % | 26.(6) % | 20.0 % |
| $[C_1, C_3]$ | 6.(6) % | 3.(3) % | 0.0 (%) | 6.(6) % |
| $[C_2, C_2]$ | 30.0 % | 23.(3) % | 26.(6) % | 26.(6) % |
| $[C_2, C_3]$ | 3.(3) % | 6.(6) % | 6.(6) % | 6.(6) % |
| $[C_2, C_4]$ | 3.(3) % | 3.(3) % | 3.(3) % | 3.(3) % |
| $[C_3, C_3]$ | 13.(3) % | 13.(3) % | 13.(3) % | 13.(3) % |
| $[C_3, C_4]$ | 6.(6) % | 6.(6) % | 6.(6) % | 6.(6) % |

The results for the scenarios with the simultaneous variation of the credibility level and the value for the ratio-z were obtained and presented as one can see from Tables 6.13 to 6.16. It is possible to note that the assignment results changed relatively more for these four scenarios, when comparing with the previous ones with non-simultaneous variations.

Then, for these new combined variations scenarios, there were five alterations for the scenarios "$\lambda = 0.70$ and ratio-$z = 2$" and "$\lambda = 0.70$ and ratio-$z = 3$", four alterations in the category interval assignments for the scenarios "$\lambda = 0.70$ and ratio-$z = 4$", "$\lambda = 0.80$ and ratio-$z = 2$" and "$\lambda = 0.80$ and ratio-$z = 4$", and two alterations for the scenario "$\lambda = 0.80$ and ratio-$z = 3$", highlighted in grey colour in Tables 6.13 and 6.15.

For the scenarios where "$\lambda = 0.70$", simultaneous changes in the parameters (credibility level and ratio-z) led to worse modifications in the percentage of actions in each interval of categories, situation where the number of actions assigned to the single category $C_1$ was five times as in the original configuration (16.(6)% instead of 3.(3)%). For the scenarios where "$\lambda = 0.80$", the number of actions with average performance (assigned to the single category $C_3$) is higher than the original configuration (16.(6)% instead of 13.(3)%), so more actions equal or above average, as there were no changes for the intervals $[C_2, C_4]$ and $[C_3, C_4]$, where $C_4$ is the maximum category.

Table 6.15: Robustness analyses for the scenarios considering a variation of the credibility level ($\lambda = 0.80$ instead of $\lambda = 0.75$) simultaneously with a variation of the value for the ratio-z in comparison with the original configuration.

| Actions | Original configuration ($\lambda = 0.75$ and and ratio-$z = 3$) | | Scenario "$\lambda = 0.80$ and ratio-$z = 2$" | | Scenario "$\lambda = 0.80$ and ratio-$z = 3$" | | Scenario "$\lambda = 0.80$ and ratio-$z = 4$" | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum |
| $a_1$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_2$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_3$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_4$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_5$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_6$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_7$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_8$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ | $C_3$ |
| $a_9$ | $C_2$ | $C_2$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ | $C_2$ | $C_3$ |
| $a_{10}$ | $C_1$ | $C_2$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ |
| $a_{11}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{12}$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ | $C_3$ | $C_4$ |
| $a_{13}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{14}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{15}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{16}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{17}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{18}$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ | $C_2$ | $C_4$ |
| $a_{19}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{20}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{21}$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ |
| $a_{22}$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ | $C_1$ | $C_3$ |
| $a_{23}$ | $C_2$ | $C_3$ | $C_3$ | $C_3$ | $C_2$ | $C_3$ | $C_3$ | $C_3$ |
| $a_{24}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{25}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{26}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{27}$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{28}$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ | $C_1$ | $C_2$ |
| $a_{29}$ | $C_2$ | $C_2$ | $C_1$ | $C_1$ | $C_2$ | $C_2$ | $C_2$ | $C_2$ |
| $a_{30}$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |

Table 6.16: Exploitation of the robustness analyses for the scenarios related with the variation of credibility level ($\lambda = 0.80$ instead of $\lambda = 0.75$) simultaneously with the variation of the value for the ratio-z.

| Categories or interval of categories | Percentage of actions for the original configuration (ratio-$z = 3$) | Percentage of actions for the scenario "$\lambda = 0.80$ and ratio-$z = 2$" | Percentage of actions for the scenario "$\lambda = 0.80$ and ratio-$z = 3$" | Percentage of actions for the scenario "$\lambda = 0.80$ and ratio-$z = 4$" |
|---|---|---|---|---|
| $[C_1, C_1]$ | 3.(3) % | 6.(6) % | 3.(3) % | 3.(3) % |
| $[C_1, C_2]$ | 33.(3) % | 30.0 % | 33.(3) % | 33.(3) % |
| $[C_1, C_3]$ | 6.(6) % | 10.0 % | 10.0 % | 10.0 % |
| $[C_2, C_2]$ | 30.0 % | 23.(3) % | 23.(3) % | 23.(3) % |
| $[C_2, C_3]$ | 3.(3) % | 3.(3) % | 3.(3) % | 3.(3) % |
| $[C_2, C_4]$ | 3.(3) % | 3.(3) % | 3.(3) % | 3.(3) % |
| $[C_3, C_3]$ | 13.(3) % | 16.(6) % | 16.(6) % | 16.(6) % |
| $[C_3, C_4]$ | 6.(6) % | 6.(6) % | 6.(6) % | 6.(6) % |

Table 6.17: Changes in the assignment results obtained for the combined scenarios considered in the robustness analyses.

| Scenarios | "$\lambda = 0.70$ and ratio-$z = 2$" | "$\lambda = 0.70$ and ratio-$z = 3$" | "$\lambda = 0.70$ and ratio-$z = 4$" | "$\lambda = 0.80$ and ratio-$z = 2$" | "$\lambda = 0.80$ and ratio-$z = 3$" | "$\lambda = 0.80$ and ratio-$z = 4$" |
|---|---|---|---|---|---|---|
| Percentage of changes | 16.(6) % | 16.(6) % | 13.(3) % | 13.(3) % | 6.(6) % | 13.(3) % |

Then, the model run is considered stable and robust, considering the stability and the robustness analyses carried out, as there were none or just a few differences in the results obtained when changing the credibility level and/or when changing the weights of the criteria (by modifying the number of blank cards considered in the SRF procedure or the value for the ratio-z, in all the scenarios considered).

## 6.3. Summary

Being defined all the model inputs, then it was executed in *MCDA-ULaval* software and the results analyzed. In the assignment procedure, no actions were assigned to the best category $C_5$ (very good performance) what led to the conclusion that there was no under assessment of the reference action characterizing that category. Furthermore, many actions were assigned to the worst category $C_1$ (very

poor performance), which meant the lack of performance in terms of quality and access in provisioning health care of the assessed Portuguese health care providers according to the model here constructed.

Then, a stability analysis was carried out and further analyses were conducted to test the robustness of the model. Those analyses were focused on changes of the credibility level and the criteria weights, (by changing the number of blank cards or changing the value of the ratio-z, in the SRF procedure), simultaneously and non-simultaneously, creating scenarios and analyzing them. Thus, considering the new results obtained for the assignment procedure, it was possible to note that the established model is stable and robust, in fact with none or just a few changes (in the maximum case, *i.e.,* for the scenarios "$\lambda = 0.70$ and ratio-$z = 2$" and "$\lambda = 0.70$ and ratio-$z = 3$", the change from the original results to the new ones was 16.(6) %) in the category interval assignment results.

# 7. Conclusions and research prospects

## 7.1. Achievements

Quality and access to health care provisioning are of extreme relevancy. The Portuguese public health care expenditure has been declining in the past few years, which implies some issues in the public funding of the SNS. This reduces its capability to provide the best care to its users. In order to decrease expenditure with the health system, cost containment has been established to reduce it, compromising the quality of the health care services provided. The progressive aging of the Portuguese population as well as the emergence of more chronic diseases and innovative technological procedures leading to more health gains tend to increase costs, however, if they are contained, so the quality and access may be threatened. Those restrictions may generate barriers to the access of health care provisioning and may compromise infrastructures or equipment which also reduces the quality of care delivered. Thus, to assess the access and the quality of the Portuguese health care providers, mainly focusing on the public ones, detailed analyses needed to be carried out, being the focus of this dissertation as it was aforementioned.

In order to assess Portuguese public hospitals and then to succeed in the main goal of this dissertation, then initially the state of the health care sector was contextualized and how the main parameters are linked and involved with each other. This step was carried out and extremely relevant, due to the fact that a characterization of the health sector in Portugal throughout the past decades and the actual phase of the health care provisioning by SNS, from services delivered to management or even expenditure and financing issues, which keeps possible to analyze the way SNS works and focus on its objectives.

Afterwards, “quality” in health care was defined for services delivered to the Portuguese population when needed. Through a literature review, it allowed us to define the multidimensional characterization of “quality”, being defined by its accessibility, effectiveness, efficiency, equity, person-centeredness and safety. Moreover, it was studied how quality could be taken into account to assess the Portuguese health care providers through its quality evaluation and how it may be measured, considering indicators to be undertaken when evaluating health care procedures, services and outcomes, as well as costs.

Quality presents a variety of dimensions, which implied an MCDA approach, taking some comprehensive learnings in the MCDA methods, especially the ELECTRE family. The applied method was the ELECTRE TRI-nC in order to build a model in interaction with the DM for assessing the overall quality and access of the Portuguese public hospitals. The source of the data set is reliable as this is from the ACSS benchmarking. Thus, being updated the data set used, following the correct guidelines and including indicators, being already taking into account the literature review studies. The hospitals and hospital centers (actions) selected presented the same technologies and technological procedures

in order to avoid a biased assessment. To build the model, as aforementioned, the ELECTRE TRI-nC was applied, as it is a model with a non-systematic compensatory character (able to be applied to health care decisions and evaluations where positive performances in a certain criterion cannot compensate weaker performances in other ones, especially when considering life-threatening issues) and ordinal classification capability to analyze. The interaction with the DM allowed establishing the five categories, $C_1$ to $C_5$, from the worst performance to the best one, each one with one or more reference actions (one for $C_1$, for $C_3$ and $C_5$, and two for $C_2$ and $C_4$). The criteria chosen came from the literature review and from the ACSS benchmarking indicators which best evaluate quality in the health care sector. Criteria weighting was carried out through the SRF procedure in the DecSpace platform, supported by an interaction with the DM. Preference parameters as well as the credibility level and veto thresholds were also defined in an interaction with the DM.

Therefore, the model was executed in the *MCDA-ULaval* software and the assignment results were obtained, so the actions were assigned to a category interval (a single category, where the minimum and the maximum were the same, or an interval of categories, where the minimum and the maximum did not match). Analyzing the assignments, it was possible to note that the best category $C_5$ had not any action assigned to it. Furthermore, many actions were assigned to the worst category in a single way (this meant, the actions were classified as $[C_1, C_1]$ being $C_1$ (very poor performance) the minimum and maximum category attributed to them, which led to the logical infer, according to our model, that the quality of the Portuguese public hospitals was really low, analyzed for the year of 2019, besides the fact that many actions were consecutively assigned to the second-worst category $C_2$ (poor performance). In an example to prove the lack of quality in the health care providers in Portugal (at least the ones assessed), 18 were assigned to categories weaker than $C_3$ (below an average performance), *i.e.,* assigned to category intervals $[C_1, C_1]$, $[C_1, C_2]$ or $[C_2, C_2]$. An overall analysis of the results obtained led to note that the minimum category to which the actions were assigned to was $C_1$ (very poor performance) and the maximum was an interval of categories $[C_3, C_4]$, between an average and a good performance, which meant some weakness in the performance of the Portuguese health care providers considered in the case study for the standards defined in this dissertation. The action $a_{30}$ (Lisboa Central Hospital Center, EPE) was assigned to the category $C_1$ which is considerable worrisome as this is one of the main health care providers in Portugal. Two of the thirty actions were assigned to the interval of categories $[C_3, C_4]$, $a_3$ (Póvoa do Varzim/Vila do Conde Hospital Center, EPE) and $a_{12}$ (Baixo Vouga Hospital Center, EPE) meaning that those two health care providers had the best performance in the analysis done when considering the reference actions associated to the defined categories. Moreover, it was verified that 13 actions, 43.(3)% of the actions considered, were assigned to $C_1$ (very poor performance) as the minimum category to which they belong, only 3 actions, 9.(9)% of the actions considered, were assigned to $C_4$ (good performance) as the maximum category to which they belong and no actions were assigned to the category $C_5$ (very good performance).

Consecutively, the model was tested in its stability and robustness in order to understand if it was producing reliable results. The analyzes included changes in the credibility level and the weights of the criteria, creating scenarios (by changing the number of blank cards in the SRF procedure through the

DecSpace platform as well as by changing the value for the ratio-z there). The maximum alteration of the assignment results in the robustness analyses was 16.(6)% (for the scenarios "$\lambda = 0.70$ and ratio-$z = 2$" and "$\lambda = 0.70$ and ratio-$z = 3$") which is a low value, concluding that the model is considered robust.

Every goal considered initially for this dissertation was successfully carried out, within the application of an MCDA approach, through the DCM-SRF procedure and then ELECTRE TRI-nC method, so the quality of Portuguese public hospitals was then assessed, being built a model for this purpose, validated by stability and robustness analyzes which successfully tested its reliability and then validating this developed dissertation.

## 7.2. Limitations

The models are built to reproduce situations that are real but in a virtual way. So if reality is not perfect, the models neither, with subjacent limitations sometimes relevant. In the case study of this dissertation, the data set from ACSS benchmarking included reliable indicators of clinical quality. In spite of presenting many quality indicators, the ACSS benchmarking is not so vast and complete, since there are many more indicators to assess health care providers, according to the literature review. Then, to strengthen the model built and the robustness of the criteria chosen, it would require more data to be gathered and handled. For instance, outcomes from user's satisfaction, which is considerably difficult to acquire, is of extreme relevance for an MCDA approach in this sector, as well as information focused on the infrastructures used in the health care procedures.

The assignment results obtained through the execution of the model depend on the criteria weights and on the method and criterion parameters established, which is defined in an interaction between the DM and the analyst. Since just one DM supported those steps of the model construction, it was restricted to a few attributions and one perspective regarding weights and thresholds. With more than one DM, it would allow to compare categories, thresholds and weights and therefore build a different model, adapted by other opinions and new scenarios would be considered. Moreover, another restriction of this model was not including subcriteria for each criterion, which could introduce some diversity and could turn this analysis more complete.

## 7.3. Research prospects

As aforementioned in Chapter 2, Portugal is one of the European countries with more investment in the health care sector, where the expenditure is high and has been increasing throughout the past years. However, hospital equipment has not been updated and then becoming obsolete. The private health care providers are conquering space, hiring workforce from the SNS, taking advantage of their weaknesses.

Surely, the MCDA approach carried out here in this dissertation, assessing Portuguese public hospitals seems to be an adequate tool to be used in the future. The SNS needs to be reformulated and is required to get more investment in, where quality has been threatened. So, changes in the SNS should assure the provisioning for the needs of the patients to guarantee the quality of the services delivered, making the workforce and health care providers more capable. The results obtained in this dissertation could be a contribution to future research in the health care field. Moreover, new scenarios should be considered to test the robustness of the models built, in spite of the reliability of the model in this dissertation proved to be robust.

The application of the model built may also be done for private hospitals, which would be interesting to be studied, if the data set may be gathered and handled from them to assess those health enterprises and their status within the sector, making comparisons with the public and public-private partnerships.

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