Developing scenario approaches to enhance the planning of health human resources with mathematical programming models

Mariana Garcia Raposo

Thesis to obtain the Master of Science Degree in

Biomedical Engineering

Supervisor(s): Prof. Dr. Mónica Duarte Correia de Oliveira
Prof. Dr. António Manuel Alvarenga Rodrigues

Examination Committee

Chairperson: Prof. Dr. João Pedro Estrela Rodrigues Conde
Supervisor: Prof. Dr. Mónica Duarte Correia de Oliveira
Members of the Committee: Prof. Dr. Ana Catarina Lopes Vieira Godinho de Matos

November 2017

“If a man knows not to which port he sails,

no wind is favorable.”

– Seneca

Acknowledgments

To Professor Mónica Oliveira and Professor António Alvarenga, thank you for your guidance and knowledge, and for presenting me to Dr. Marco Alves and Dr. Mário Amorim Lopes, who were also fundamental for my work.

To all the experts that had the time and interest to answer my questionnaire, thank you. Literally, nothing could have been done without you.

To all the amazing people I met in this 5-year journey, the opportunities I got and everything I learned. I would never have gotten to where I am today were it not for our group projects, late nights and fun times. Thank you for cheering me up and making me believe.

To Diogo, the most focused person I know, for making my days brighter and transmitting to me the serenity and motivation I needed.

To my parents, for their patience and unconditional support. I am eternally grateful for all the opportunities you gave me.

Because this master thesis could not have been done by myself, thank you all.

Abstract

Even in this increasingly technological era, health workforce is the most crucial resource of any healthcare system. Indeed, the existence of a match between supply and demand of health human resources (HHR) should be a priority in healthcare planning. Mathematical programming models are often used in HHR planning, although they are usually extremely sensitive to alterations in the input parameters.

This thesis proposes a new methodology for building scenarios to enhance the planning of HHR with optimization models in two different ways: first, by making experts to explicit their assumptions about the future; second, by contributing to the uncertainty analysis of the models and thus increasing the robustness in decision-making. It innovates both on the combination of different methods of foresight and on the transparency of the process of scenario building, which includes the following main steps: gathering of drivers through a web platform; building of cognitive maps to cluster the drivers into key variables; use of morphological analysis to create the scenarios; workshop with experts to quantify the input parameters from the model.

The methodology was designed to provide inputs to a model developed within the *HHRPLAN project*, which aims to plan the vacancies to open/close in the medical course and specializations for the next 30 years. This application resulted in four contrasted scenarios: "A Sick System", "Healthy Country", "Population One Technology Zero" and "New Technology Meets Old Habits". The model will be run under these scenarios and its results will be discussed to better plan HHR in Portugal.

Keywords: Foresight, Scenario Methods, Health Human Resources, Health Workforce, Uncertainty Modeling, Mathematical Programming Models

Resumo

Mesmo num mundo cada vez mais tecnológico, os recursos humanos para a saúde (HHR) são o bem mais importante de qualquer sistema de saúde. A existência de um equilíbrio entre a oferta e procura de HHR deve ser uma prioridade para o planeamento em saúde. Modelos de programação matemática são muitas vezes usados no planeamento de HHR, mesmo sendo extremamente sensíveis a alterações nos *inputs*.

A presente dissertação propõe uma nova metodologia para construir cenários e melhorar o planeamento de HHR através de modelos de otimização por duas vias: (1) *obriga* os peritos a explicitar as suas suposições sobre o futuro e (2) contribui para a análise da incerteza do modelo, aumentando a robustez da tomada de decisão. O processo de construção de cenários inclui principalmente as seguintes fases: recolha de *drivers* através de uma plataforma online; construção de mapas cognitivos para agrupar estes fatores em variáveis-chave; uso de análise morfológica para criar os cenários; workshop com peritos para quantificar os *inputs* do modelo.

A metodologia foi projetada para fornecer *inputs* a um modelo desenvolvido pelo projeto HHRPLAN, que tem como objetivo planear as vagas a abrir/fechar para o Mestrado Integrado em Medicina e para as especialidades médicas nos próximos 30 anos. Esta aplicação resultou em quatro cenários: "Um Sistema Doente", "Um País Saudável", "População Um Tecnologia Zero" e "Nova Tecnologia Encontra Hábitos Antigos". O modelo será testado para estes cenários e os seus resultados serão discutidos para permitir um melhor planeamento de HHR em Portugal.

Palavras-chave: Prospetiva, Métodos de Cenários, Recursos Humanos em Saúde, Modelação da Incerteza, Modelos de Programação Matemática

Table of Contents

List of Figures

List of Tables

List of Acronyms

ACSS	Administração Central do Sistema de Saúde Central Administration of the Health System
CfWI	Centre for Workforce Intelligence
CIA	Cross Impact Analysis
FIL	Future In Logic
HC	Home Care
HHR	Health Human Resources
HHRPLAN	Health Human Resources Planning
LP	Linear Programming
LTC	Long-Term Care
MD	Medicine Degree
MILP	Mixed Integer Linear Programming
NCD	Non-Communicable Diseases
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
PMT	Probabilistic Modified Trends
STEEP	Social, Technological, Economic, Environmental and Political
TEEPSE	Technological, Economic, Environmental, Political, Social and Ethical
TIA	Trend Impact Analysis

Chapter 1

Introduction

1.1. Motivation

There are several drivers that make planning in healthcare truly important nowadays (Rais & Viana 2011). To start with, there is a high uncertainty in the demand for healthcare and the consequences of a possible shortage may be disastrous, reason why some oversupply may be required (Almeida & Cima 2015). In fact, one shall not forget the social and ethical responsibilities inherent to the health sector. Moreover, external forces such as the healthcare system (including the reimbursement type and incentives, between others) and industry forces (such as competition), have a big impact on the healthcare industry as we know it today, asking for increased survival and profitability rates, together with a good control of the operations and efficient delivery of services (Rhyne & Jupp 1988), increasing the need for a good planning.

Optimization problems related to healthcare have been developed for more than three decades to support planning (Rais & Viana 2011). However, the relevance and importance of planning and control in this field has increased over the last years, both in practice and in the literature (Hans et al. 2012). This phenomenon may be explained by the current age distribution of the developed countries, derived from decreasing rate births and an increasing longevity (Rais & Viana 2011). Current research related to healthcare optimization focus on several healthcare dimensions, such as service planning, resource scheduling, logistics, medical therapeutics, disease diagnosis and preventive care (Rais & Viana 2011). Given the characteristic uncertainty of this sector, these models must account for uncertainty, as it will highly influence their results.

Health Human Resources Planning

Health human resources (HHR) may be defined as the workers involved in the delivery of care, including physicians, nurses, clinical assistants and other administrative staff (Lopes et al. 2016). The healthcare sector is labor-intensive and human resources are the most important input for the delivery of healthcare (Bloor et al. 2003), corresponding to the largest proportion of healthcare expenditure (Bloor & Maynard 2003). In other words, the quantity and quality of the healthcare is strictly related to the quantity and quality of the existing human resources (Malgieri et al. 2015). Therefore, being able to foresee the necessary amount of health professionals at some point in the future is both an ethical and economic goal (Malgieri et al. 2015).

The HHR planning has its specificities when comparing to planning within other industries, not only due to the possibly catastrophic consequences of failure but also because of the time it takes to train qualified staff (Malgieri et al. 2015). In fact, the time and effort required to train health human resources is, in general, higher than in most professions (Lopes et al. 2015). Particularly for Portugal, the training of physicians consists on a six-years masters degree, followed by an exam to access the medical specialization and finally the medical specialization, which may last between four and six years (Saúde 2012). Furthermore, the HHR market cannot be considered a free market for several reasons, such as the public sector regulation and all the existing licensing and professional regulations (Bloor & Maynard 2003). It is indeed a rigid market, preventing self-adjustment (Lopes 2017). Thus, other mechanisms have to be used in order to match supply and demand and create an equilibrium (Bloor & Maynard 2003).

Regarding the healthcare market, one should always consider both sides – the suppliers of health services and the patients demanding for their services – in order to assess if the existing workforce is enough in quantity and skills to meet the current and future demand (Lopes et al. 2015). Effective workforce planning can de defined as achieving "a proper balance between the supply and demand for different categories of health workers, in both the short and longer-term" (Ono et al. 2013). This is, in fact, equivalent to ensure that the right people, with the right skills, are in the right places at the right time, to provide the right services to the right people. This certainly is a difficult task, and both under and oversupply have their disadvantages, summarized in Table 1.1. On the one hand, a shortage of health professionals may compromise patient safety and cause avoidable deaths, by leading to a lower quantity and quality of medical care, work overload for the available clinicians and increase of the waiting lists (Lopes et al. 2015; Roberfroid et al. 2009). On the other hand, a surplus may cause economic inefficiencies and misallocated resources (Roberfroid et al. 2009), along with inflated costs through supplier-induced demand (Lopes et al. 2015; Léonard et al. 2009).

Table 1.1: Summary of the possible consequences of under and oversupply in healthcare (based on: Roberfroid et al. 2009; Lopes 2017).

Undersupply (shortage)	Oversupply (surplus)
• Lower quantity and quality of medical care and pressures for shorter visits; • Work overload leading to overworked HHR, with stress-induced dissatisfaction and sleep-deprivation, which may ultimately compromise patient safety; • Underservicing and inability to meet population needs; • Unacceptable long queues and waiting lists, leading to consumers' dissatisfaction with the access and potentially causing avoidable patient deaths; • Unfilled public positions; employment of temporarily resident doctors to fill unmet needs; substitution of services by alternative providers.	• Underemployment and wasted resources; • Inefficiencies and misallocated resources under the guise of unemployment; • Downward pressure on HHR incomes; • Insufficient work and/or variety of work to maintain specialized skills; • Increase in emigration; • Increasing costs due to supply-induced demand.

The uncertainties that increase the complexity of HHR planning – illustrated in Figure 1.1 – exist both in the supply and demand sides (Ono et al. 2013). Indeed, Carello & Lanzarone stressed that there is an inherent uncertainty in numerous healthcare optimization problems which should not be neglected, since it may influence significantly the quality and feasibility of the problem solution (Carello & Lanzarone 2014).

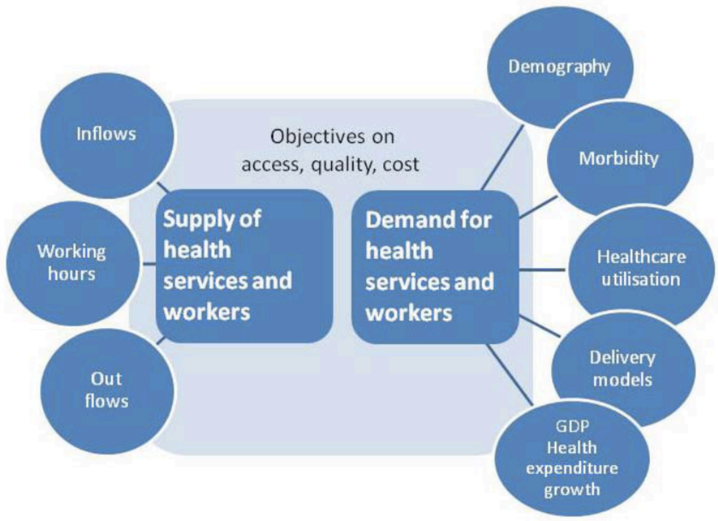


Figure 1.1: Factors that affect the current and future supply and demand of HHR (source: Ono et al. 2013).

1.2. Objectives and Methodology

This thesis aims at developing and applying a foresight methodology to inform the planning of HHR based upon a mathematical programming model. Actually, not only will it contribute to robustness in decision-making, but it will also make experts and decision makers to explicit their assumptions about the future and think about it.

As supported by the literature review (Chapter 2), the uncertainty treatment within mathematical programming models is extremely important. The most common ways to deal with uncertainty in modeling is through sensitivity analysis or stochastic programming. The main limitation of these approaches is that they usually test variations of the input parameters one by one, instead of looking for coherent combinations of them. This change of paradigm can only be reached with literature research together with input from experts, characteristic from scenario methodologies.

The use of scenarios to inform quantitative modeling is the goal of the robust workforce planning framework from the British Centre for Workforce Intelligence (CfWI) (Centre for Workforce Intelligence 2013a; Centre for Workforce Intelligence 2014a). Moreover, Ricci et al. also built qualitative health scenario stories concerning non-communicable diseases in Europe with a similar final goal of contributing to modeling (Ricci et al. 2016). These studies, together with other scenario studies in health and in HHR planning, were reviewed and inspired the new methodological proposal.

1.3. Thesis Outline

This Master Thesis is organized as follows: Chapter 2 includes some basic theoretical concepts, including key notions on mathematical programming models and scenario planning. An analysis of the state of the art on health planning models dealing with uncertainty is also done, along with the review of scenario studies in health. Chapter 3 gives an overview of the proposed methodology and details each step as clearly as possible, unlike what was mostly found in the literature review. A preliminary application of this new methodology is presented in Chapter 4, with the final goal of building scenarios to enhance the planning of health human resources with a specific MILP model. In fact, this application mainly aims to test the methodology and find potential limitations or even get insights on how to improve it in the future. The results from the applied methodology are presented and discussed in Chapter 5, including the results from the morphological analysis and the preliminary scenario narratives. Finally, Chapter 6 outlines the main conclusions of this work and presents possible developments for future work.

Chapter 2

Background Concepts and Literature Review

In this section some basic theoretical concepts will be explained, including key notions on mathematical programming models and scenario planning. The state of the art on health planning models dealing with uncertainty is also analyzed, along with the review of scenario studies in health.

2.1. Planning tools

The specific characteristics of healthcare make planning vital, not only at the operational level but also considering a longer time horizon, trying to prepare for the future. In fact, due to the high complexity of the health systems, there are usually multiple objectives for the same problem. These *problems* are often modeled through simulation or optimization models in order to support planning and better inform decision makers on how to reach the system goals.

Masum et al. (2010) identified five approaches on health foresight: forecasting, scenario planning, Delphi, technology roadmapping, and mass collaboration. In fact, healthcare planning is mostly done through forecasting models and, specifically for HHR planning, there are mostly supply-based and demand-based models. Lopes (2017) reviewed the analytical tools that can be used to conduct the forecasts and aggregated them in three different approaches, including population-based methods, which rely on demographic data, econometric models, looking at trends in aggregates, and operations research methods, including simulation, linear programming, Markov chains and Markov processes.

<u>Mathematical programming models</u>

A mathematical programming model is a tool from Operations Research which always involves optimization, meaning that its objective is to maximize or minimize something: the *objective function* (Williams 2013). This function is composed of a set of *decision variables* and subject to a set of *constraints* (Moreira 2003). Any specification of the decision variables that satisfies all of these constraints is in the *feasible region* and, in turn, any point of this region that optimizes the objective function is an *optimal solution* (Winston 2004). To sum up, the problem can be seen as choosing “the values of the decision variables so as to maximize the objective function, subject to the specified constraints” (Lieberman & Hillier 2010). Figure 2.1 summarizes the general components of these models, based on Lieberman & Hillier (2010) and Winston (2004).

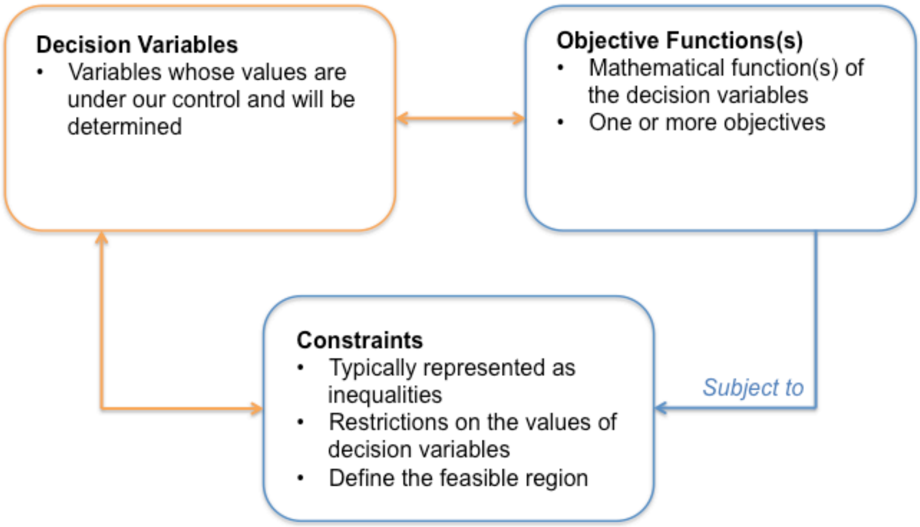


Figure 2.1: General components of mathematical programming models.

If all the mathematical equations appearing in both the objective function(s) and the constraint(s) are linear, then one is facing a linear programming (LP) model, opposing to non-linear programming models (Lieberman & Hillier 2010). A particular class of the LP models are the mixed integer linear programming (MILP) models, where only some of the variables are required to be integer, meaning they include both continuous and integer variables (Winston 2004).

Another possible classification for the mathematical programming models is in deterministic and stochastic models. While the former are based on initial conditions and parameters with no uncertainty associated, the latter are used when some of the data in the model are uncertain and can be specified by a probability distribution (Williams 2013).

When considering deterministic mathematical programming models, one way of addressing the problem of input data uncertainty is through sensitivity analysis. It aims to quantify the effects of changing a parameter value on the optimal objective function value, and thus evaluate reactively the robustness of a solution. A more proactive approach can be achieved by stochastic programming and scenario planning, as they incorporate uncertainty into the models (Owen & Daskin 1998).

2.2. Review of health planning models dealing with uncertainty

Mathematical programming models have widely been used in the health care planning literature, with various specifications (Brailsford & Vissers 2011). These differences appear mostly in the planning purpose, the number and types of services considered in the model, the number and types of objectives pursued and the way they deal, or not, with uncertainty.

This literature review focus on models that account for uncertainty, as it is crucial for an adequate planning in healthcare (Owen & Daskin 1998). For this purpose, Web of Science, Science Direct and Google Scholar[1] were the main databases consulted, and the search was made with different

[1] These databases are available at http://webofknowledge.com, http://www.sciencedirect.com and https://scholar.google.pt, respectively.

combinations of the following keywords: “planning”, “healthcare”, “health”, “care”, “hospital”, “stochastic”, “uncertainty” and “mathematical programming”. Each of the models found is briefly described below, with a greater emphasis on how they deal with uncertainty.

Concerning the organization of hospitals into networks, Mestre et al. (2012) suggested a multiservice hierarchical mathematical programming model for optimizing the location and structure of hospital supply, while maximizing patients' geographical access to hospital services. The model was run under 3 alternative scenarios that corresponded to different policy options. This was done changing some input variables and assumptions for each scenario. After that, recognizing that some parameters are uncertain, sensitivity analysis of key parameters was performed on each scenario to show how robust the model results are.

Abdelaziz & Masmoudi (2012) created a multi-objective stochastic programming model to assign beds to hospital departments, with demand considered uncertain and modeled as a normally distributed random variable. A chance-constrained approach, together with a recourse and a goal programming approaches, were applied in order to obtain a certainty equivalent program to the multi-objective stochastic program.

Regarding models specific to workforce planning, there is a large body of research that develop mathematical programming models to support workforce planning at a strategic level, exploring a wide range of sectors. However, when it comes to healthcare, few studies can be found, and even less if we restrict to the ones that explicitly deal with uncertainty.

The majority of studies found have focused on nurses, with different planning purposes. Carello & Lanzarone (2014) developed a cardinality-constrained robust assignment model for the nurse-to-patient assignment problem in Home Care (HC) services, which considers the uncertainty in patients’ demands by modifying a deterministic assignment model, thus avoiding the necessity of assuming probability distributions or generating scenarios. Focusing on an identical problem, Nguyen & Montemanni (2016) proposed a unified approach for the interrelated dimensions of workforce planning – rostering, assignment, routing and scheduling – and its optimization. Indeed, they used a methaeuristics algorithm that results from the combination of genetic algorithms and linear programming models, and considered the uncertainty of nurses’ availability through robust optimization, using discrete scenario sets. Trying to tackle the nurse scheduling problem (NSP), Jafari et al. (2015) faced the uncertainties in the nurses' preferences (to work in their favorite shifts) and the number of surplus nurses by applying four different types of the fuzzy solution approaches.

Regarding the long-term care (LTC), Cardoso et al. (2012) built a simulation model based on a Markov cycle tree structure to predict annual demand for these services. Instead of a simple scenario analysis, the uncertainty was accounted for through an integrated approach combining scenario analysis with probabilistic sensitivity analysis using Monte Carlo simulation. This approach considered two key types of uncertainties: parameter uncertainty caused by incomplete information and model/ structural uncertainty, due to simplifications and assumptions in use. Later on, Cardoso et al. (2015) built a multi-objective stochastic model for planning the delivery of long-term care, considering both the demand and supply uncertainties through the use of a scenario tree approach. Particularly, the two parameters estimated were the number of individuals requiring all the types of LTC and the length of stay in the hospital.

Providing an effective staffing plan for emergency departments is another planning purpose. This stochastic problem was modeled by Ganguly et al. (2014), who created a chance-constrained mixed integer linear programming model, making use of historical data and applying sensitivity analysis to several factors.

Even though this literature review is not exhaustive, it is possible to conclude that there are several methods to account for uncertainty in mathematical programming models related to planning in healthcare, being common the use of stochastic programming and sensitivity or scenario analysis. At this point, it is important to stress out that the *scenario approaches* mentioned by these papers are not the same as the scenario definition and methodologies from the foresight literature (defined in the next section). In fact, instead of coherent combinations of input parameters with some meaning to the decision-maker, the scenarios used are simply an adaptation of the neutral values, usually to cover a pessimistic and optimistic version of the future. The main idea one should get from this review is that healthcare planning models are hypersensitive to uncertainty modeling and therefore it is something that should always be accounted for.

2.3. Foresight and scenario planning

Foresight, future studies and scenario-building are close definitions, often used as synonyms (Rialland & Wold 2009). There are several definitions for them in the literature: for instance, Huss (1988) defines scenario as “a narrative description of a consistent set of factors which define in a probabilistic sense alternative sets of future business conditions”, while Godet (2000) states that a scenario is "a description of a future situation and the course of events which allows one to move forward from the original situation to the future situation". Indeed, scenarios are not predictions, but rather hypothetical stories about how the future might unfold (Scearce & Fulton 2004).

The Institute for Prospective Technological Studies from The Joint Research Centre (2015) states that there are four distinctive characteristics of foresight, when compared to other future studies such as forecasting, explained bellow.

To start with, foresight must be *open to alternative futures*, in the sense that it assumes that the future is not pre-determined and therefore it can progress to alternative directions. It is also *action-oriented*, since it supports actors to shape the future, having a connection between the possible futures and the actions that should be undertaken to increase the chance of arriving at the desired one. Moreover, it is a *participatory* approach, as several groups of actors – such as different stakeholders and policy makers – must be taken into account in the process of exploring the future. This involvement is in fact desired for HHR planning, since it is an activity of public interest (Malgieri et al. 2015). Finally, it is *multidisciplinary*, meaning that problems should not be reduced to one dimension or perspective, but instead one should try to capture all the realities and variables influencing them. Figure 2.2 summarizes these characteristics, emphasizing that this discipline combines thinking, debating and shaping the future.

Figure 2.2: The foresight triangle: thinking, debating and shaping the future (source: The Joint Research Centre - Institute for Prospective Technological Studies 2015).

Sikken et al. (2008) also emphasizes these differences, summarizing them in Figure 2.3. Particularly, it is specified that, while forecasting uses data from the past to make assumptions and build a linear projection to a single future, scenario methodologies start from the current realities and create multiple futures that challenge assumptions. Moreover, it is clarified that in scenario thinking one should account for uncertainty about the future, making it explicit. This fact was previously mentioned in an article about the use of scenarios at Shell, where it is advocated that we should “accept the uncertainty, try to understand it, and make it part of our reasoning” (Wack 1985).

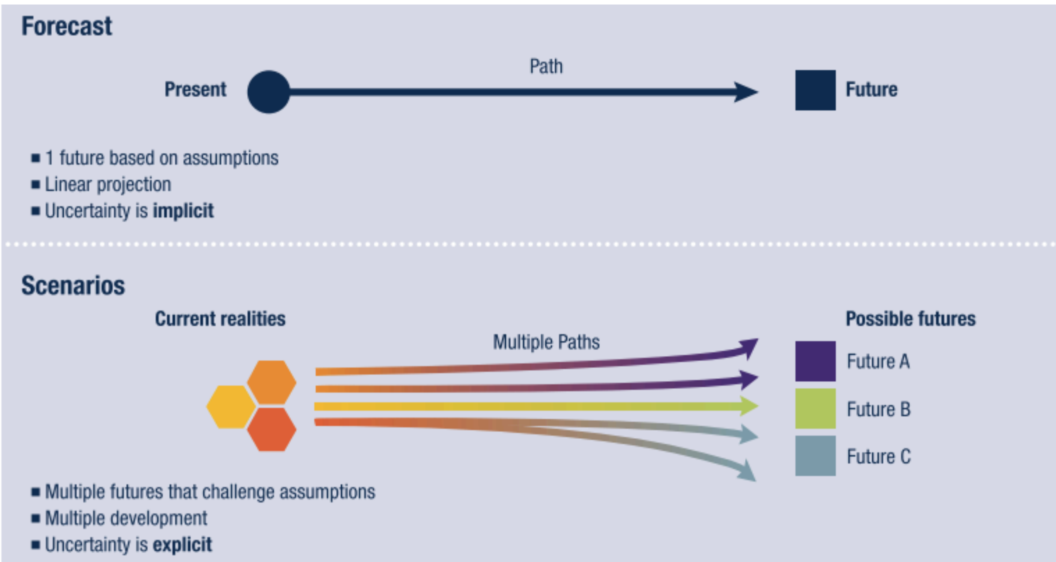


Figure 2.3: Forecasting versus scenario thinking (source: Sikken et al. 2008).

One can think of scenarios as a long-term macro view which may be used as a backdrop for more traditional future studies, such as forecasting (Huss 1988). It makes experts not only to think about the future but actually to explicit their assumptions while they do it, providing them a better understanding of change and future uncertainties. Therefore, one of the goals of this approach is in fact to improve the quality and effectiveness of policy making (European Foresight Platform 2010).

Scenario building usually starts with an horizon scanning, which consist on the "exploration of potential challenges, opportunities, and likely future developments" (Centre for Workforce Intelligence 2014b). Indeed, this leads to the identification of key external drivers, which are not controllable by the organization (or they would be within the *vision* domain), and may be subject to its influence or entirely given factors. This scanning usually includes both desk research and inputs form experts.

Besides, these drivers, also referred to as drivers of change or driving forces, may be defined as "developments causing change, affecting or shaping the future" (Giesecke et al. 2016), which in fact may cause one or more effects.

2.3.1. Scenario typologies

There is more than one typology in the literature to classify scenarios. One of them considers the user's perspective and will de detailed in this section. It was first introduced by Börjeson et al. (2006) and it is based on the three principle questions that can be asked about the future: "what will happen?"; "what can happen?"; and "how can a specific target be reached?". The first question is connected to *predictive* scenarios, as one attempts to predict what is going to happen and thus only probable futures are explored. On the other hand, the second question implies the exploration of possible or plausible futures, giving rise to *explorative* scenarios (also known as exploratory or descriptive). Finally, the last question is related to *normative* scenarios, exploring what is desirable to happen in the future and how it can be reached.

2.3.2. Scenario main methodologies

The idea of scenarios as telling stories of the future is as old as humankind (Scearce & Fulton 2004). However, it was not until the 1950's that they were seen as a tool for strategy, having origin in military and corporate planning (Scearce & Fulton 2004).

It is widely recognized that scenarios emerged from two distinct geographical centers – the USA and France –, even though it is accepted that others may have existed, not having an adequate mention in the literature (Willis & Cave 2014). These centers, which have played a major role in the development of the field, have emerged almost simultaneous in the 1960's (Rialland & Wold 2009). The historical development of both centers has lead to the creation of different methodologies, also referred to as schools. Table 2.1 is inspired on (Bradfield et al. 2005), (Rialland & Wold 2009) and (Willis & Cave 2014) and summarizes the historical evolution of the three main schools, emphasizing the main actors and institutions responsible for the developments between the 1950's until the 1970's, both in the USA and France.

Table 2.1: Foundations of the USA and French Centers between 1950's–70's and respective schools originated.

	The USA Centre	The French Centre
1950's	Herman Kahn (*Rand Corporation*) • Method for analyzing military strategies • "Thinking the unthinkable"	Gaston Berger (French philosopher) • Founded the *Centre d'Etudes Prospectives* • Developed *La Prospective* methodology • Primary objective: develop normative scenarios to guide policy makers
1960's	Kahn left RAND and founded the *Hudson Institute* • Apply scenario methodology to social forecasting and public policy	Pierre Masse • Use of prospective scenario techniques in the national economic plans Bertrand de Jouvenel • Founded *Association Internationale de Futuribles* (international future movement) • Joined the *Centre d'Etudes Prospectives* (1966) • Use of scenarios to construct positive images of the future
1970's	Olaf Helmer and Ted Gordon left RAND and founded the *Institute of the Future* • Worked together with Dalkey and investigators from the *Stanford Research Institute* • Scenarios as a planning tool Pierre Wack (*Royal Dutch Shell Company*) • Scenario planning as permanent strategy • Use of scenarios to guide strategy and to foresee the oil prince shock of the 70's	Michael Godet (SEMA) • Head of the Department of Future Studies at SEMA • Developed scenarios for several French national institutions (EdF, Elf) • Added mathematics and computer-based probabilistic to *La Prospective* • Use of tools such as morphological analysis, Micmac, Mactor, Smic-Prob-Expert
School Originated	Intuitive Logics Probabilistic Modified Trends	La Prospective

A. The intuitive-logics school

The intuitive-logics methodology, also referred to as the "Shell approach" to scenarios, was first proposed by Herman Kahn at the Rand Corporation and latter used at Royal Dutch Shell by Pierre Wack and his colleagues (Bradfield et al. 2005; Amer et al. 2013). It is a reasonably flexible methodology and emphasizes the importance of the learning process (Rialland & Wold 2009). Moreover, it is qualitative by nature, not using any mathematical algorithm (Rialland & Wold 2009; Amer et al. 2013). There are many variations of the intuitive logics methodology published, differing in the number of discrete steps, which varies from 5 to 15 or more (Bradfield et al. 2005). Accordingly to Bradfield et al. (2005), this is the approach that has received most of the attention in the literature.

B. The Probabilistic Modified Trends (PMT) school

This school includes two distinct matrix-based methodologies – the Trend-Impact Analysis (TIA) and Cross-Impact Analysis (CIA) – both quantitative approaches attempting to consider the probabilistic modification of extrapolated trends (Bradfield et al. 2005). Each of these models generates a range of alternative futures and, when combined with expert judgments, they create scenarios (Bradfield et al. 2005).

Trend-Impact Analysis

The TIA model is usually associated with the Futures Group (Huss 1988; Bradfield et al. 2005). Moreover, what drove to the development of the TIA was the fact that traditional forecasting methods relied only on the extrapolation of historic data, not considering the effects of future events without precedents (Bradfield et al. 2005).

Main steps:

1. Collect historical (time-series) data related to the issue under study;
2. Generate a naïve (surprise-free) extrapolation using an algorithm to select specific curve-fitting historical data;
3. Develop a comprehensive list of unprecedented future events that may cause deviations on the naïve forecast;
4. Establish the probability of occurrence of the unprecedented events over time and their expected impact; Produce adjusted extrapolations;
5. Write scenarios from at least two of the forecasts.

Cross-Impact Analysis

The CIA model was first developed at the Rand Corporation by Olaf Helmer and Ted Gordon (Bradfield et al. 2005). This methodology is similar to the TIA, but it includes an extra layer of complexity, taking into account the interaction between the impacting events, as it considers unrealistic to forecast an event in isolation (Amer et al. 2013; Huss 1988). Particularly, it aims to determine the conditional probabilities of pairs of future events, given that specific events have or have not happened, and consequently correcting the initial probabilities (Bradfield et al. 2005).

Several variants of this model were developed by researchers, some of which are proprietary methodologies, such as Interactive Future Simulations (IFS), Interactive Cross Impact Simulation (INTERAX) and Cross Impact Systems and Matrices (SMIC), each following different steps (Bradfield et al. 2005; Huss 1988).

C. La prospective

As summarized in Table 2.1, the French approach to scenario planning appeared with the philosopher Gaston Berger, who believed that the future is not predetermined, but rather something that can be modeled and created (Bradfield et al. 2005). What started as the creation of normative scenarios of the future to guide policy makers and provide a basis for action, soon was expanded by Michael Godet to a mathematical and computer-based probabilistic approach (Bradfield et al. 2005). Godet has developed tools such as Micmac for identifying key variables, Mactor, which helps analyzing actors' strategies, SMIC-PROB-EXPERT, a variation of a cross-impact analysis for determining the probability of scenarios and MORPHOL, which is a computer version of morphological analysis (Bradfield et al. 2005; Amer et al. 2013). Morphological analysis is a process to visually explore and analyze all the possible solutions, eliminating incompatible combinations of factors and creating plausible combinations (Amer et al. 2013).

2.3.3. Comparison of scenario's main methodologies

The three schools mentioned in the previous section can be characterized in 14 features to facilitate its comparison (Table 2.2)

Table 2.2: Comparison of the main features of the three main schools (adapted from Bradfield et al. 2005).

	Intuitive-Logics	PMT	*La Prospective*
Purpose	Multiple, from a one-time activity to develop strategy, to an ongoing activity related to anticipation and organizational learning.	One-time activity to improve extrapolative prediction and policy evaluation.	Usually a one-time activity to develop more effective policy and strategic and tactical plans.
Type	Descriptive or normative.	Descriptive.	Typically descriptive but can be normative.
Scope	Broad or narrow, ranging from global, regional, country and industry to an issue specific focus.	Narrowly focused on the probability and impact of specific events on historic trends.	Generally narrow, but examines a broad range of factors within it.
Methodology	Process oriented - inductive or deductive, essentially subjective and qualitative.	Outcome oriented - directed, objective, quantitative and analytical, using computer-based forecasting and simulation models.	Outcome oriented - directed, objective, quantitative and analytical, relying on computer-based analysis and mathematical modeling.
Scenario team	Internal team of the organization.	External team of experts (external consultants).	Combination of some key individuals from within the organization led by an external expert.
Role of external experts	Design and facilitate the process; periodic brainstorming for new	Dominant - expert-led process using proprietary tools and expert judgments	Dominant - expert-led process using proprietary tools to conduct

	Intuitive-Logics	PMT	*La Prospective*
	ideas.	to identify high impact unprecedented future events and their probability.	comprehensive analysis and expert judgments to determine scenario probabilities.
Tools	Brainstorming, STEEP[2] analysis, clustering, matrices, system dynamics and stakeholder analysis.	Proprietary tools for TIA, CIA and Monte Carlo simulations.	Proprietary tools such as Micmac, Mactor, MORPHOL, Delphi and SMIC-PROB-EXPERT.
Starting point	A particular management decision, issue or area of general concern.	Issues for which detailed and reliable time series data exists.	A specific phenomenon of concern.
Identification of key driving forces	Intuition - brainstorming techniques, analysis of STEEP factors, research and discussion with experts.	Curve fitting of historical time series data to identify trends; expert judgment to gather potential high impact unprecedented future events.	Interviews with stakeholders and comprehensive structural analysis using computer tools.
Developing the scenario set	Defining the scenario logics as organizing themes or principles (often as matrices).	Monte Carlo simulations to create an envelope of uncertainty around base forecasts.	Matrices of sets of probable assumptions based on key variables for the future.
Exercise output	Qualitative - set of equally plausible scenarios in narrative form.	Quantitative - baseline case plus upper and lower quartiles of adjusted time series forecasts. May include short storylines.	Quantitative and qualitative - multiple scenarios supported by comprehensive analysis, including possible actions and their consequences.
Use of probabilities	No - all scenarios are equally probable.	Yes - conditional probability of occurrence of unprecedented and disruptive future events.	Yes - probability of the evolution of variables under assumption sets of actors' behavior.
Number of scenarios generated	Generally 2 to 4.	Usually 3 to 6, depending on the number of simulations.	Multiple.
Scenario evaluation criteria	Comprehensiveness, internal consistency and coherence, supported by rigorous structural analysis. All scenarios equally plausible.	Plausible and verifiable in retrospect.	Comprehensiveness, internal consistency and coherence, supported by rigorous structural and mathematical analysis; plausible and verifiable in retrospect.

[2] Acronym for Social, Technological, Economic, Environmental and Political.

Even though the scenario horizon is very important for building scenarios, it was chosen not to include it in the comparison table (Table 2.2) since it is independent of the methodology. It is usually between 3 and 20 years (Bradfield et al. 2005) and it is also called the horizon of ruptures, implying the possibility of a big change – a rupture – in the field of study.

From Table 2.2 one can conclude that the Intuitive Logics is a qualitative approach, the PMT is quantitative by nature and La Prospective includes both qualitative and quantitative techniques. Indeed, the French school can be seen as a mix between the other two, as this pattern appears in other features.

2.4. Review of scenario studies in health

In this section a literature review of foresight studies in health will be made. Even though efforts were made to find a comprehensive set of studies concerning the use of scenario building in health, this should not be seen as a systematic review.

The search was performed using different combinations of the following terms: "foresight", "scenarios", "future", "healthcare", "health", "care" and "workforce". This review includes both academic and grey literature, as the scientific databases used found little suitable results. The scientific databases used were mainly Google Scholar, Web of Science, PubMed and Science Direct[3]. Additional institutional sources included the British Centre for Workforce Intelligence[4], CPB Netherlands Bureau for Economic Policy Analysis, the Dutch National Institute for Public Health and the Environment, The Economist Intelligence Unit – Perspectives, European Foresight Platform, the Foresight and Modelling for European Health Policy and Regulation (FRESHER), the Institute for Alternative Futures, the Institute for Prospective Technological Studies - Joint Research Centre (European Commission, the World Economic Forum and World Health Organization[5].

14 Scenario studies were analyzed and characterized according to 9 aspects to facilitate their comparison (Table 2.3). These characteristics are its key issue, approach used, participatory methods applied, participants in the scenario process, core team of scenario building, time horizon, study outputs, type of scenarios developed and scenario topic (i.e. if it develops either global or problem specific scenarios), aiming to *totally* characterize their methodological design.

The review and comparison of the studies aims to elucidate on what is being done in foresight for the health context, and where innovation can take place. This process will indeed support the new proposed methodology.

[3] These databases are available at: https://scholar.google.pt; http://webofknowledge.com; https://www.ncbi.nlm.nih.gov/pubmed/ and http://www.sciencedirect.com.

[4] Given that The Centre for Workforce Intelligence website is not available online anymore, the search was done in The National Archives.

[5] The sources are available, respectively, at: http://webarchive.nationalarchives.gov.uk/20161007102445/http://www.cfwi.org.uk/publications; http://www.cpb.nl/en; http://www.rivm.nl/en; http://perspectives.eiu.com; http://www.foresight-platform.eu; http://www.foresight-fresher.eu//en/; http://www.altfutures.org; https://ec.europa.eu/jrc/en/research/crosscutting-activities/foresight; https://www.weforum.org/reports and http://www.who.int/publications/en/

Table 2.3: Review of scenario studies in health – key issue; approach; participatory method and participants; core team; time horizon; study outputs; scenario type and topic.

Study Title	Key Issue	Approach/ method	Participatory method	Participants in scenario process	Core team	Time horizon	Study outputs	Scenario type	Scenario topic
"The future of pensions and healthcare in a rapidly ageing world: scenarios to 2030" (Sikken et al. 2008)	"How may the future of pensions and healthcare look like in 2030 and what may be the role of governments, the private sector and individuals?"	Intuitive Logics: • Scenarios developed through an inductive approach and represented in a two-by-two matrix (using the extremes of two main drivers)	• Discussion with stakeholders to formulate the central question • Expert interviews and refined at workshops to identify the driving forces • Workshops, interviews and expert consultations to develop 3 scenarios	• In total, almost 200 participants in 9 workshops in New York, Beijing, Milan, Rome, Geneva, Dalian and Davos; • Representatives from over 60 companies and over 40 non-business organizations	Project team (12): World Economic Forum in collaboration with Mercer	20 years	3 scenarios + strategic options	Qualitative and Exploratory	Problem specific (pensions and healthcare sector)
"The future of the European biomedical healthcare sector: Four scenarios" (Andersen & Piester 2008)	"What are the opportunities, barriers and requirements for the optimization of the biomedical healthcare sector and the sustainable development of its workforce?"	Intuitive Logics: • Desk research and STEEP analysis to identify the main drivers of change • Scenario development (2-by-2 matrix) • Examination of plausible implications of each scenario configuration	• Strategic discussions between scenario experts, sector experts and company managers to perform the final examination	• Panel of experts	Scenario team (European Foundation for the Improvement of Living and Working Conditions)	10 years	4 scenarios	Qualitative and Exploratory	Problem specific (Biomedical healthcare sector)
"A scenario analysis of the future residential requirements for people with mental health problems in Eindhoven" (Bierbooms et al. 2011)	"In the coming 5 years, what types of residence should be organized for people with mental health problems?"	Intuitive Logics (Deductive method) - 4 steps: • Exploration of the external environment through document analysis • Identification of the key uncertainties • Development of scenarios • Translation of scenarios into guidelines	• Semi-structured interviews to identify key uncertainties • 1 Workshop to develop the scenarios	• Interviews to 20 representatives of different stakeholders (mental health care providers (7), public housing corporations (5), local government (2), financiers (2), patients' representatives (2), and patients' family organizations (2)) • Workshop panel of 11 experts	3 authors: 1 facilitator (Tilburg University and RIVM, Netherlands)	5 years	4 scenarios + guidelines for planning organization al strategy	Qualitative and Exploratory	Problem Specific (People with mental health)

Study Title	Key Issue	Approach/ method	Participatory method	Participants in scenario process	Core team	Time horizon	Study outputs	Scenario type	Scenario topic
"The future of healthcare in Europe" (Economist Intelligence Unit 2012)	What will be the healthcare landscape in Europe in 2030?	Intuitive Logics • Literature review to identify drivers • Define trends likely to impact the direction of healthcare until 2030 • Development of the scenarios using a two-by-two matrix	• 28 individual interviews with leading experts during 4 months	Interviewed experts in different professional roles: • Academics • Clinicians • Healthcare providers • Payers • Policymakers • Medical suppliers • Representatives of patients	Authors: Alexandra Wyke, Paul Kielstra and Conrad Heine (Economist Intelligence Unit, sponsored by Janseen)	20 years	5 scenarios (scenario narratives, "what if?" questions, critical factors and pros & cons)	Qualitative and Exploratory	Problem specific (healthcare in Europe)
"Four futures for dietetics workforce supply and demand: 2012-2022 scenarios" (Rhea & Bettles 2012)	Critically assess future changes and their implications for dietetics workforce supply and demand	Adaptation of the Intuitive Logics • Two-by-two matrix with workforce supply and demand to create 4 scenarios • 5 change drivers associated to each scenario • Description of the scenarios, strategic questions and assessed probability	1-day workshop • Identification of 10 change drivers • Assessment of the probability of each scenario	• A panel of 14 experts (including 2 facilitators) • 31 participants in the workshop	2 futurists (Marsha Rhea and Craig Bettles) + 8 representatives of the Dietetics Workforce Demand Study Task Force + Authors of the technical papers (9) + 4 project consultants	10 years	4 scenarios	Qualitative and Exploratory	Problem specific (Dietetics Workforce)
"Health and Health Care in 2032" (Institute for Alternative Futures 2012)	"What will health and health care look like in the USA in the year of 2032?"	Intuitive Logics - "Aspirational Futures" approach: • "Zone of conventional expectation" (1 scenario) • "Zone of growing desperation" (1 scenario) • "Zone of high aspiration" (2 scenarios)	• Individual Interviews • Brainstorming • 2-days workshop in a National Symposium with "clinicians, academics, social and biomedical scientists, policy makers, entrepreneurs and big business executives from global brands"	• 6 interviewed experts • 59 national symposium participants	Robert Wood Johnson Foundation Staff and Consultants (8) + Institute for Alternative Futures Staff (7) + Workshop Consultants (4)	20 years	4 scenarios + Scenario Likelihood and Preferability + Areas of Opportunity and recommend ations	Qualitative and Exploratory	Health and Healthcare Scenarios (USA)

Study Title	Key Issue	Approach/ method	Participatory method	Participants in scenario process	Core team	Time horizon	Study outputs	Scenario type	Scenario topic
The Future Pharmacist Workforce (Centre for Workforce Intelligence 2013a; Centre for Workforce Intelligence 2013b)	"Thinking up to the year 2040, what factors will influence the requirements of the future pharmacist workforce and the future pharmacist workforce numbers and deployment?"	Intuitive Logics • Use of TEEPSE[6] influences to ask experts for drivers, competed by research • Scenario generation: cluster the driving forces, create outcomes and evaluate each cluster for to build an impact/ predictability matrix	• Horizon Scanning - telephone interviews and focus groups • Scenario generation workshop	Diverse group of key stakeholders, including (but not limited to) pharmacists: • Interviews (46) • Focus group (4) • Scenario generation workshop (24)	Centre for Workforce Intelligence (CfWI)	28 years	4 scenarios	Qualitative and Exploratory	Problem specific (pharmacist workforce)
"Sustainable Health Systems: Visions, Strategies, Critical Uncertainties and Scenarios" (World Economic Forum 2013)	"What could health systems look like in 2040?"	Intuitive Logics; • PESTLE[7] analysis to help finding the drivers of chance • Iterative process to incorporate critical uncertainties, scenarios, visions and strategies	• Over 100 interviews to identify key factors that influence the health systems • 8 national workshops (in China, Germany, the Netherlands, Spain and England) and 3 global workshops (in Turkey, Switzerland and the USA)	• More than 200 stakeholders and experts from governments, industry and civil society	Project team (11): World Economic Forum in collaboration with Mckinsey & Company	30 years	Visions to 2040 + Country Strategies + Critical Uncertainties + 3 Scenarios	Qualitative and Exploratory	Health Systems Scenarios
"Public Health 2030: A Scenario Exploration" (Institute for Alternative Futures 2014)	"What will public health look like in the U.S.A in the year 2030?"	Intuitive Logics - "Aspirational Futures" approach: • "Zone of conventional expectation" (1 scenario); • "Zone of growing desperation" (1 scenario); • "Zone of high aspiration" (2 scenarios)	• Individual Interviews • National Workshop (2 days)	• Interviewed Experts (29) • National Workshop Participants (26)	Project Advisory Committee (13) + National Workshop Technical Advisors (4) + IAF Staff (6)	20 years	4 scenarios + Scenario Likelihood and Preferability + Recomen-dations	Qualitative and Exploratory	Public Health Scenarios (U.S.A)

[6] Taxonomic classification of the macro environment that consists of grouping the drivers into Technological, Economic, Environmental, Political, Social and Ethical.
[7] Acronym for Political, Economic, Social, Technological, Legal and Environmental.

Study Title	Key Issue	Approach/ method	Participatory method	Participants in scenario process	Core team	Time horizon	Study outputs	Scenario type	Scenario topic
"A healthier Netherlands: Key findings from the Dutch 2014 Public Health Status and Foresight Report" (National Institute for Public Health and the Environment 2014)	"What is the most desirable future for Dutch public health?"	Intuitive Logics: • Formulation of 4 societal challenges • Formulation of 4 perspectives (scenarios) from each challenge • Formulation of the opportunities and options in each scenario	• Discussion sessions with stakeholders to formulate societal challenges • Interaction with stakeholders to build the scenarios • Expert meetings to explore potential interrelationships between the scenarios	Stakeholders: • Scientific Advisory Committee (15) • Policy Advisory Group (26)	Authors: National Institute for Public Health and the Environment (RIVM), Netherlands	N/A	Trends in Public Health + 4 scenarios + Opportunities and Options	Qualitative and Exploratory (Opportuni-ties and Options are Normatives)	Public Health Scenarios (Netherlands)
"A scenario-planning approach to human resources for health: the case of community pharmacists in Portugal" (Gregório et al. 2014)	"What is the role that community pharmacists may play in the Portuguese health system?"	Intuitive Logics - 3 steps: • Relevant questions to be addressed and definition of the scenarios horizon • Face-to-face scenario-building workshops • Development of the scenarios' narratives by the authors	Scenario development workshops: • 1st workshop – context analysis and design of draft scenarios (thematic brainstorming technique) • 2nd workshop – scenario analysis and validation; consistence and plausibility done by expert consensus	• Panel of 8 experts from practice and academic settings	3 authors: 1 facilitator (WHO Collaborating Centre for Health Workforce Policy and Planning, FFUL and University of Oslo)	10 years	3 scenarios	Qualitative and Exploratory	Problem specific (Pharmacists workforce)
"Tomorrow's healthy society: Research priorities for foods and diets" (Bock et al. 2014)	"To identify research priorities for foods and diets for health"	Intuitive Logics - matrix-based scenario development approach (using the extremes of two main drivers) • State-of-the-art literature review – starting point for discussions • 3 workshops to identify the drivers and create scenarios	3 workshops in plenary and in smaller workshop groups, each during 2 days • 1st workshop - collective brainstorming and subsequent voting to identify the drivers and trends • 2nd workshop - scenario-specific working groups to develop narratives for each scenario • 3rd workshop – revise and complete scenarios; identify scenario-specific challenges and opportunities to define research needs	• 40 experts and stakeholders with a broad range of different backgrounds	Steering Committee (9) + 2 facilitators (JRC Foresight, European Commission)	40 years	4 scenarios + Research priorities	Qualitative (with some quantitative data) and Exploratory	Problem Specific (food and diets)

Study Title	Key Issue	Approach/ method	Participatory method	Participants in scenario process	Core team	Time horizon	Study outputs	Scenario type	Scenario topic
“In-depth review of the psychiatrist workforce” (Centre for Workforce Intelligence 2014b; Centre for Workforce Intelligence 2014a)	Thinking up to the year 2033, what driving forces may influence the requirements for the future psychiatrist workforce and the future psychiatry workforce numbers and proportions?	Intuitive Logics • Horizon scanning: use of TEEPSE influences to ask experts for drivers • Scenario generation (cluster the drivers; rate uncertainty/impact) • Quantification of the scenarios • Workforce modeling	• Phone interviews to stakeholder + focus group (horizon scanning) • Scenario generation workshop • Delphi panel through an online survey to quantify the scenarios	• More than 70 stakeholders	Centre for Workforce Intelligence (CfWI)	20 years	4 scenarios	Quantitative and Exploratory	Problem specific (psychiatrist workforce)
“Health Scenarios Stories - Foresight and Modelling for European Health Policy and Regulation (FRESHER)” (Ricci et al. 2016)	Detect emerging health scenarios to test and assess future policy options to tackle the burden of chronic non-communicable diseases (NCD) in Europe	Intuitive Logics • Horizon scanning: literature review and 3 workshops • Scenario generation: categorization of the variables by importance and uncertainty to create the scenarios space (desk analysis and survey); matrix-based scenario development approach • Consolidation of the scenarios	• 3 regional workshops to identify trends (Vienna, Brussels and Lisbon) • Online survey • Project meeting, Delphi survey and experts interview to consolidate the scenarios	• Each workshop with between 25 and 28 experts with different backgrounds (such as medicine and care, society, policy, media, research and industry) • Delphi: 110 experts with different backgrounds (mainly European researchers and academics, policy makers and consultants)	FRESHER team	34 years	4 scenarios	Qualitative and Exploratory	Problem specific (chronic non-communica ble diseases in Europe)

A big effort was made to homogenize all the characteristics of each study and build Table 2.3 because, apart from the scenario horizon and the number of output scenarios, the methodologies of each study are not very clear: for instance, none of them specified the school followed, which shows the lack of scientific structure that exists in foresight literature. Indeed, the approach followed by each one of the studies was analyzed and it appears that all of them followed the Intuitive Logics methodology, with some adaptations, and indeed are qualitative and exploratory. Moreover, most of them are problem-specific and developed four scenarios.

2.5. Scenario studies in HHR planning

Four of the fourteen scenario studies analyzed are focused on HHR planning, even though only one of them is specific to doctors (in this case, psychiatrists). These will be described in further detail in this section, mainly focusing on the methodology.

The British Centre for Workforce Intelligence (CfWI) developed two studies in this category which were included in our analysis: (Centre for Workforce Intelligence 2013a; Centre for Workforce Intelligence 2013b) and (Centre for Workforce Intelligence 2014b; Centre for Workforce Intelligence 2014a). Both of them followed the CfWI robust workforce planning framework, introduced by Willis (2014) and illustrated in Figure 2.4 (Willis 2014).

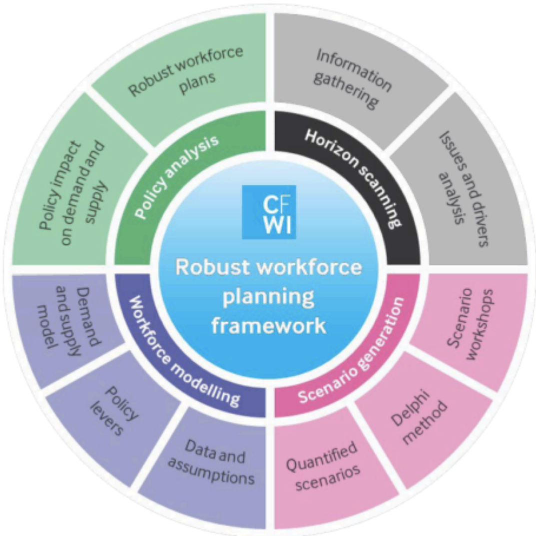


Figure 2.4: The CfWI robust workforce planning framework (source: Willis 2014).

This robust framework relies on four major steps: horizon scanning; scenario generation; workforce modeling and policy analysis. Given that the purpose of this master thesis is to build scenarios to inform a mathematical programming model for health human resources planning, both of these studies are particularly interesting (sub-sections A and B).

The qualitative health scenario stories concerning NCD in Europe, built by Ricci et al. (2016), also aim to contribute to quantitative modeling. However, it did not focus on workforce planning, so it will not be detailed in this literature review.

A. *In-depth review of the psychiatrist workforce*

Concerning the future psychiatrist workforce (Centre for Workforce Intelligence 2014b; Centre for Workforce Intelligence 2014a), the horizon scanning was first performed in order to identify the driving forces with a possible impact on the future demand and supply for this specific workforce. This was done with phone interviews and a focus group, asking experts to consider possible TEEPSE influences throughout the following questions:

"Thinking up to the year 2033, what driving forces (both trends and uncertainties) may influence:

- The requirements for the future psychiatrist workforce?
- The future psychiatrist workforce numbers and proportions?"

The second step – scenario generation – was achieved through a workshop with stakeholders, where they were asked to freely group the driving forces into clusters by looking for causal and chronological relationships between them. Afterwards each cluster was rated for impact and uncertainty to facilitate the choice of the two clusters with greatest uncertainty and impact. These were combined to create four scenarios, which are presented in a table (Figure 2.5) together with their key assumptions and key trends.

Scenario 1	Scenario 2	Scenario 3	Scenario 4
Key assumptions			
Progressive societal attitudes towards mental health (MH) and illness	Progressive societal attitudes towards MH and illness	Regressive societal attitudes towards MH and illness	Regressive societal attitudes towards MH and illness
Consultant psychiatrist-delivered model for MH services	Peer-supported model for MH services	Consultant psychiatrist-delivered model for MH services	Peer-supported model for MH services
Key trends			
MH teams begin to enjoy parity of esteem with physical healthcare providers and can influence commissioners	Research leads to better understanding of the biological and molecular basis of many MH problems, which increases the range and efficacy of medical interventions available	There is a drive to increase the workload of each consultant, including the expectation for psychiatrists to provide psychological therapies	Mental health services, medical education and training are low priorities
Genesis of severe mental illness is prevented by targeted treatments and evidence-based psychosocial interventions	Medical input is provided by GPs, neurologists and geriatricians, which is seen as positive by commissioners as fewer consultant psychiatrists are needed	Mental health services – though still consultant-delivered – are so compromised that a crisis occurs as recruitment declines and retention plummets	Poor MH becomes the norm. People who can afford MH care through insurance increasingly opt for psychological therapies over drugs.
The productivity of consultant psychiatrists has increased thanks to technology and legislative changes	Most care is delivered by peer-support workers and other non-medical members of the MH team	SAS doctor grades expand due to cost pressures	The profession reaches crisis. Psychiatrists retain a basic statutory role but little else.

Figure 2.5: Summary of the plausible future scenarios built by (Centre for Workforce Intelligence 2014a).

A Delphi panel exercise was done using an online survey in order to quantify some uncertainties about demand and supply. For the demand assumptions, four questions were asked (one about the current demand and other three about the future demand) for each scenario and each of the six psychiatrists specialties. Concerning the supply assumptions, a foresight of the average participation rate and the average retirement age (by gender) for 2033 were asked, for each of the four scenarios. The average values of each uncertain variable were used as inputs of the model, but it is worth mentioning that an uncertainty analysis was performed using both the range and spread of values from the Delphi panel.

The workforce model used was in fact a system dynamics model, used to forecast demand and supply of psychiatrists. The inputs of the model were divided into four categories: facts (i.e. baseline data); assumptions made due to not available/ poor data; assumptions derived from Delphi; and parameters that can be controlled.

B. The future pharmacist workforce

This study was also done by the CfWI, thus its methodology is very similar to the previous one, following the same framework (Figure 2.4). In (Centre for Workforce Intelligence 2013a), the horizon scanning is specified and all the drivers are highly detailed, including: heading; frequency of mention; brief description; proposed impact on the workforce; links containing more info about the driver; and further questions for discussion and/or research.

The same process was used to cluster the driving forces, but experts were also asked to create two extreme but plausible outcomes for each cluster. The clusters were rated for impact and uncertainty and an impact/predictability matrix was built (Figure 2.6).

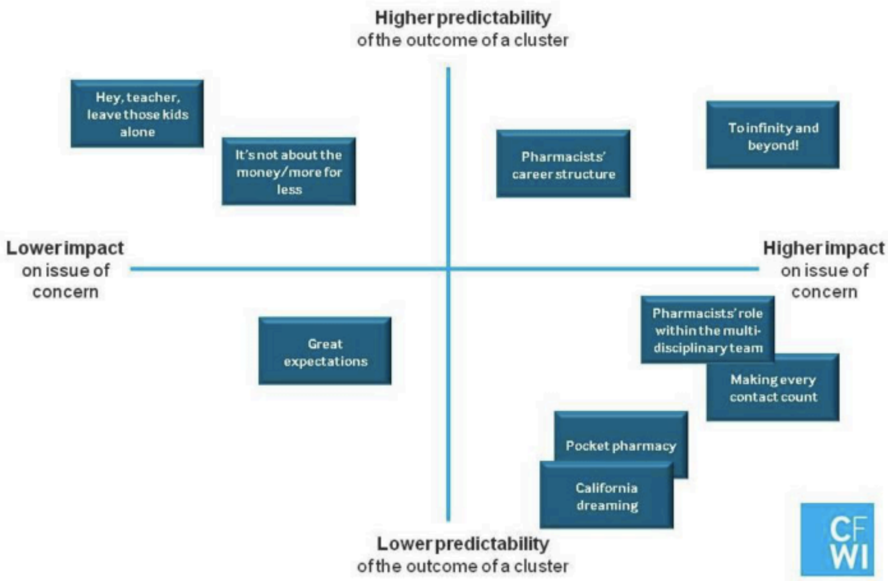


Figure 2.6: Impact/predictability matrix from (Centre for Workforce Intelligence 2013b).

Each of the clusters were described and discussed with stakeholders. The four relatively high-impact/high-uncertainty clusters, present in the lower right quadrant of Figure 2.6, were agreed to be very similar in content and therefore were combined into two new clusters, used to build the four scenarios.

C. A scenario-planning approach to human resources in health: the case of community pharmacists in Portugal

Gregório et al. (2014) focused specifically on the future of community pharmacists. In fact, this paper is an application of the method proposed by Lapão and Thore, presented in Figure 2.7.

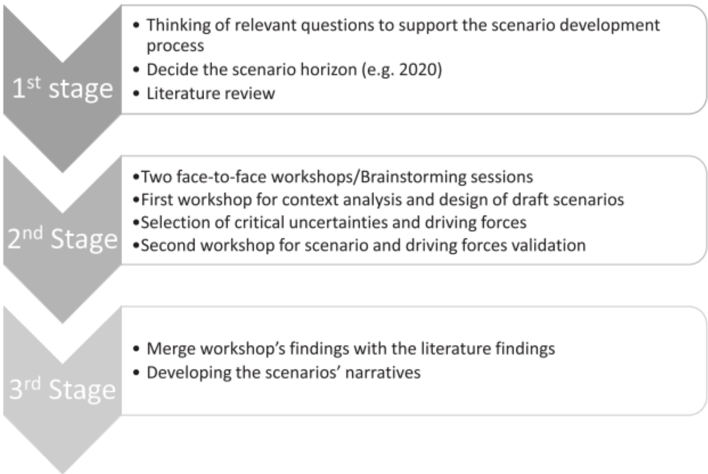


Figure 2.7: The methodology of scenario development proposed by Lapão and Thore (source: Gregório et al. 2014)

Particularly, the methodology of the second and third stages will be detailed. During the first workshop, the literature review (i.e. workforce, economic, technological, political, and demographic trends) was exposed and experts were asked to think freely about different possibilities for the future role of community pharmacists. Answers were then summarized into themes, and the ones with highest influence (voted by the experts) were considered critical uncertainties. These were condensed into two driving forces, each with two extremes, and the initial draft of scenarios was done. The second workshop was done to check the drafts for consistency and plausibility. The final scenario analysis was done by combining the existing scenarios with the information from the second workshop and from the literature review. The three final scenarios were presented in a two-by-two matrix and described (Figure 2.8). A table with the implications and consequences of each scenario was also done, including the demand, main functions and responsibilities, main skills needed, and the integration with primary health care.

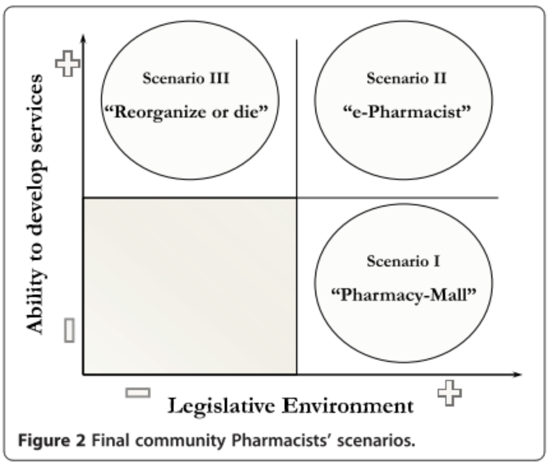


Figure 2.8: Scenario space of (Gregório et al. 2014).

D. Four futures for dietetics workforce supply and demand: 2012 to 2022 scenarios

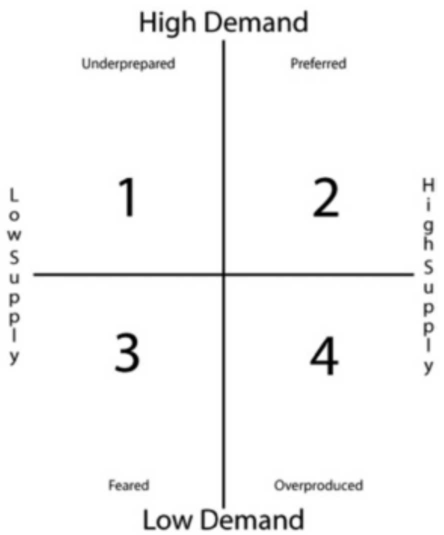
In order to access future changes and their consequences for dietetics workforce supply and demand, Rhea & Bettles (2012) used a different methodology (Rhea & Bettles 2012). It started with a one-day workshop, where a panel of 14 experts (i.e. leaders from inside and outside the profession) identified ten key drivers of change. Afterwards, the authors performed an in-depth research on each driver, including a forecast of their likely direction and their potential implications for the dieticians. This information was used as an input to the second workshop: the scenario workshop.

A four-quadrant approach was used, with supply as the horizontal axis and demand as the vertical one. This framework, present in Figure 2.9 (Left), gave rise to four different zones: underprepared future; preferred future; feared future; and overproduced future.

The 31 leaders were then divided into four teams, and each was first assigned to one of the four scenarios. Later, each team followed the next three steeps for the corresponding scenario:

i. Selection of 5 change drivers (out of the 10 existing ones) believed to highly impact their future;
ii. Brief description of each scenario;
iii. Preliminary probability rating (high/medium/low) to access the likelihood of each scenario.

Afterwards, the members of each team rotated and discussed with each scenario team leader, in order to improve all the scenarios. All participants rated the scenarios for their probability and preferability (i.e. how challenging they are to the profession), by placing circles and squares, respectively, on the four-quadrants, as presented in Figure 2.9 (Right).



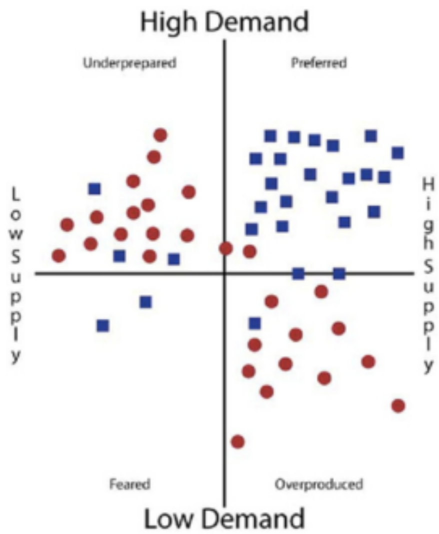


Figure 2.9: (Left) The four-quadrant approach to supply and demand of dietetics workforce. (Right) Most likely (red circles) and most challenging (blue squares) scenarios rated by the workshop participants. Both figures from (Rhea & Bettles 2012).

2.6. Summary

Planning in healthcare is extremely important as is often done through mathematical programming models. Given the special characteristics of the sector, along with the usual high sensitivity of these models to changes in the input parameters, make uncertainty analysis extremely important. This analysis is mostly done through stochastic programming or sensitivity analysis, not considering the knowledge of decision makers nor any coherent combination of parameters. A shift of paradigm could be achieved with the use of a foresight methodology to build future scenarios together with experts and generate outputs that can be used to inform mathematical programming models, similarly to CfWI. In fact, the existing foresight literature is still not very structured and lacks some methodological details and coherence. Indeed, there is space in the literature to develop a structured methodology to built scenarios and enhance mathematical programming models.

Chapter 3

Methodological approach

Given the conclusions from the previous chapter, a new methodology was developed to build scenarios to enhance healthcare planning with mathematical programming models. An effort was done to describe the proposed methodology as clearly and detailed as possible, unlike what was mostly found in the literature review.

3.1. Methodological overview

The proposed methodology follows the Intuitive Logics approach together with *La Prospective*, making use of characteristic tools from the French school such as cognitive maps and morphological analysis.

An overview of the methodology, which aims to inform an existing mathematical programming model in the field of planning in healthcare, is illustrated in Figure 3.1. It starts with the identification of the key issue and selection of the input parameters from the model that are intrinsically uncertain (*Step 1*). *Step 2* is based on the contact with experts through a web-based platform to gather a wide range of perspectives, which must be analyzed and aggregated to form the drivers (*Step 3*). The drivers that are interrelated will then be clustered into key variables (*Step 4*) and a morphological analysis is used to create the scenarios (*Step 5*). These scenarios must be described in a story-like narrative (*Step 6*) and a final technical step is needed to quantify the input parameters for each scenario (*Step 7*). Finally, a number of coherent combinations of parameters are reached (one for each scenario) and will serve as inputs to the mathematical programming model, leading to the same number of outputs that must be analyzed.

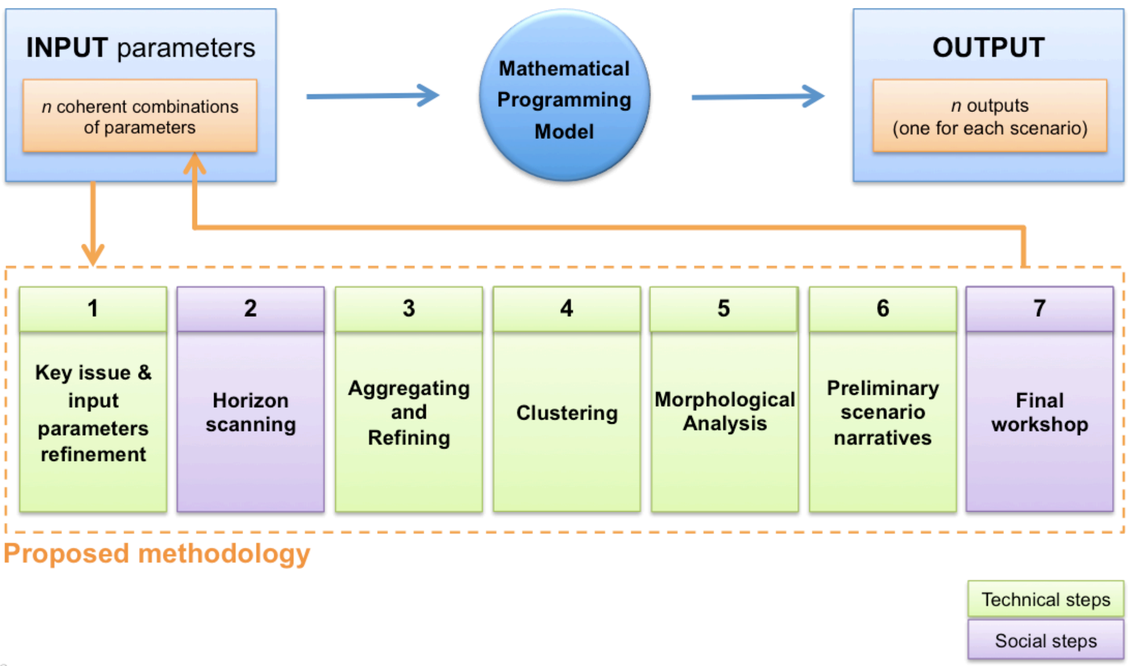


Figure 3.1: Overview of the proposed methodology (in orange) and its interrelation with an existing mathematical programming model (in blue). The scenario building includes 7 steps and culminates in the generation of coherent combinations of parameters to be tested in the model.

3.2. Key issue and input parameters refinement

The proposed methodology aims to develop scenarios to enhance the planning in healthcare, specifically dealing with the inherent uncertainty of the mathematical programming models' inputs. Not only will it contribute to robustness in decision-making, it will also make experts and decision makers explicit their assumptions about the future and think about it. The key issue should indeed be made explicit, possibly in the form of a question. Moreover, the time horizon *T* must be decided.

The input parameters are generally from different types and can therefore be categorized into four different groups, similarly to (Centre for Workforce Intelligence 2013a):

i. **Baseline data** – Present facts that are known;
ii. **Assumptions** – Estimated parameters, not likely to change over time;
iii. **Controllable parameters** – Policy choices;
iv. **Intrinsically uncertain parameters** – Parameters likely to change over time.

In fact, the intrinsically uncertain parameters are the ones that will be elicitated through scenario generation.

3.3. Horizon scanning – web-based platform

The second phase of the methodology aims to identify the driving forces with a possible impact on the future of HHR, specifically on the *intrinsically uncertain parameters*. This must be done through a desk research on the field of study in combination with a participatory method to ask experts for drivers that will influence each parameter within a defined time horizon and how (i.e. increase, decrease or maintain).

This step is usually done through a workshop or expert interviews. However, in this methodology an online platform is used to apply the questionnaire. Experts shall be personally contacted by email (or telephone, if possible), explaining the purpose of the project and requesting them to answer the web questionnaire. This option highly facilitates the process, as face-to-face participatory methods are usually expensive and time consuming.

Questioning protocol

Before the questioning, it must be emphasized that, in each question, experts should consider possible TEEPSE influences, so that experts do not focus only on micro questions, but rather have a macro perspective.

The questionnaire *per se* consists of two questions for each parameter:

i. First question: "**In the next *T* years, how do you think *the parameter* will evolve?**" (i.e. increase, decrease, or maintain);
ii. Second question: "**And why?** Mention at least **3 factors** that will influence it.".

3.4. Aggregating and Refining

Similarly to Laukkanen (2012), the methods to gather and process data can be divided in low-structured, semi-structured and structured. The first two methods correspond to the gathering of data through interviews or questionnaires and give rise to rich natural data, differing because the second one elicits mostly causal statements. Alternatively, in structured methods the respondents pick from a common pool of concepts the ones they find relevant, resulting in less data and much easier processing. In scenario building, the participation of experts should be as open as possible, meaning that some space has to be given to experts for them to think freely about the future. It is then unadvisable to use a concept pool approach through multiple-choice questions on the web-based platform, even though this method would simplify greatly the analysis of the data. Thus, semi-structured methods can be applied, as the questionnaire will elicit only causal statements. This means that the original data will be extremely rich and voluminous, and will contain different expressions, synonyms and fuzzy statements (Laukkanen 2012). This variability complicates the possibility of use of a text-mining approach to aggregate the answers from different experts that have the same meaning. Moreover, when performed manually, this aggregation will indeed be highly dependent on the researcher's judgment, being desirable to use a team of researchers to perform this task.

The following workflow (Figure 3.2) may help in the process of aggregation, albeit there is always space to choose different paths:

Assign an ID to each expert

Organize the answers by question (i.e. parameter) and, for each, group the ones that have the same meaning and the corresponding expert IDs. This is essential so that in the end one can distinguish the experts that mentioned the same driver for different parameters.

Name each group – from now on called a driver – with a word/expression that clearly represents the grouped answers, avoiding mentioning one specific evolution (e.g. choose "evolution" instead of "increase"), as more than one will be considered in the scenarios.

Perform the same 3 steps for the rest of the parameters, bearing in mind the already named drivers to avoid redundant ones. Some adjustments may be needed in the names of the drivers in this process as more answers are considered.

Build tables with all the drivers as rows and the parameters as columns to summarize all the information and facilitate further analysis. Different tables can be created and three examples are enlightened here, with decreasing level of detail:

A complete table with all the information, i.e. each cell has the IDs of the experts that mentioned the causal relationship between the corresponding driver and parameter. With this table one can keep track of which experts mentioned each driver (and consequently their number);

A summary table, similar to the previous one but only containing the number of experts that mentioned each driver-parameter relationship;

A binary table, with "1" if any expert established a causal relationship between the corresponding driver and parameter or "0" otherwise. Easily sum the lines to know how many parameters each driver affects or the columns to know how many drivers affect each parameter.

Organize the drivers in TEEPSE. This could also be done before the previous step.

Figure 3.2: Suggestion of workflow for the aggregation and refining step of the proposed methodology.

3.5. Clustering

The aggregation of the answers will probably give rise to a big number of interrelated drivers. These should now be clustered to form the *key variables* and ensure their independence.

This can be achieved by looking for causal relationships or influences between the drivers to build the clusters (i.e. key variables) that, as said before, must be as independent as possible. The use of cognitive maps may help in this process as they facilitate the visualization of the problem (Figure 3.3). In cognitive maps each *node* represents a concept and the *links/ arrows* symbolize the relationships between them which, in this case, may be either of causality or influence (Thietart 2001; Amer et al. 2013). Each arrow may have an associated weight to indicate how strong its relationship is, but, for the purpose of this methodology, this feature is not needed.

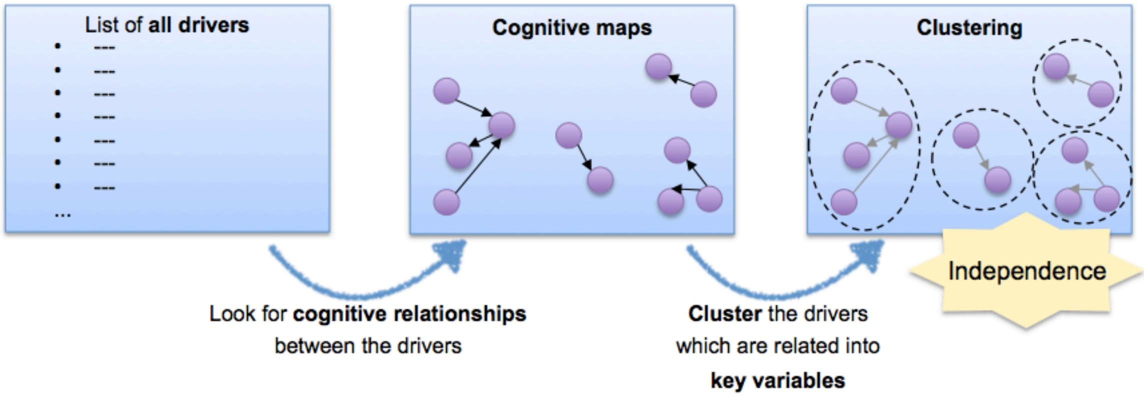


Figure 3.3: Process of clustering the drivers into key variables.

The process of clustering can either be done by the researchers using desk research and possibly some information contained in the answers to the questionnaire or, if possible, through a workshop with experts. The latter option is preferable as there is almost no information from the first questionnaire to help in this process.

After building the clusters (i.e. key variables), each one of them must be named, trying to summarize everything it includes. A more detailed description should also be written, considering all the drivers included and even looking at the raw answers if needed.

3.6. Morphological Analysis

Having all the key variables, the next step is to generate the scenarios through a morphological analysis. This tool is characteristic from the French school, being a more structured and systematic way to obtain all the combinations of the plausible evolutions of the key variables (Amer et al. 2013; Bradfield et al. 2005). It starts with the definition of a number of plausible future evolutions (also known as *configurations*) for each key uncertainty, which must be contrasting and challenging (Amer et al. 2013). These configurations should be based on the qualitative information given by experts in the second step and are usually two, but can also be more depending on each case.

The initial morphological space will indeed result from all the combinations of the configurations from each key variable, and thus the number of solutions is equal to the product of the number of configurations for each key variable (Godet 2000). For instance, if an exercise has 4 key variables and each one of them 2 configurations, the number of solutions will be $2 \times 2 \times 2 \times 2 = 2^4 = 16$. It is easily seen that this number will increase rapidly with the number of key variables and configurations, being infeasible to analyze so many possible combinations – or scenarios. Therefore, the addition of *exclusion constraints* is extremely important to reduce the morphological field, excluding the combinations that are in fact incompatible, in the sense that they are highly implausible together.

Finally, a reasonable number of internally consistent scenarios (roughly between 2 and 5) must be selected considering the differences and similarities between the different scenarios.

There are several software programs specific to implement morphological analysis, each with their advantages and disadvantages. Any of them may be used, as long as it allows to include the number of variables needed.

3.7. Preliminary scenario narratives

This step of the methodology aims to draft the narrative of each scenario. These narratives should be based on the respective combination of configurations from the morphological analysis and enriched by all the information gathered from experts. The researchers may also include additional details from the literature. While writing, one should think what would be like to live in each future to “add detail and color” to each one of them (Scearce & Fulton 2004).

3.8. Final workshop

Workshops are an essential tool in a scenario-building methodology (Rialland & Wold 2009). A final workshop encourages experts to discuss and validate the exclusion constraints used to reduce the morphological space, the results from the morphological analysis and the final scenario narratives, and make some adjustments if needed. In fact, it is advisable to involve experts with different backgrounds, ideally the ones that answered the web-based questionnaire. Additionally, this workshop also aims to elicitate the input parameters of the MILP model, and therefore the experts must be asked for quantitative forecasts for each parameter under the different scenarios.

To conduct the final workshop the facilitator needs two main inputs: (1) the results from the morphological analysis and particularly the preliminary scenarios, which must be well detailed and explained and (2) the current values of the *intrinsically uncertain parameters* considered. These values may be obtained by desk research or rather be provided by the researchers that built the optimization model, in case they already have them.

A facilitator with strong knowledge in scenario planning and the use of morphological analysis must conduct this social phase, which includes four main steps:

i. Summary of the work done, including the morphological analysis and results, and description of each scenario, followed by a discussion;
ii. Individual predictions of the future value of each parameter under each scenario;
iii. Discussion of all the individual predictions;
iv. Group predictions – all experts must agree on a final value with the help of the facilitator.

To simplify the process of elicitation, timelines may be used for each parameter with the present value already marked. The experts will then sign the future value, for instance by placing post-its.

It is important to care about the workshop environment as it is proved to influence the effectiveness of the group work. Particularly, the layout of the workshop room must ensure easy eye-to-eye contact between the participants and also visual access to a *screen*.

Chapter 4

Application of the methodology

The proposed methodology will now be applied to build scenarios to enhance the planning of health human resources with a specific MILP model: a multi-methodological framework to assist the planning of medical training developed within the HHRPLAN project (PTDC/IIMGES/4770/2014) and applied to Portugal (Instituto Superior Técnico 2017a). The whole process of this preliminary application will be described, apart from the final results that will be in the next chapter.

This application mainly aims to test the methodology and find potential limitations or even get insights on how to improve it in the future.

4.1. Key issue and input parameters refinement

To start with, the key issue of this study must be stated. Given that it aims to inform an existing mathematical programming model, the key issue will be derived from it. In fact, it is a multi-objective MILP model, deterministic and multi-period. It receives a set of inputs and predicts the number of vacancies that need to be opened/closed both in the medical course and in each medical specialty, in several periods of the next 30 years (Instituto Superior Técnico 2017a). Therefore, the key issue of this study may be stated as: “How will the HHR look like in the next 30 years in Portugal?”. In this case, the time horizon was already determined by the authors of the model and was considered suitable for the scenario methodology.

The inputs of the model were divided considering its uncertainty, as explained on Section 3.2, and are presented in Table 4.1. For the purpose of the scenario generation, only the “intrinsically uncertain parameters” will be considered.

Table 4.1: Input parameters of the MILP model and respective division into “Baseline data”, “Assumptions”, “Controllable Parameters” and “Intrinsically Uncertain Parameters”.

Baseline data	
Base vacancies in the Medicine Degree (MD)	
Base vacancies in the medical specialties	
Assumptions	
Approval rate in the MD	Probability of a master’s degree student to finish the course in the expected time
Dropout rate in the MD	Probability of a master's degree students to give up the course
Attrition rate in the MD	Probability of master's degree student to fail the years
Dropout rate in the medical specialization	Probability of a physician to give up the specialty
Number of hours of training	Number of hours of training required to be provided per physician during the medical specialization

Controllable parameters	
Duration of the MD	
Duration of the medical specialties	
Maximum capacity of the training system	Maximum number of available vacancies for all specialties
Cost per physician doing the medical specialization	Salaries paid to physicians doing the medical specialization
Cost per physician involved in medical training	Salaries paid to physicians giving medical training
Intrinsically uncertain parameters	
Physicians' supply	Number of physicians of each specialty available
Physicians' demand	Number of physicians of each specialty required
Education costs	Cost per master's degree student in medicine
Emigration rate	Probability of a physician with specialization to emigrate
Immigration rate	Probability of a physician with specialization to immigrate

It should be noted that both the physicians' supply and demand inputs are defined per specialty. Regarding the social steps, this level of detail is infeasible. Therefore, all Portuguese specialties were grouped into *clinical*, *surgical* and *diagnosis* (Appendix A).

4.2. Horizon scanning – web-based platform

To avoid misunderstandings, both the email and the platform were written in Portuguese, since all the experts contacted are Portuguese.

A personalized email was sent to a total of 53 experts, along with an email to ACSS that presumably was spread inside the organization (see Appendix B). These emails included a brief description of the project and of the type of questions they were asked to answer. It was also mentioned that they could forward the email to other people with interest and knowledge in the area of healthcare. The first email was sent on the 17th of July, asking for answers until the 31st of July. A reminder was sent on that day to the ones that had not answered yet (or had chosen to remain anonymous), with a final deadline of 11 of August. A total of 27 answers were considered and, from Figure 4.1 (Left), one can see that the majority of respondents were male (78%).

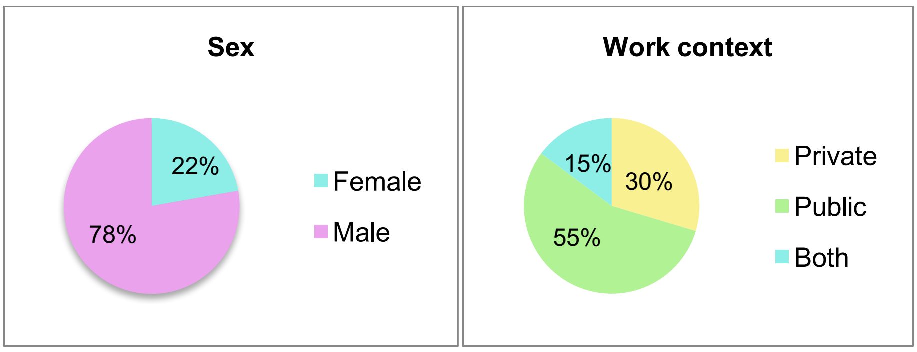


Figure 4.1: (Left) Distribution of the sex of the respondents; (Right) Distribution of the work context of the respondents: private, public or both.

Concerning the work context, most of the experts who submitted the questionnaire worked in the public sector (55%). It should be noted as well that these experts covered a wide range of occupations, as Table 4.2 elucidates.

Table 4.2: Distribution of the respondents' occupations.

<table>
<tr><td colspan="2">Doctor</td><td>11</td></tr>
<tr><td colspan="2">Professor</td><td>3</td></tr>
<tr><td colspan="2">Economist</td><td>3</td></tr>
<tr><td rowspan="2">Public healthcare</td><td>Hospital administrator</td><td>2</td></tr>
<tr><td>Manager</td><td>2</td></tr>
<tr><td rowspan="3">Health technologies company</td><td>CEO</td><td>2</td></tr>
<tr><td>Director</td><td>1</td></tr>
<tr><td>Technical consultant</td><td>1</td></tr>
<tr><td rowspan="2">Private healthcare</td><td>Clinical information manager</td><td>1</td></tr>
<tr><td>Hospital manager</td><td>1</td></tr>
</table>

Several platforms were explored, some specific to build forms, such as Google Forms, Cognito Forms and TypeForm, and others to create free general websites: Wix and Weebly. Weebly[8] was the chosen platform, as it was the only one that presented all the needed characteristics:

i. Possibility of including 26 input fields;
ii. Possibility of including both text fields and radio buttons;
iii. Possibility of creating several pages instead of a long form (not mandatory, but desirable).

Furthermore, it should be noted that Weebly also allowed to include images, to choose the scheme of colors as well as the fonts and sizes of text. Indeed, it supported the effort to create a simple platform, appealing to the viewer. On the other hand, this platform has three main limitations:

i. The free version only allows to include up to 4 input fields in each page;
ii. Questions in different pages are independent: every time a respondent fills one page and presses the button to continue, an email is sent with the corresponding data;
iii. Because of (ii), experts should not go back in the web platform. In fact, it would be possible to continue the questionnaire but it is a very confusing situation, as the previous answer would not appear to the expert. To simplify, experts were told that was impossible.

The consequence of *limitation (i)* appeared in the questions about the physicians' supply and demand, as each should include 6 questions (which were divided in 2 pages) (see Figures C.1 to C.4).

A total of 27 answers were considered, even though 3 of them were incomplete. These incomplete answers exist not because the fields were not mandatory – as they all were –, but rather because of *limitation (ii)*. It is worth mentioning that, even though it was asked for a minimum of three factors for each parameter, some experts answered with fewer factors to some questions, and these were considered anyway.

The homepage (Figure 4.2) has a brief description of the project – essentially the main goal and context – and some information about the questionnaire – the estimated response time (12 minutes);

[8] https://www.weebly.com

the nine variables relevant to the study (physicians' demand of *clinical*, *surgical* and *diagnosis* specialties; physicians' supply of *clinical*, *surgical* and *diagnosis* specialties; education costs in medicine; emigration rate and immigration rate) and the type of questions asked for each variable. The names and contacts of the responsible team were also mentioned in case an expert needed to contact for some reason.

Figure 4.2: Homepage of the web-based platform, available at http://scenarios-hhrplan.weebly.com.

After pressing the button in the homepage and agreeing to participate, the expert goes to the registration page (Figure 4.3), where some personal data should be inserted. It is mentioned that the aim of these questions is to characterize the pool of participants, that the data given is confidential and the registration of the answers is anonymous. Furthermore, there will not be any connection made between the answers given and the characteristics of the respondents. Specifically, it is asked the sex, training area, occupation and if he/she works in the private and/or public sector.

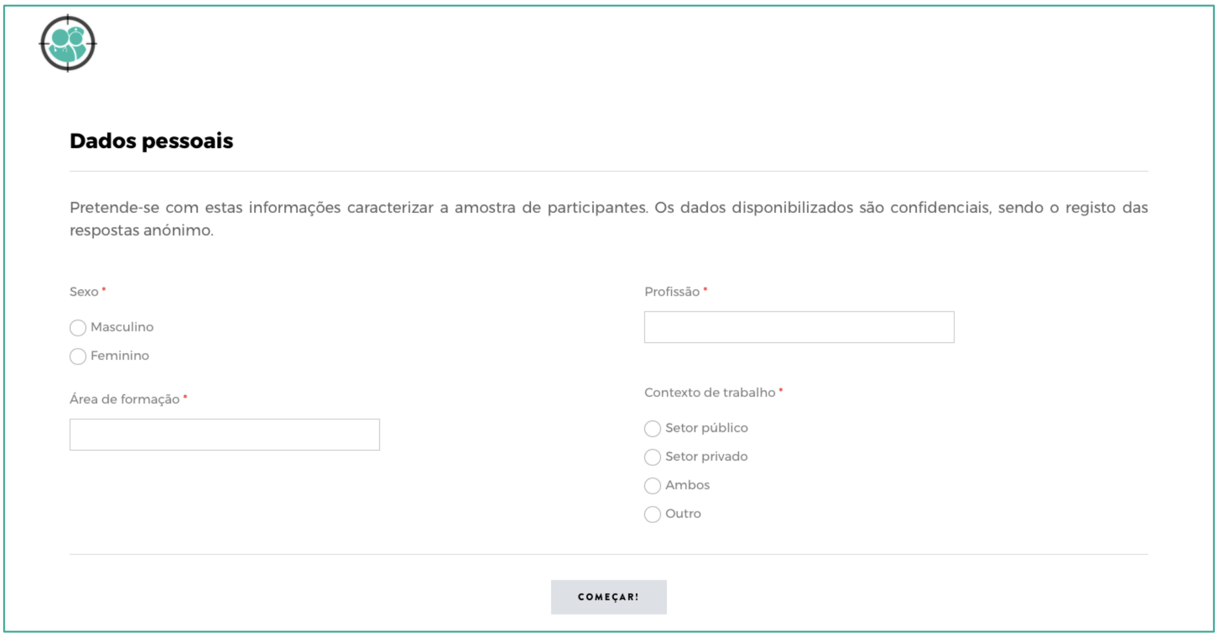


Figure 4.3: Registration page of the web-based platform, available at http://scenarios-hhrplan.weebly.com/registration.html.

Before starting the questionnaire, some additional important information is given: it is emphasized that after submitting each answer it is not possible to go back; there are not right or wrong answers; and possible TEEPSE influences should be considered (Figure 4.4). This final note is also highlighted by a simple scheme so that experts have a comprehensive view when answering the next questions.

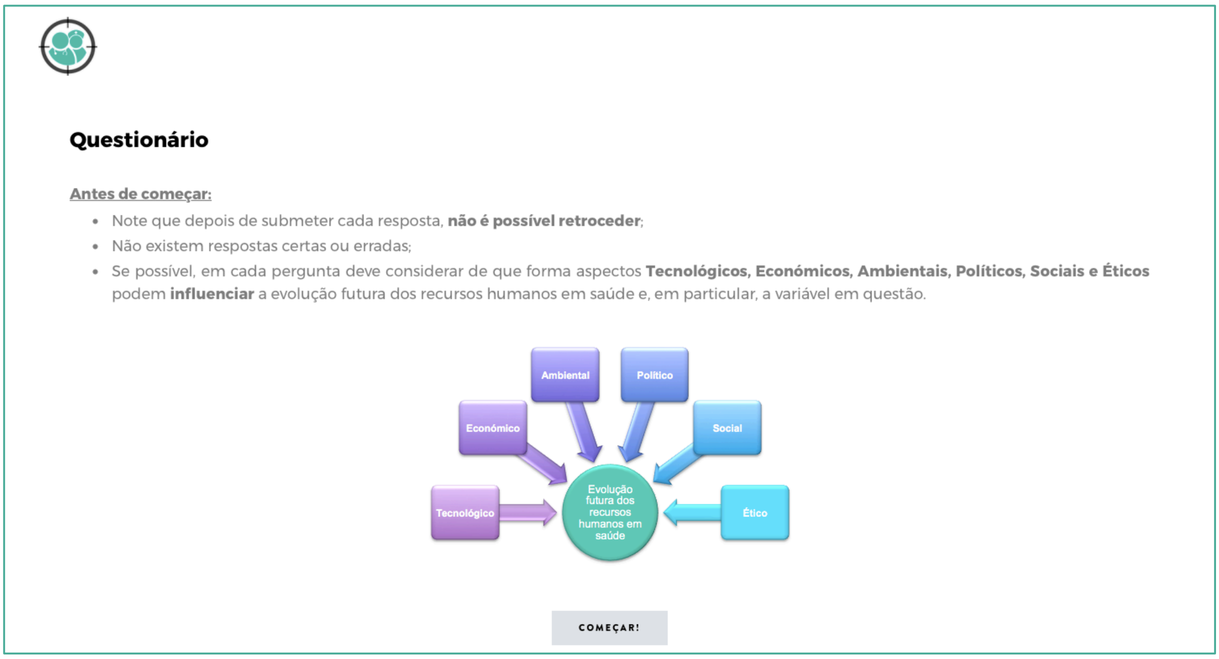


Figure 4.4: Information needed before starting the questionnaire, available at http://scenarios-hhrplan.weebly.com/start-form.html.

Please note that the input parameters of the model were referred to as variables only during this phase, in order to facilitate the understanding of the experts.

An example of the webpage with the questions for each parameter is available in Figure 4.5, in this case specifically for the variable “Education Costs”. The pages of the other variables are similar and can be found in Appendix C.

Figure 4.5: Webpage of the seventh parameter – Education Costs – available at http://scenarios-hhrplan.weebly.com/3-education-costs.html.

After submitting the answers for all the parameters, there was an end-page thanking each expert for his/hers participation. Two additional features were included in this page: on the one hand, it allowed experts to optionally input their email account to receive the results of the study, knowing it would break the anonymity; on the other hand, they could submit any existing doubt, suggestion or comment, either including their name and/or email or not (Figure C.7).

4.3. Aggregating and refining

All data received from the questionnaires was organized and analyzed using Microsoft Excel. Even though it was asked for experts to enumerate a group of factors (at least three) that would influence the future evolution of some parameter, each one of them was analyzed individually. Concerning the prediction of the future evolution of each parameter (the first question), it was realized that it could only be explained by the corresponding group of factors, and not by each of them individually. In fact, some people presented similar factors to explain different evolutions, which clearly shows that a deep analysis of the answers is extremely important. Hence, no correspondence could be made between the future evolution of each parameter and the individual factors, and in fact the future evolution was not explicitly used forward on the methodology. However, it is interesting information to have and is presented in Table 4.3.

Table 4.3: Expected evolution of each of the parameters by the 27 experts.[9]

Evolution	Increase	Decrease	Maintain
Demand of clinical specialties	20	3	4
Demand of surgical specialties	12	7	8
Demand of diagnosis specialties	15	6	6
Supply of clinical specialties	18	3	3
Supply of surgical specialties	14	5	5
Supply of diagnosis specialties	16	4	4
Education costs	15	3	5
Emigration rate	16	1	6
Immigration rate	9	5	9

For the purpose of this master thesis, the aggregation of the answers given by the experts was performed manually by the author. This process was done as carefully as possible, trying to achieve consistent results. Answers that appeared to make no sense were not considered.

This aggregation resulted in 74 groups that are, in fact, the drivers. These were named with a word/expression meant to be easily understood and organized accordingly to the TEEPSE framework. The results from this aggregation are presented in Table 4.4, along with the number of experts that mentioned each relationship between each driver and parameter, the sum of all causal links for the respective driver and the number of experts that mentioned each driver. For instance, 10 experts referred that a “higher specialization and improvement of care” has influence on the physicians' demand of clinical specialties. This first driver was mentioned 16 times overall, by 12 different experts.

Table 4.4: Results from the aggregation of the answers from the horizon scanning: 74 drivers; number of experts that mentioned each driver-parameter relationship (DC/S/D = physicians demand of *clinical*, *surgical* and *diagnosis* specialties; SC/S/D = physicians supply of *clinical*, *surgical* and *diagnosis* specialties; C = education costs in medicine; E = emigration rate; I = immigration rate); a sum of all causal links of each driver (#L); and the number of experts that mentioned each driver (#E).

DRIVER \ PARAMETER	DC	DS	DD	SC	SS	SD	C	E	I	#L	#E
TECHNOLOGICAL											
Higher specialization and improvement of care	10	1	0	2	0	0	3	0	0	16	12
Technological evolution (in diagnosis and therapeutics)	3	0	0	0	0	0	13	0	0	16	14
Developments in genomics and personalized treatment	2	0	1	2	0	0	0	0	0	5	5
Impact of Information Technologies and Artificial Intelligence	1	0	3	0	0	1	0	0	0	5	4
Innovation in surgical techniques	0	11	0	0	4	0	0	0	0	15	14
Balance between surgical and pharmaceutical treatments	0	3	0	0	0	0	0	0	0	3	3
Shift from surgical to non-invasive clinical methods	0	7	0	1	3	0	0	0	0	11	10
Safety of surgical techniques and anesthesia	0	1	0	0	0	0	0	0	0	1	1
Innovation in the diagnostic technologies	0	1	20	0	1	8	0	0	0	30	21
Automation	0	3	5	0	1	4	0	0	0	13	9
Development of tissue engineering	0	1	0	0	0	0	0	0	0	1	1
Telemedicine (diagnosis and monitoring)	0	1	2	0	0	0	0	0	0	3	2
Technologies in education	0	0	0	0	0	0	9	0	0	9	9
Existing advanced medical technologies in and outside Portugal	0	0	0	0	0	0	0	2	0	2	2
Importance of advanced research in and outside Portugal	0	0	0	0	0	0	0	1	0	1	1

[9] Please note that not all the lines sum 27 because some experts did not finish the questionnaire.

DRIVER \ PARAMETER	DC	DS	DD	SC	SS	SD	C	E	I	#L	#E
ECONOMIC											
Health insurances facilitate the access to healthcare	2	3	0	0	0	0	0	0	0	5	3
Drive for efficiency of healthcare resources	1	0	0	0	0	0	0	0	0	1	1
Purchasing power for health	2	1	0	0	0	0	0	0	0	3	2
Horizontal and vertical substitution of physicians	2	0	1	0	0	2	0	0	0	5	5
Growth of the private healthcare market	0	0	1	2	0	3	1	2	1	10	6
Efficiency of the diagnosis technologies	0	0	1	0	0	2	0	0	0	3	3
Education costs	0	0	0	2	2	2	0	0	0	6	2
Flexibility of the healthcare market	0	0	0	1	1	1	0	0	0	3	1
Value of surgery in the health economy	0	0	0	0	1	0	0	0	0	1	1
Globalization of the health business	0	0	0	0	0	1	0	0	0	1	1
Drive for efficiency in the universities	0	0	0	0	0	0	4	0	0	4	4
Evolution of the costs with personnel (in Medical schools)	0	0	0	0	0	0	3	0	0	3	3
Private investors in the medical schools	0	0	0	0	0	0	1	0	0	1	1
Universities with better facilities	0	0	0	0	0	0	1	0	0	1	1
Wages and working conditions (Porugal vs. Abroad)	0	0	0	0	0	0	0	10	3	13	11
Easier transportation and communication	0	0	0	0	0	0	0	2	1	3	2
Evolution of the Portuguese economy	0	0	0	0	0	0	0	1	0	1	1
Attractiveness of the Portuguese healthcare market	0	0	0	0	0	0	0	0	14	14	14
Cheaper labor from outside Portugal	0	0	0	0	0	0	0	0	1	1	1
ENVIRONMENTAL											
Incidence of diseases	1	1	0	0	0	0	0	0	0	2	1
Climate change	1	0	0	0	0	0	0	0	0	1	1
POLITICAL											
Access to healthcare services	3	3	1	0	0	0	0	0	0	7	4
Physicians supply	3	2	1	0	0	0	0	8	8	22	14
Organization of hospitals in centers of excellence	0	1	0	0	0	0	0	0	0	1	1
Number of Med schools and vacancies	0	0	0	11	9	7	0	0	0	27	11
Distribution of wages between specialties	0	0	0	2	3	2	0	0	0	7	4
Distribution of vacancies between specialties	0	0	0	0	0	2	0	0	0	2	2
Focus on practical education	0	0	0	0	0	0	2	0	0	2	1
Evolution of the teacher/student ratio	0	0	0	0	0	0	3	0	0	3	3
Evolution of the course structure	0	0	0	0	0	0	2	0	0	2	2
Evolution of the education budget	0	0	0	0	0	0	1	0	0	1	1
Mutual recognition of medical qualifications	0	0	0	0	0	0	0	3	2	5	3
Smooth migratory flows	0	0	0	0	0	0	0	1	3	4	3
Internationalization of the healthcare market	0	0	0	0	0	0	0	2	3	5	3
Role of the Medical Council	0	0	0	0	0	0	0	0	1	1	1
SOCIAL											
Aging population	10	6	5	3	0	0	0	0	1	25	13
Incidence of chronic diseases	7	1	2	0	0	1	0	0	0	11	8
Patient empowerment	10	4	6	1	1	3	0	0	0	25	11
Shift to preventive medicine	1	2	3	2	0	0	0	0	0	8	7
Induced needs	1	1	1	0	0	0	0	0	0	3	1
Aesthetic medicine	0	1	0	0	0	0	0	0	0	1	1

DRIVER \ PARAMETER	DC	DS	DD	SC	SS	SD	C	E	I	#L	#E
Incidence of oncological diseases	0	2	0	0	0	0	0	0	0	2	2
Patient self-management	0	0	1	0	0	0	0	0	0	1	1
Physicians demand	0	0	0	6	8	8	0	0	0	22	10
Migration of physicians	0	0	0	3	3	2	0	0	2	10	5
Social status and attractiveness of the medical profession	0	0	0	6	5	5	1	0	0	17	7
Evolution of the healthcare policies and financing	0	0	0	3	3	1	0	0	0	7	3
Treatments' complexity and multidisciplinarity	0	0	0	1	0	0	0	0	0	1	1
Intellectual and vocational requirements	0	0	0	1	3	1	0	0	0	5	3
Work opportunities	0	0	0	1	2	1	0	0	0	4	2
Reduction in the family incomes	0	0	0	0	0	0	1	0	0	1	1
Students' internationalization trend	0	0	0	0	0	0	1	0	0	1	1
Demand in other countries	0	0	0	0	0	0	0	3	2	5	5
"Anywhere" generation	0	0	0	0	0	0	0	6	2	8	6
Importance of language and culture in the migration	0	0	0	0	0	0	0	2	4	6	4
Racism and xenophobia	0	0	0	0	0	0	0	0	1	1	1
Population decrease	0	0	0	0	0	0	0	0	1	1	1
ETHICAL											
Guidance of patients (from primary to secondary care)	0	0	0	1	0	0	0	0	0	1	1
New referencing networks	0	0	0	0	0	1	0	0	0	1	1

4.4. Clustering

The 74 drivers were then clustered into seven key variables, in order to guarantee their independence. This was achieved by looking for causal relationships or influences between the different drivers and creating cognitive maps. It should be emphasized that these relationships are not directly associated to the answers given by the experts and presented in Table 4.4, but were rather created by the researchers through self-knowledge and desk research.

The cognitive maps were built using draw.io[10], which is a browser-based diagramming application. Given that these maps were built only to help in the clustering process, the simplest notation possible was used: circles represent the drivers and arrows – which may be one or two-sided – are causal relationships or influences. The map corresponding to the first key variable – "Aging and the rise in chronic disease" – is represented in Figure 4.6, and the other 6 maps are available in Appendix D.

The description of the seven key variables can be found in Tables 4.5 to 4.11, along with the drivers they include and the frequency of mention. This was calculated as the fraction of the 27 experts that mentioned at least one of the drivers included (i.e. the *union* of all the experts).

[10] https://www.draw.io

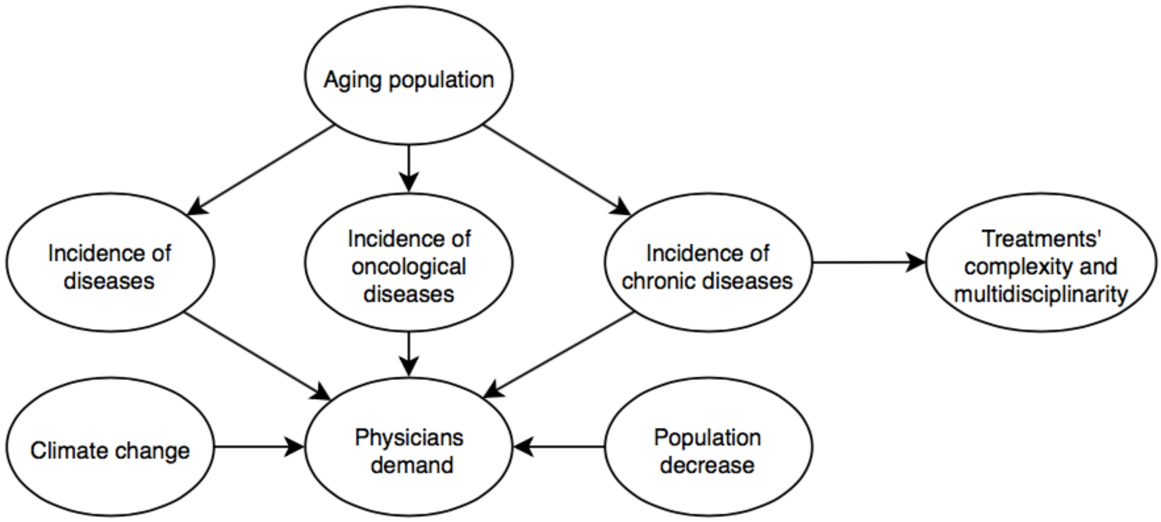


Figure 4.6: First cognitive map - Aging and the rise in chronic disease.

Table 4.5: Aging and the rise in chronic disease: drivers, frequency of mention and description.

	A – Aging and the rise in chronic disease
Drivers (8)	Aging population; Incidence of chronic diseases; Incidence of diseases; Incidence of oncological diseases; Treatments' complexity and multidisciplinarity; Population decrease; Physicians demand; Climate change
Frequency of mention	70%
Description	An increase in the average life span, along with a lower birth rate and a better health care in the developed countries, has driven to an increasingly aging population. As the population ages, the relevance of chronic diseases and even complex multimorbidity (two or more chronic diseases) increases, leading to an increase in the demand for general practitioners (family medicine, internal medicine and, in future, geriatrics) and possibly to a decrease in the other specialties. The treatment of patients with multipathologies should include a more integrated approach between specialties and also between the primary and secondary care, as the complexity of the pathways increases.

Table 4.6: Access to healthcare and evolution of the private healthcare market: drivers, frequency of mention and description.

	B – Access to healthcare and evolution of the private healthcare market
Drivers (8)	Access to healthcare services; Health insurances facilitate the access to healthcare; New referencing networks; Induced needs; Growth of the private healthcare market; Organization of hospitals in centers of excellence; Flexibility of the healthcare market; Guidance of patients (from primary to secondary care)
Frequency of mention	59%

Description	Depending on the flexibility of the healthcare market, the growth of the private healthcare market, along with the spread of health insurances, will facilitate the access to healthcare, with the risk of increasing not only the care needed but also the unnecessary (induced needs). The access to healthcare may also be influenced by new referencing networks, which allow a faster guidance of patients from primary to secondary care. The organization of hospitals is indeed crucial, with the possibility of being organized in centers of excellence in the future.

Table 4.7: Patient empowerment and self-management: drivers, frequency of mention and description.

C – Patient empowerment and self-management	
Drivers (3)	Patient empowerment; Patient self-management; Aesthetic medicine
Frequency of mention	44%
Description	Patients are more aware of their needs and want to be in control of their health, not only through healthcare but also using self-diagnosis techniques. They want to know more about their health status and how to improve it. Patients are also more demanding and have greater expectations for healthcare, increasing the demand for specialized care. This increased knowledge makes them less afraid of surgeries, which may cause an increase in aesthetic medicine (together with the social importance of image in today's world).

Table 4.8: Mutual recognition of medical qualifications and attractiveness of the Portuguese HC market: drivers, frequency of mention and description

D – Mutual recognition of medical qualifications and attractiveness of the Portuguese healthcare market	
Drivers (18)	Students' internationalization trend; "Anywhere" generation; Easier transportation and communication; Smooth migratory flows; Social status and attractiveness of the medical profession; Work opportunities; Existing advanced medical technologies in and outside Portugal; Importance of advanced research in and outside Portugal; Attractiveness of the Portuguese healthcare market; Mutual recognition of medical qualifications; Internationalization of the healthcare market; Importance of language and culture [in the migration]; Racism and xenophobia; Globalization of the health business; Migration of physicians; Demand in other countries; Wages and working conditions (Portugal vs. abroad); Cheaper labor from outside Portugal
Frequency of mention	85%

Description	The migration of physicians will depend mostly on three factors: (1) the openness of the students and physicians to move, (2) the regulations considering the recognition of medical qualifications in different countries and (3) the existing variation of working conditions. To start with, there is an increasing openness of the Portuguese mentality, decreasing the need to live in the same country all life long. This "anywhere" generation will indeed develop strategies to work without geographical borders, which is facilitated by easier and better communications and transportations. Secondly, given the needs and demand for doctors across the world, *global* policy actions may take place to regulate the mutual recognition of medical qualifications and consequently facilitate the migration of doctors (not only in Europe but also between the different continents). With the globalization and internationalization of the healthcare market, there is a global competition for the best jobs as the migration of physicians to acquire experience in other markets is increasingly more common. Thirdly, the migration of physicians will rely on the social status and attractiveness of the medical profession, the existing work opportunities, wages and working conditions, advanced research and medical technologies.

Table 4.9: Evolution of the Portuguese economy and of public funding in the health sector: drivers, frequency of mention and description.

E – Evolution of the Portuguese economy and of public funding in the health sector	
Drivers (8)	Purchasing power for health; Reduction in the family incomes; Evolution of the Portuguese economy; Role of the Medical Council; Evolution of the healthcare policies and financing; Drive for efficiency of healthcare resources; Distribution of vacancies between specialties; Distribution of wages between specialties
Frequency of mention	37%
Description	The evolution of the Portuguese economy directly impacts the average family incomes and consequently the purchasing power for health. On the other hand, the evolution of the healthcare policies and financing, together with social demands, may be an incentive to improve the organization of healthcare resources and streamline processes, leading to an increase in efficiency. The role of the Medical Council in this readjustment shall not be forgotten, especially when it comes to the balance in vacancies and wages between specialties.

Table 4.10: Medical course structure and changes in Med Schools: drivers, frequency of mention and description.

F – Medical course structure and changes in Med Schools	
Drivers (13)	Number of Med schools and vacancies; Physicians supply; Intellectual and vocational requirements; Private investors in the medical schools; Evolution of the education budget; Drive for efficiency in the universities; Technologies in education; Evolution of the course structure; Focus on practical education; Universities with better facilities; Evolution of the teacher/student ratio; Evolution of the costs with personnel (in Medical schools); Education costs

Frequency of mention	85%
Description	The evolution of the education budget will influence the drive for efficiency in the universities – both in the management of staff and the optimization of academic resources – and the use of technologies in education. Probably, there will be an increase in the number and complexity of the technological support material needed to teach, including the widespread use of the computer and specific software, simulation equipment, and possibly e-learning. This technological evolution in teaching may have different impacts in the role of teachers: on the one hand, a more active participation may be needed when compared to traditional lectures to hundreds of students; on the other hand, the support given by alternative pedagogic methods (such as simulation equipment and e-learning) may decrease the human effort needed.

Table 4.11: Technological evolution in health: drivers, frequency of mention and description.

G – Technological evolution in health	
Drivers (16)	Shift to preventive medicine; Efficiency of the diagnosis technologies; Horizontal and vertical substitution of physicians; Technological evolution (in diagnosis and therapeutics); Developments in genomics and personalized treatment; Innovation in the diagnostic technologies; Telemedicine (diagnosis and monitoring); Impact of Information Technologies and Artificial Intelligence; Automation; Higher specialization and improvement of care; Innovation in surgical techniques; Balance between surgical and pharmaceutical treatments; Shift from surgical to non-invasive clinical methods; Development of tissue engineering; Safety of surgical techniques and anesthesia; Value of surgery in the health economy
Frequency of mention	96%
Description	Developments in histological, cellular, molecular and genetic-based diagnosis may improve the prediction of the risk of disease, patient diagnosis and treatment, resulting in a personalized treatment. These developments, along with a better understanding of diseases and their mechanisms, lead to a greater specialization of medicine. In fact, an increased efficiency in the diagnosis technologies leads to a faster and more accurate diagnosis, allowing a shift to preventive measures and possibly to non-invasive therapies. The emergence of new surgical techniques, safer and more efficient, highly increases the range of therapeutic alternatives, not forgetting the possibilities of tissue engineering. Moreover, the increased use of Information Technologies and Artificial Intelligence to aggregate information and support decision will free highly differentiated resources. Automation will also play a big role both in diagnosis and therapeutics and may result in a reassessment of tasks between different medial specialties (horizontal substitution) and between different work classes, such as physicians and nurses (vertical substitution), as there is a need of professionals who can operate these new technologies.

4.5. Morphological Analysis

This preliminary application of the methodology also aimed to test a new software program, *FIL – Future in Logic*, which can be used for morphological analysis. It is still under development and was created by António Alvarenga and Marco Alves, resulting from the cooperation between *ALVA Research and Consulting*[11] and *WavEC Offshore Renewables*[12]. However, Morphol, an existing software reported in the literature, was also used to benchmark and confirm the results.

To perform the morphological analysis one needs to outline, for each one of the already defined key variables, hypotheses of future evolution (Table 4.12). These hypotheses have three main characteristics: they must be plausible, contrasted and challenging. We thought of having two hypotheses for each key variable, but it was understood that key variable D – Attractiveness of the Portuguese healthcare market – clearly had three different possible future evolutions. Thus, having two hypothesis for each of the six key variables, and three hypothesis for the remaining one, the number of solutions in the initial morphological space is $2^6 \times 3 = 192$.

Table 4.12: Key variables and hypothesis

	Key variables		Hypothesis
A	**Aging and the rise in chronic disease**	1	Aging, rise in chronic diseases and consequent increase in the complexity and multidisciplinarity of the pathways.
		2	Increase in the birth rate and consequent rearrangement of the age pyramid.
B	**Access to healthcare and evolution of the private healthcare market**	1	Maintenance of the access to healthcare: market not flexible enough to allow the growth of the private market; organization of hospitals and pathways in the public sector remain the same.
		2	Better access to healthcare: the spread of health insurances and the growth of the private market facilitate the access to this sector; better referencing networks improve the access to the public sector.
C	**Patient empowerment and self-management**	1	Maintenance of the information asymmetry on health services: patient awareness and empowerment remains the same.
		2	Increase on patient's awareness and expectations, starting to have an active role in managing their health.
D	**Mutual recognition of medical qualifications and attractiveness of the Portuguese HC market**	1	Mutual recognition of medical qualifications at international level is very limited, along with the closure of borders and troubled migratory flows.
		2	Medical qualifications recognized worldwide, allowing the migration of physicians. However, Portugal is not attractive enough to them due to low investment in advanced research and medical technologies, along with worse working conditions when compared to other countries.
		3	Medical qualifications recognized worldwide, allowing the migration of physicians who find the Portuguese market attractive due to the investment in advanced research and medical technologies and better working conditions.

[11] http://www.alva-rc.com/index.html
[12] http://www.wavec.org

Key variables			Hypothesis
E	**Evolution of the Portuguese economy and of public funding in the health sector**	1	Low level of growth of the Portuguese economy, with increased restrictions in the health budget. Vacancies and wages between medical specialties unbalanced.
		2	Recovery of the Portuguese economy and increased financing for health. New policies improve the management of the vacancies and wages between medical specialties.
F	**Medical course structure and changes in Medical Schools**	1	The budget for medical universities and their autonomy do not allow for big changes in teaching. Lack of new technologies and practical classes limited by old facilities.
		2	Increased efficiency in the universities and evolution of the medical course structure, with focus on practical education and the use of new technologies.
G	**Technological evolution in health**	1	Slow adoption of new technologies in the health sector, either because of financial or ethical constraints.
		2	Technological evolution and fast introduction of new health technologies, with a big focus on automation, information technologies and artificial intelligence and telemedicine.

This initial space was reduced with the addition of eight pairwise exclusion constraints represented in the cross-consistency assessment matrix (Table 4.13). These constraints exist mostly due to the relationship between the evolutions of the Portuguese economy (E), medical schools (F), technology in health (G) and migration of doctors (D) and are detailed in Appendix E.

Table 4.13: Cross-Consistency Assessment matrix (the letters and numbers represent the key variables and respective hypothesis, defined in Table 4.12). Orange cells represent pairwise exclusion constraints.

	A1	A2	B1	B2	C1	C2	D1	D2	D3	E1	E2	F1	F2	G1	G2
A1															
A2															
B1															
B2															
C1															
C2															
D1															
D2											D2E2				
D3										D3E1				D3G1	
E1													E1F2		E1G2
E2												E2F1			
F1															F1G2
F2														F2G1	
G1															
G2															

These exclusion constraints were included in the FIL software (Figure 4.7) in order to reduce the morphological space. They are extremely important, not only because they exclude the configurations that theoretically do not make sense, but also to reduce the morphological space into something that can actually be analyzed. Even though Morphol has a similar function, in the available version it does not work and so each one of the resulting scenarios (given from FIL and confirmed in Microsoft Excel) had to be selected *a posteriori*.

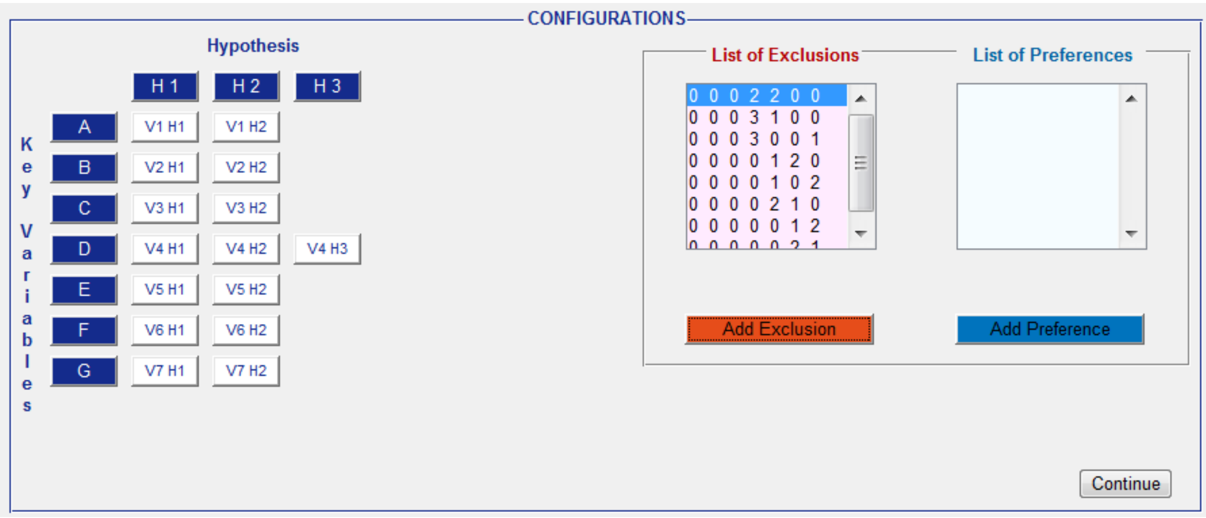


Figure 4.7: List of Exclusions inserted in the FIL software.

Chapter 5

Results

In this section the results from the applied methodology will be presented and discussed. Please note that in a foresight methodology the intermediary results are also important as they represent an incredible amount of information. Thus, the results from the morphological analysis and the preliminary scenario narratives are described in here, even though they still take part of the methods.

5.1. Results from the morphological analysis

The exclusions detailed in Table 4.13 were included in the FIL software (Figure 4.7) and gave rise to the Indicator Matrix, which is partly presented in Figure 5.1 (as it appears in the software) and completely in Table 5.1. This matrix lists all the internally consistent scenarios and their respective Proximity Indicators:

- **"CT"**: Sum of common hypothesis between the specific scenario and all the others. For instance, if the totality of the internally consistent scenarios were "111", "211" and "121", the "CT" from the first scenario would be $1 + 1 + 2 = 4$, as there is one scenario with "1" as the first hypothesis, one scenario with "1" and the second hypothesis and finally two scenarios with "1" and the third hypothesis.
- **"CM"**: Number of scenarios that differ in only one configuration. For the same example ("111", "211" and "121"), the "CM" of the first scenario would be $1 + 1 = 2$, since the other two scenarios only differ in one configuration. These scenarios are specified as the "Closest Scenarios".
- **"CX"**: Number of scenarios that are completely different. Using the same example, the "CX" of "111" would be zero.

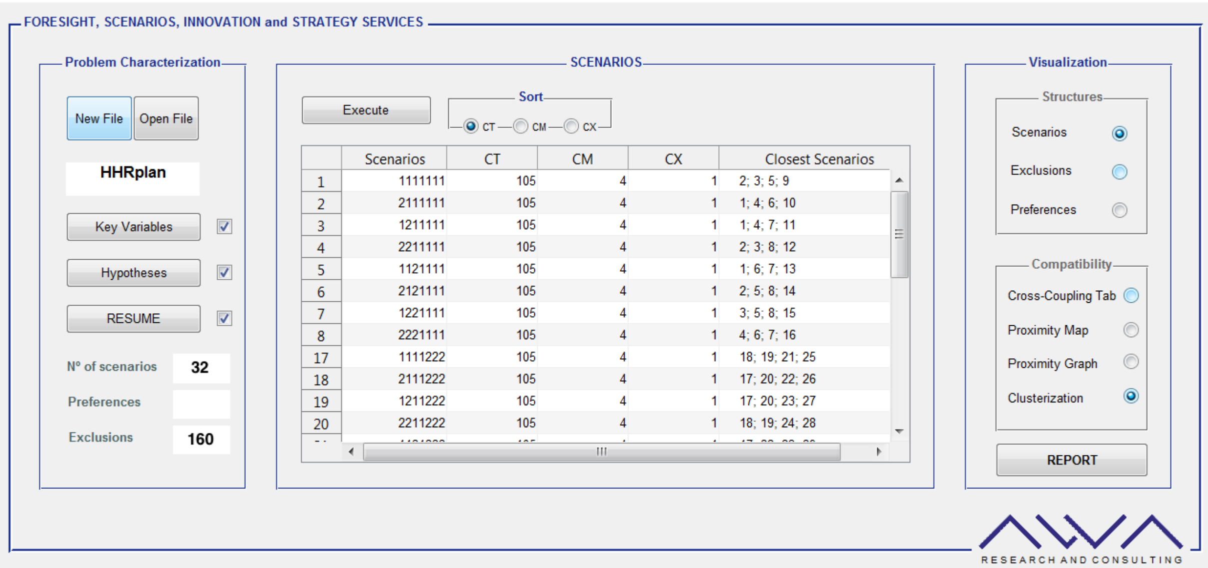


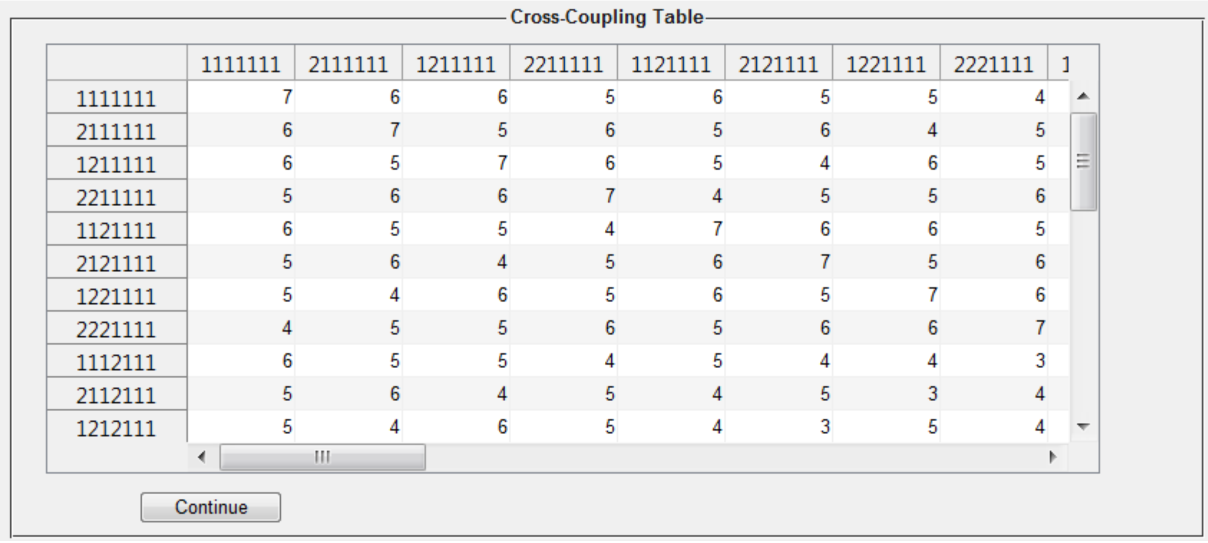
Figure 5.1: Indicator matrix from the FIL software, including the internally consistent scenarios and the respective proximity indicators (CT, CM and CX) and closest scenarios. Considering each scenario, "CT" refers to the sum of common hypothesis with the other scenarios; "CM" is the number of scenarios that differ in only one configuration; and "CX" represents the number of scenarios that are completely different. Complete matrix in Table 5.1.

Table 5.1: Complete indicator matrix, copied from FIL.

	Scenarios	CT	CM	CX	Closest Scenarios
1	1111111	105	4	1	2; 3; 5; 9
2	2111111	105	4	1	1; 4; 6; 10
3	1211111	105	4	1	1; 4; 7; 11
4	2211111	105	4	1	2; 3; 8; 12
5	1121111	105	4	1	1; 6; 7; 13
6	2121111	105	4	1	2; 5; 8; 14
7	1221111	105	4	1	3; 5; 8; 15
8	2221111	105	4	1	4; 6; 7; 16
9	1112111	97	4	2	1; 10; 11; 13
10	2112111	97	4	2	2; 9; 12; 14
11	1212111	97	4	2	3; 9; 12; 15
12	2212111	97	4	2	4; 10; 11; 16
13	1122111	97	4	2	5; 9; 14; 15
14	2122111	97	4	2	6; 10; 13; 16
15	1222111	97	4	2	7; 11; 13; 16
16	2222111	97	4	2	8; 12; 14; 15
17	1111222	105	4	1	18; 19; 21; 25
18	2111222	105	4	1	17; 20; 22; 26
19	1211222	105	4	1	17; 20; 23; 27
20	2211222	105	4	1	18; 19; 24; 28
21	1121222	105	4	1	17; 22; 23; 29
22	2121222	105	4	1	18; 21; 24; 30
23	1221222	105	4	1	19; 21; 24; 31
24	2221222	105	4	1	20; 22; 23; 32
25	1113222	97	4	2	17; 26; 27; 29
26	2113222	97	4	2	18; 25; 28; 30
27	1213222	97	4	2	19; 25; 28; 31
28	2213222	97	4	2	20; 26; 27; 32
29	1123222	97	4	2	21; 25; 30; 31
30	2123222	97	4	2	22; 26; 29; 32
31	1223222	97	4	2	23; 27; 29; 32
32	2223222	97	4	2	24; 28; 30; 31

The same Indicator Matrix was obtained using the Morphol software, confirming the results. Likewise, both programs achieved a similar Cross-Coupling Table, where the number of common hypothesis between each pair of scenarios is represented (Figure 5.2 and Appendix E).

Moreover, both programs have similar outputs that help to visualize the reduced morphological field and choose the most representative scenarios, mainly the Proximities Map and Proximities Graph.



Cross-Coupling Table

	1111111	2111111	1211111	2211111	1121111	2121111	1221111	2221111
1111111	7	6	6	5	6	5	5	4
2111111	6	7	5	6	5	6	4	5
1211111	6	5	7	6	5	4	6	5
2211111	5	6	6	7	4	5	5	6
1121111	6	5	5	4	7	6	6	5
2121111	5	6	4	5	6	7	5	6
1221111	5	4	6	5	6	5	7	6
2221111	4	5	5	6	5	6	6	7
1112111	6	5	5	4	5	4	4	3
2112111	5	6	4	5	4	5	3	4
1212111	5	4	6	5	4	3	5	4

Figure 5.2: Cross-Coupling Table obtained from FIL. Symmetric matrix where each value represents the number of common hypothesis between both scenarios. The complete table is present in Appendix E.

5.1.1. Morphological Space/ Proximities Map

The Proximities Map is in fact a two-dimensional representation of the Morphological Space where the relative location of each scenario is given by the distances between them. These distances are actually calculated from the number of common configurations between the different scenarios, represented in the Cross-Coupling Table. This map is extremely important for the analysis of the resulting scenarios since it shows which are the closest and most remote scenarios.

The maps obtained by FIL and Morphol are presented in Figures 5.3 and 5.4, respectively. At first sight, it appears that both maps differ greatly. A deeper analysis shows that in both maps, the same two groups of scenarios are easily distinguished (left vs. right), even though they are inverted. In fact, after examining each quadrant, one may conclude that, apart from an 180º rotation, they include the same scenarios.

It was already expected that the graphical outputs from both programs would be different, as they highly depend on the algorithm used to represent the distances aforementioned. Nevertheless, given the relevance of this map, it is important that we can reach similar conclusions using any morphological analysis software, which is in fact observed.

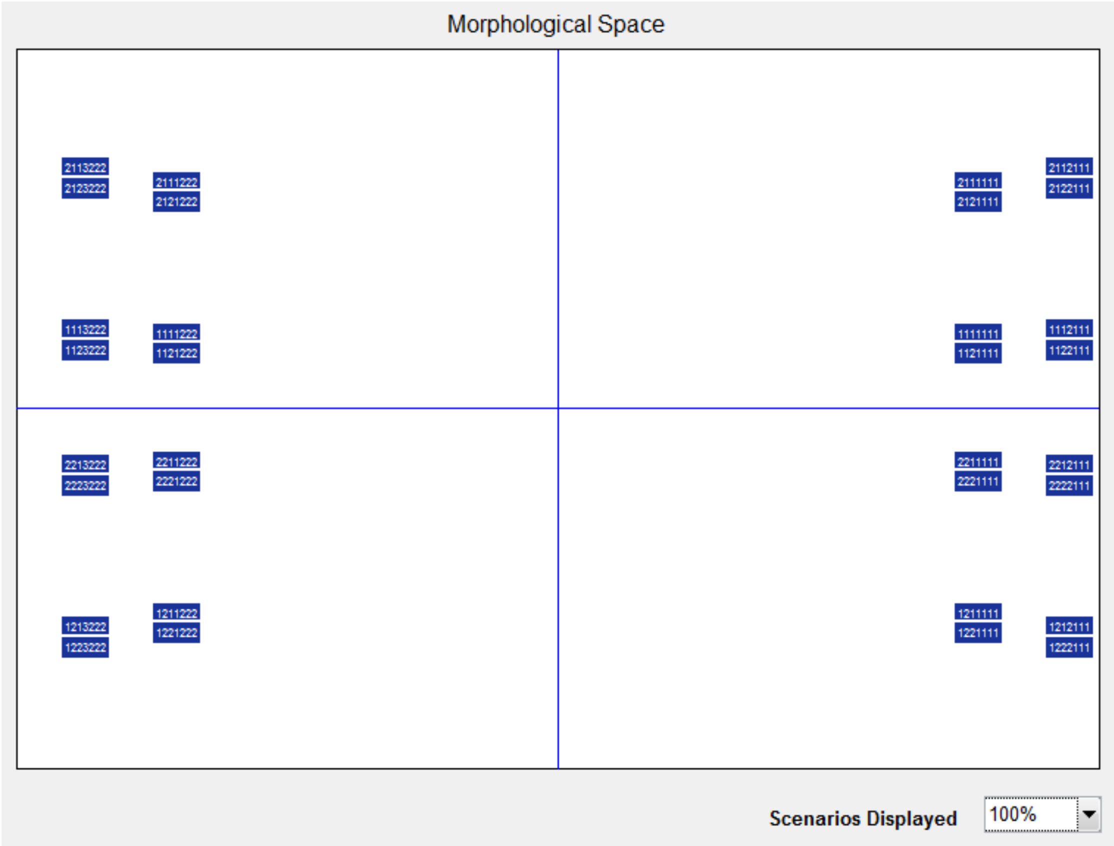


Figure 5.3: Proximities Map obtained by the FIL software.

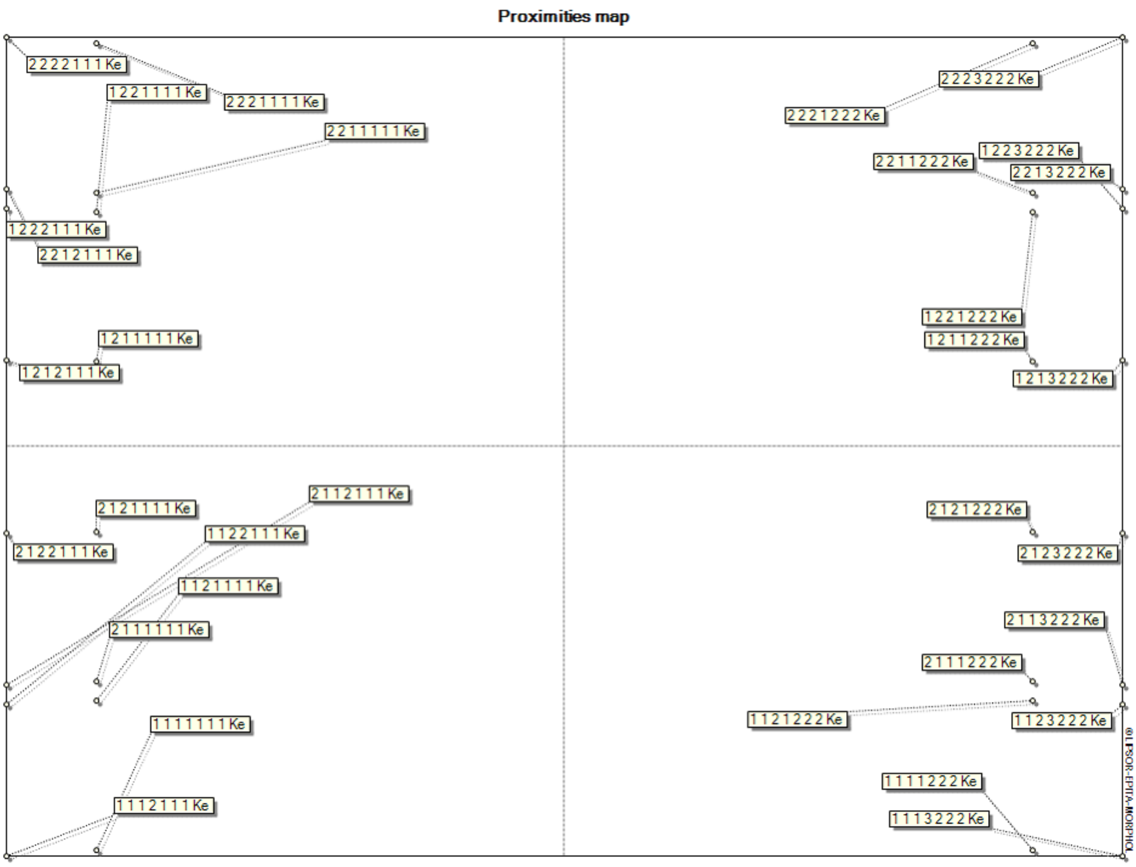


Figure 5.4: Proximities Map obtained by the Morphol software.

5.1.2. Proximities Graph

The Proximities Graph is a direct representation of the Cross-Coupling Table, with all the internally consistent scenarios and linkages between them, i.e. the number of common hypothesis between each pair of scenarios. In these graphs the relative position of each scenario does not have any meaning. To facilitate the visualization, only the linkages between the closest scenarios – with 5 or 6 common hypothesis – were represented in the graphs obtained from FIL and Morphol (Figures 5.5 and 5.6, respectively). The output from Morphol is much less confusing than the one obtained from FIL, facilitating the analysis of the problem. Figure 5.6 shows once more the existence of two well-delimited groups. Even though it appears that they are not related, we cannot forget that only the strongest linkages (with 5 and 6 common hypothesis) are represented. The complete Proximity Graphs are presented in Appendix F and show that these groups are in fact connected (Figures F.1 to F.3)

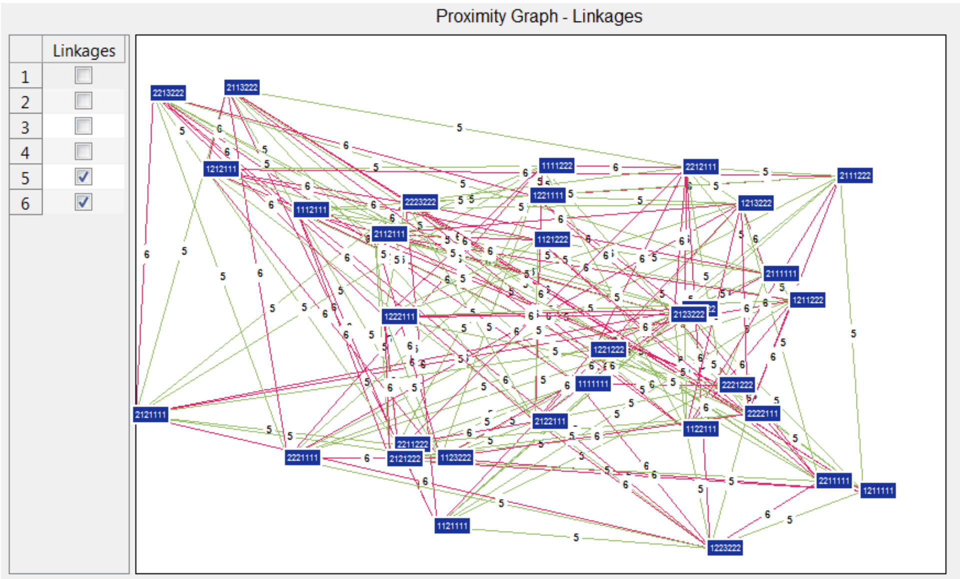


Figure 5.5: Proximities Graph from the FIL software. Only the linkages between scenarios with 5 (green) or 6 (red) hypothesis in common are presented in here.

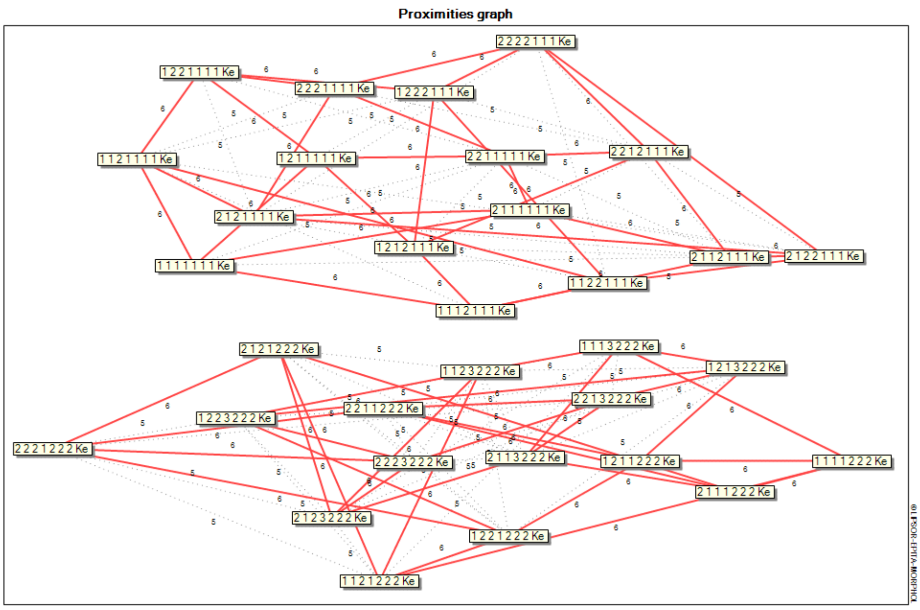


Figure 5.6: Proximities Graph from the Morphol software. Only the linkages between scenarios with 5 (dashed line) and 6 (solid red line) hypothesis in common are presented in here.

5.1.3. Hierarchical Binary Clustering Tree

FIL offers an additional output, which is a Hierarchical Tree that helps the user in the process of clustering (Figure 5.7). This is an interesting feature that is still under development, as they aim to include the option of choosing how many clusters the user wants, apart from the graphical visualization.

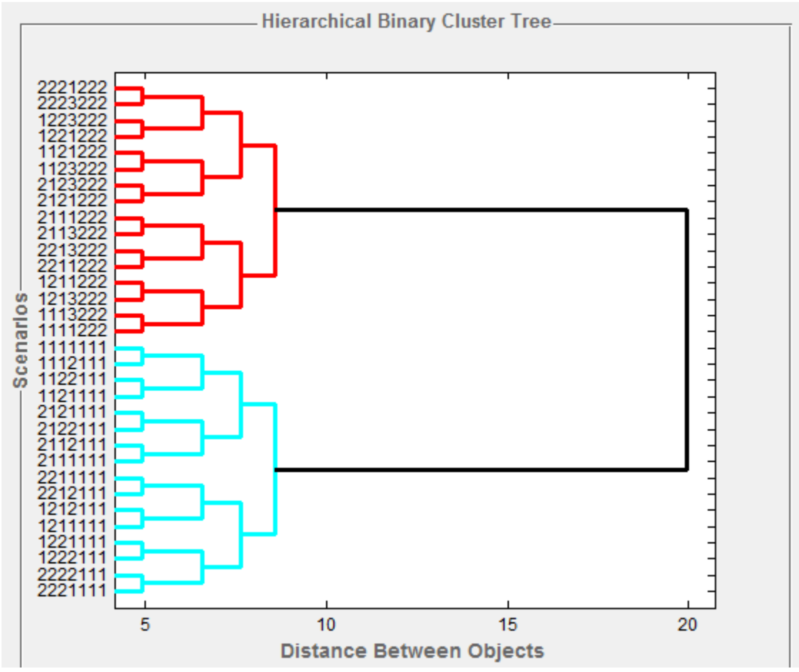


Figure 5.7: Hierarchical Binary Clustering Tree – output from FIL that helps clustering the scenarios, in this case in powers of two.

From Figure 5.7 it is clear that the generated scenarios can easily be clustered into two groups, or even other powers of two. The symmetrical look of this tree is not usual and happened by chance due to the exclusion constraints used, not having any special meaning.

5.1.4. Selection of scenarios

Finally, the major outcome from the morphological analysis is the selection of the most representative configurations within the reduced morphological space. These scenarios will be used next as a basis for the development of the preliminary scenario narratives.

It was decided that an adaptation of the Extreme World Method would be used. The Extreme World Method basically consists of selecting one scenario with all the positively resolved uncertainties, and another with all the negative ones (Goodwin & Wright 2009; Instituto Superior Técnico 2017b). Given that all the negative hypothesis were defined as being the *hypothesis 1* and all the positive ones as the *hypothesis 2* (or 3, when it exists), the two selected scenarios considering only this method would be “1111111” and “2232222”. Supposedly, these two scenarios are the most extreme ones and it is *certain* that the future will be somewhere in the middle. The variation used consisted in choosing two more scenarios, in order to include in-between realities. The choice of these two scenarios followed two criteria:

- They could not be included in the list of “closest scenarios” from the two extreme scenarios;
- The most representative scenarios should be chosen, which is given by the high CT indicator.

The analysis of the Hierarchical Binary Clustering Tree, together with the Proximities Map, also helped in this process: scenarios “2221111” and “1111222” where indeed chosen for respecting the two criteria and being as distant as possible between one another (and the extreme scenarios). A Proximities Map from Morphol with the selected scenarios marked is present in Figure F.4.

5.2. Preliminary scenario narratives

Starting from the combination of configurations from the selected scenarios, these will now be named and described. The narratives were enriched by all the information gathered from experts and written in the present, i.e. as if we were in 2047. The four storylines and respective combinations are “A Sick System” (1111111), “Healthy Country” (2223222), “Population One Technology Zero” (2221111) and “New Technology Meets Old Habits” (1111222).

5.2.1. “A Sick System” (1111111)

We are now in 2047. A rise in the average life span, along with a lower birth rate and a better health care in the developed countries, has resulted in an increasingly aging population. This results in a growth of the relevance of chronic diseases and even complex multimorbidity, leading to a recent increase in the demand for general practitioners and to a decrease in the other specialties. The access to healthcare remains the same, which is specially critic given the increased complexity of the clinical pathways derived from the rise in the number of patients with multipathologies: on one hand, the organization of hospitals and referencing networks cannot keep up with the development of clinical pathways; on the other hand, the growth of the private healthcare market and the health insurances is stagnated. In fact, this may be related to the low level of growth of the Portuguese economy in the past years, which caused not only a limited health budget, but also a low purchasing power for health services. This way, the healthcare resources need a reorganization to increase efficiency and update vacancies and wages discrepancy between specialties, bringing them to a balance.

Moreover, the amount and complexity of the technological material to support teaching increased significantly in the past years, but the Portuguese universities could not follow this trend, mostly due to their low budget and absence of autonomy. Therefore, medical courses lack the assets necessary for an appropriate practical teaching, resorting mainly to a theoretical one. This is reflected in the health sector in general: the large advances in medical technologies during the last decades are being very slowly adopted by the Portuguese healthcare market. At the social level, the information asymmetry between doctors and patients still exists, since the patient awareness and empowerment has not increased as it was expected in the past. Finally, and given that the mutual recognition of medical qualifications at international level is strained, possible disparities between supply and demand of physicians cannot be balanced by the migration of doctors.

5.2.2. “Healthy Country” (2223222)

The last three decades have been good for Portugal, and in particular for healthcare. To start, there has been an increase in the birth rate and consequent rearrangement of the age pyramid. Indeed, patients are more aware of their needs than ever before and are starting to have a more active role in managing their health. They are interested in knowing more about their health status and they use self-diagnosis techniques to control it. Alongside this, patients are more demanding and have greater expectations for healthcare, increasing the demand for specialized care. Moreover, the Portuguese economy is clearly recovered and there is an increase in financing for health. New policies improved the management of the vacancies and wages of medical specialties, bringing them to a balance and standardizing the demand and supply. Concerning the private healthcare market, it has grown in the last years, along with the spread of health insurances, which facilitates the access to healthcare. In the public sector, new referencing networks allow a faster guidance of patients from primary to secondary care, as well as the creation of specialized centers.

Technological evolution has reached both the medical education and practice. On the one hand, the increase in the education budget enhanced the use of technologies in this field, including the widespread use of the computer and specific software, simulation equipment, and e-learning; indeed, there has been an update in the medical course structure, focusing on practical education and the use of new technologies. On the other hand, the technological evolution enabled advances in medicine both for diagnosis and surgical techniques. Developments in histological, cellular, molecular and genetic-based diagnosis improved the understanding and risk prediction of disease, patient diagnosis, and treatment, leading to personalized treatment. Besides, the increased efficiency in the diagnosis technologies led to a faster and more accurate diagnosis, allowing grounds for preventive measures, not to mention the use of Information Technologies and Artificial Intelligence to aggregate information and support medical decision. The changes induced by technology, including the use of automation in diagnosis and therapeutics, lead to a reassessment of tasks between different medical specialties (horizontal substitution) and between different work classes, such as physicians and nurses (vertical substitution).

Lastly, the current economic paradigm, along with the investment in advanced research and medical technologies, has been very attractive to foreign doctors, thereby increasing physicians' immigration. This has been only possible given that the medical qualifications are recognized worldwide nowadays.

5.2.3. "Population One Technology Zero" (2221111)

The low level of growth of the Portuguese economy in the past years had consequences in the health domain, causing increased restrictions in the health budget as well as a low purchasing power for health. Given this economic pressure, along with social demands, the healthcare resources lack a reorganization to increase efficiency and update vacancies and wages between specialties, which are presently unbalanced. The low budget for the health sector also influences the slow adoption of new technologies in the Portuguese universities and in the health sector in general: the Portuguese healthcare market is not keeping up with the big advances in medical technologies of the last decades. All these factors highly limit the application of personalized treatment, preventive measures and early diagnosis.

Socially speaking, there have been improvements since the 2020's: the birth rate has been increasing, leading to a rearrangement of the age pyramid. Now, patients want to know more about their health status and the use of self-diagnosis techniques, starting to have an active role in managing their own health. They are also more demanding and have greater expectations for healthcare, increasing the demand for specialized care. More recently, there has been a growth of the private healthcare market, along with the spread of health insurances. These developments have facilitated the access to healthcare, but are associated with a possible increase of induced needs. Surprisingly, the management of the public sector is also improved, as new referencing networks allow a faster guidance of patients from primary to secondary care, along with the creation of specialized centers – probably due to the driving force of increasing efficiency. It is important to note that, given that the mutual recognition of medical qualifications at international level is very limited, possible unbalances between supply and demand of physicians cannot be balanced by the migration of doctors, reason why planning is extremely important.

5.2.4. "New Technology Meets Old Habits" (1111222)

The picture of the 2040's demography in the developed countries is of an increasingly ageing population, mainly caused by an increase in the average life span, low birth rate and better health care. As the population ages, the relevance of chronic diseases and even complex multimorbidity increases, leading to a recent increase in the demand for general practitioners and to a decrease in the other specialties. The treatment of patients with multipathologies would improve with a more integrated approach between specialties and also between the primary and secondary care, as the complexity of the clinical pathways increases. Unfortunately, the access to healthcare remains the same: on the one hand, the organization of hospitals and referencing networks does not match the needs of the population; on the other hand, the growth of the private healthcare market and the health insurances is stagnated. In Portugal, more investment in healthcare is possible due to a recovered economy. This has helped improve vacancy management and balance wages between medical specialties that is especially important given that, due to a lack of uniformity between countries, unbalances between supply and demand of physicians cannot be easily solved by the migration of doctors. An impact of the strong economy is the increase of the education budget, which has enabled a new focus on the usage of practical classes and new technologies in the medical course, including simulation equipment, and e-learning.

Furthermore, technological and medical advances have enabled great advances in the prevention and treatment of diseases. A better understanding of histological, cellular, molecular and genetic-based diagnosis is improving the patient diagnosis and treatment and even the prediction of the risk of a disease, resulting in a personalized treatment. The emergence of safer and more efficient surgical techniques highly increases the range of therapeutic alternatives, not forgetting the possibilities of tissue engineering. The increased usage of Information Technologies and Artificial Intelligence has enabled the automation of some processes related to disease prevention and treatment, causing some reassessment of tasks between different medical specialties (horizontal substitution) and between different work classes, such as physicians and nurses (vertical substitution). There is still a significant gap in information between doctors and patients caused by a slow increase in patient awareness and empowerment, but it appears that can be diminished with the use of new technologies.

5.3. Final workshop

This section describes the design of the final workshop process and protocols, even though it was not possible to schedule it in time. This fact shows a real and common struggle, which is the difficulty of combining the availability of several experts to arrange a meeting. However, this is a central step for foresight methodologies and so it will take place after the conclusion of this master thesis.

This social step consists on a half-day workshop and will be conducted in Portuguese, just like all material used (scenario narratives, charts, etc.). However, the examples presented in here are in English to illustrate the methodology.

To conduct this final workshop and follow the four-step protocol present in Section 3.8, the facilitator needs two main inputs: (1) the results from the morphological analysis and particularly the four preliminary scenarios translated to Portuguese and (2) the current values of the 9 input parameters. The team from the HHRPLAN may provide these values since they already did the desk research needed.

After discussing the work done and the storylines of the selected scenarios (*step i*), experts will receive four sheets of paper, each with a preliminary scenario narrative and a section asking them to qualitatively predict the evolution of each parameter under each scenario (*step ii*), similar to Table 5.2. This step mainly aims to consolidate the understanding of each scenario and make experts think about how the future will be for the nine parameters. In Table 5.2 "--" represents a high decrease of the current value, "-" a decrease, "0" a maintenance, "+" an increase and "++" a high increase; experts would mark in each line the evolution they found more suitable.

Table 5.2: Final workshop - example of the table that follows each scenario and aims to ask each expert a qualitative prediction of the evolution of each parameter in the next 30 years (high decrease "--"; decrease "-"; maintenance "0"; increase "+"; high increase "++").

Under this scenario, how do you think each parameter will evolve in the next 30 years?

Demand of clinical specialties	--	-	0	+	++
Demand of surgical specialties	--	-	0	+	++
Demand of diagnosis specialties	--	-	0	+	++
Supply of clinical specialties	--	-	0	+	++
Supply of surgical specialties	--	-	0	+	++
Supply of diagnosis specialties	--	-	0	+	++
Education costs	--	-	0	+	++
Emigration rate	--	-	0	+	++
Immigration rate	--	-	0	+	++

The next step (*step iii*) consists on the group discussion of all the individual previsions, in order to facilitate the final group prevision (*step iv*). For each one of the nine parameters, the facilitator will show a big chart (probably A2 size) to all participants, like to the one presented in Figure 5.8 but only with the current value marked (i.e. the one for 2017). Then, experts will be asked to quantitatively foresee the evolution on that parameter (in the example of Figure 5.8, the Emigration Rate) for the different scenarios.

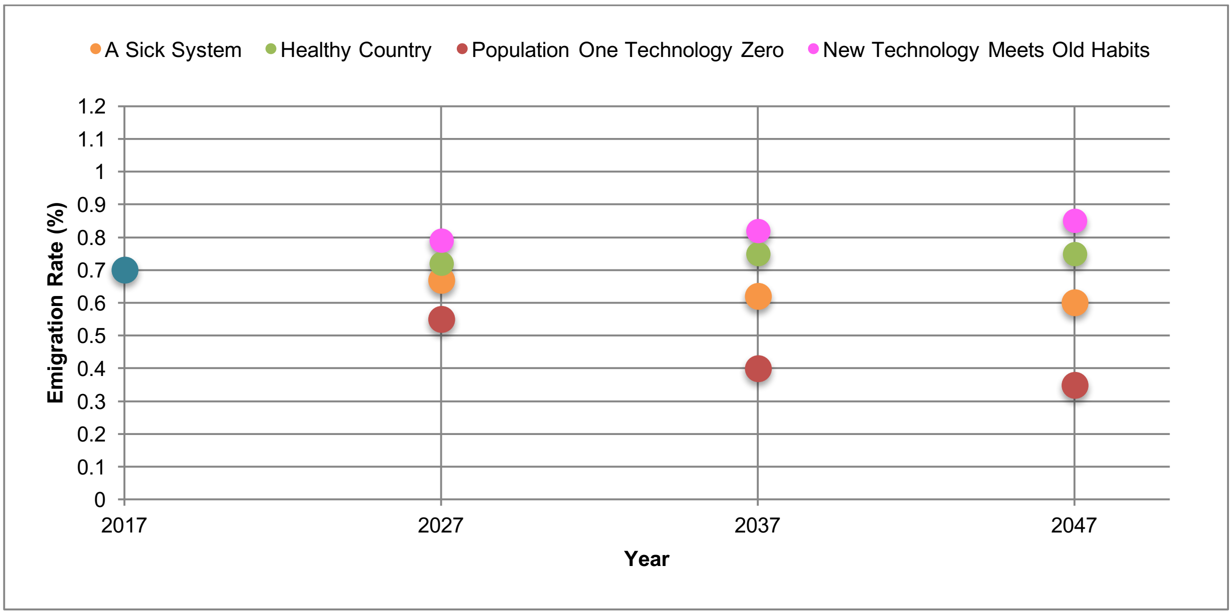


Figure 5.8: Final workshop - example of the chart that would be used to quantify the value of each parameter under each scenario.

5.4. Results from the Optimization Model

To finalize the methodology, we will need to go back to the MILP model and test it for the four scenarios, i.e. run it with the four coherent combinations of parameters elicitated in the previous step, as illustrated in Figure 3.1.

Indeed, the use of scenarios will add value to the optimization model by opening up new possibilities of analysis of the results. Thus, the differences in the solutions obtained must be considered and discussed, possibly through a second workshop with experts. It is advisable that this phase is conducted together with the researchers that built the model.

Chapter 6

Discussion

Scenario methodologies are still little known in the world of Operations Research. However, they appear to be extremely enriching, adding knowledge from a variety of experts to the *rigid* mathematical programming models. This is especially interesting when considering models with highly uncertain input parameters and with a long time horizon. On the down side, one shall not forget that these methods are time-consuming and subjective, in the sense that they highly depend on the experts included, the way the social steps are conducted and the data analyzed.

As expected, the application of the methodology provided various insights on the up and down sides of the proposed methodology, which can be used to adjust and improve it.

Fifty-three experts with different backgrounds were contacted, not counting the unknown number from ACSS. Anyway, 27 experts answered the questionnaire, which is an interesting number given that this is only a preliminary application of the methodology in the context of a master thesis. The variety on the backgrounds of the experts who accepted to take part in this study is also remarkable, as they include both doctors and non-clinicians from both the private and public sectors, not forgetting the ones that work in health technologies companies.

The web-based platform appears to have been a success, with the main advantages of being a cheap and easy way to contact with experts. This is a significant advantage especially when the respondents include people as busy as doctors usually are. Moreover, it allows for experts to indulge in anonymity and exclude the bias that may possibly happen during a workshop methodology. On the downside, it is possible to argue that it does not produce data as rich as the one generated with a face-to-face methodology, not to mention that any questions from the experts are hardly clarified.

Regarding the questioning protocol, it appears that the majority of experts were able to answer it easily. In fact, even though the first question (evolution) could not be directly related to each factor referred in the second question (but rather to the set of factors), it seems that asking for the qualitative evolution first helped thinking about the factors. Besides, the foresight of the evolution by each expert is information *per se*. Some respondents had problems while answering the questionnaire, mostly related to the chosen platform – and more specifically to the impossibility of going back. There was also a complain about the questioning protocol, particularly because of the established minimum of 3 factors for each parameter, arguing that it was time-consuming and increased the temptation of answering the same for different parameters. This phenomenon was indeed identified in some experts' answers, mostly for the questions related to the physicians' supply and demand.

The process of aggregating and refining the answers was very difficult and time-consuming: from what as seen, it does not exist any structured way to perform this task, and no foresight study includes details on this matter. A method was created and it is highly detailed in Figure 3.2, although it may have to be adapted depending on the nature of data. The analysis of the answers should definitely be done by a team of researchers to diminish the dependency on a person' judgment.

Concerning the clustering of drivers into key variables, the use of cognitive maps was very helpful, but it is still a subjective task as the information needed to build them was not all given by experts. Thus, this step of the methodology should include a social side, perhaps through a workshop with experts.

Morphological analysis is a very interesting method to reduce the space of hypothesis and visualize all the scenarios, helping to choose the most representative ones. Since it is a structured method, logical and easy to understand and explain, it is a good tool to standardize the use of scenarios. Still, one should never forget the meaning of each *combination of numbers* (i.e. scenario). In fact, the exclusion constraints will highly influence the results and thus it would be interesting to build them together with experts, perhaps in the clustering workshop. Future In Logics (FIL) proved to be an interesting software for morphological analysis, albeit it still has some limitations characteristic from an under-development software. A special note must be given to the Hierarchical Binary Clustering Tree for facilitating the process of choosing the representative scenarios.

Building preliminary scenarios before the final workshop seems to be a good approach, as it facilitates the contact with experts. As the final workshop was not tested, the final steps of the methodology cannot be well discussed and indeed may need adjustments.

Chapter 7

Conclusions and Future Work

This dissertation presents a new methodology for building scenarios to enhance the planning in healthcare with mathematical programming models, combining different methods from the literature. It does not follow a unique school of scenarios, but rather a combination of some elements from the Intuitive Logics approach together with other tools characteristic from *La Prospective*, such as cognitive maps and morphological analysis. Specifically, the proposed methodology includes the following main steps: gathering of drivers through a web-based questionnaire applied to experts in the health sector; building of cognitive maps to cluster the drivers into key variables; use of morphological analysis to create the scenarios; final workshop with experts to quantify the intrinsically uncertain input parameters from the model. It is worth emphasizing that, unlike the majority of the foresight studies found in the literature review, an effort was made to detail and clarify each step of the process.

Overall, a scenario methodology is an interesting way of dealing with the uncertainty analysis of planning models. The process itself is extremely rich, especially considering the contact with experts. During these social steps, experts are obligated to think about the future and explicit their assumptions about it, which is rarely seen in other contexts. The achievement of coherent combinations of input parameters to run the model is also remarkable, as the outputs will have an underlying meaning and thus its analysis will highly improve the robustness of the model and the resulting conclusions for the planning of HHR.

The developed methodology was first tested for HHR planning, more precisely to provide inputs to an optimization model developed within the *HHRPLAN project*. This project aims to plan the vacancies to open/close in the medical course and in each medical specialization in the next 30 years and some of its input parameters are highly uncertain given this time horizon.

Several insights appeared from this application. To start with, the web-based platform and questioning protocol can be considered a success, even though some adjustments may be needed in the future: a more friendly platform must be used to build the questionnaire, in the sense that experts should be able to go back; the number of factors needed for each parameter should be reviewed and decreased or, alternatively, the question may be changed from an obligation to a preference (i.e. "*it is desirable* that you mention at least three factors"). Regarding the aggregation of data, it should definitely be performed by a team and not by a researcher itself, as it is an important step and highly dependent on the person's judgment. It is also advisable to include an additional social step in the process of clustering, so that cognitive maps can be built together with experts. Finally, the software tested to perform the morphological analysis – Future In Logic (FIL) – presented good outputs and thus has a high potential for future studies. Sadly, the final workshop has not taken place yet and hence the methodology was not finished: we were not able to *close the loop* and return to the MILP model to test the combinations of parameters from each scenario and check its robustness.

Given the amount and quality of information that culminated in the four scenarios created, it is a pity that the methodology was not finished. Therefore, we hope that this application will be finished outside this master thesis, including the final workshop, the return to the optimization model and the analysis and discussion of the outputs obtained, possibly through a second workshop with experts.

Apart from the conclusion of the application started in this dissertation, the main suggestions of further work consist on: (1) improvement of the web-based platform, including the option of going back; (2) revision of the questioning protocol to facilitate the answering; (3) use of a team to aggregate the data and compare the results and (4) inclusion of a social step to build the cognitive maps together with experts.

References

Abdelaziz, F. Ben & Masmoudi, M., 2012. A multiobjective stochastic program for hospital bed planning. *Journal of the Operational Research Society*, 63(4), pp.530–538.

Almeida, Á.S. & Cima, J.F., 2015. Demand uncertainty and hospital costs: an application to Portuguese public hospitals. *The European Journal of Health Economics*, 16, pp.35–45.

Amer, M., Daim, T.U. & Jetter, A., 2013. A review of scenario planning. *Futures*, 46, pp.23–40.

Andersen, T. & Piester, H.N., 2008. *The future of the European biomedical healthcare sector: Four scenarios*, European Foundation for the Improvement of Living and Working Conditions.

Bierbooms, J.J., Bongers, I.M. & van Oers, H.A., 2011. A scenario analysis of the future residential requirements for people with mental health problems in Eindhoven. *BMC Medical Informatics & Decision Making*, 11(1).

Bloor, K. & Maynard, A., 2003. *Planning human resources in health care : Towards an economic approach*, Canadian Health Services Research Foundation.

Bock, A.-K. et al., 2014. *Tomorrow's Healthy Society: Research Priorities for Foods and Diets*, Joint Research Centre - European Commission.

Börjeson, L. et al., 2006. Scenario types and techniques : Towards a user's guide. *Futures*, 38, pp.723–739.

Bradfield, R. et al., 2005. The origins and evolution of scenario techniques in long range business planning. *Futures*, 37(8), pp.795–812.

Brailsford, S. & Vissers, J., 2011. OR in healthcare: A European perspective. *European Journal of Operational Research*, 212(2), pp.223–234.

Cardoso, T. et al., 2015. Introducing health gains in location-allocation models: A stochastic model for planning the delivery of long-term care. *IOP Publishing*, 616(1).

Cardoso, T. et al., 2012. Modeling the demand for long-term care services under uncertain information. *Health Care Management Science*, 15(4), pp.385–412.

Carello, G. & Lanzarone, E., 2014. A cardinality-constrained robust model for the assignment problem in Home Care services. *European Journal of Operational Research*, 236(2), pp.748–762.

Centre for Workforce Intelligence, 2014a. *In-depth review of the psychiatrist workforce: Main report*, Centre for Workforce Intelligence.

Centre for Workforce Intelligence, 2014b. *In-depth review of the psychiatrist workforce: Technical report*, Centre for Workforce Intelligence.

Centre for Workforce Intelligence, 2013a. *The future pharmacist workforce: Input to scenario generation event*, Centre for Workforce Intelligence.

Centre for Workforce Intelligence, 2013b. *The future pharmacist workforce: Scenario generation report*, Centre for Workforce Intelligence.

Economist Intelligence Unit, 2012. *The future of healthcare in Europe*, The Economist.

European Foresight Platform, 2010. Foresight for Policy Makers. Available at: http://www.foresight-platform.eu/community/forlearn/what-is-foresight/foresight-for-policy-makers/ [Accessed September 15, 2017].

Ganguly, S., Lawrence, S. & Prather, M., 2014. Emergency Department Staff Planning to Improve Patient Care and Reduce Costs. *Decision Sciences*, 45(1), pp.115–145.

Giesecke, S. et al., 2016. *Drivers and Trends of Future Developments of Non-communicable Diseases*, Foresight and Modelling for European Health Policy and Regulation.

Godet, M., 2000. How to be rigorous with scenario planning. *Foresight*, 2(1), pp.5–9.

Goodwin, P. & Wright, G., 2009. *Decision Analysis for Management Judgment* 4th ed., Chichester: John Wiley & Sons.

Gregório, J., Cavaco, A. & Velez Lapão, L., 2014. A scenario-planning approach to human resources for health: the case of community pharmacists in Portugal. *Human Resources for Health*, 12(58).

Hans, E., Van Houdenhoven, M. & Hulshof, P.J.H., 2012. A Framework for Health Care Planning and Control. In *Handbook of healthcare system scheduling*. Springer US, pp. 303–320.

Huss, W.R., 1988. A move toward scenario analysis. *International Journal of Forecasting*, 4(3), pp.377–388.

Institute for Alternative Futures, 2012. *Health and Health Care in 2032: Report from the RWJF Futures Symposium, June 20-21*, Robert Wood Johnson Foundation.

Institute for Alternative Futures, 2014. *Public Health 2030 : A Scenario Exploration*, Robert Wood Johnson Foundation.

Instituto Superior Técnico, 2017a. *From problem structuring to optimization: A multi-methodological framework to assist the planning of medical training*, Internal Report of the HHRPLAN project.

Instituto Superior Técnico, 2017b. *Report 6.3: Technical report on scenario building and analysis of policies*, Internal Report of the EURO-HEALTHY project.

Jafari, H. et al., 2015. Fuzzy Mathematical Modeling Approach for the Nurse Scheduling Problem: A Case Study. *International Journal of Fuzzy Systems*, 18(2), pp.320–332.

Laukkanen, M., 2012. Qualitative Social Comparative Causal Mapping and CMAP3 Software in Qualitative Studies. *Forum: Qualitative Social Research*, 13(2).

Léonard, C., Stordeur, S. & Roberfroid, D., 2009. Association between physician density and health care consumption: A systematic review of the evidence. *Health Policy*, 91, pp.121–134.

Lieberman, G.J. & Hillier, F.S., 2010. *Introduction to Operations Research* 9th ed., McGraw Hill Higher Education.

Lopes, M.A., 2017. *Assessing and planning for the future needs of the health care workforce*. Faculdade de Engenharia da Universidade do Porto.

Lopes, M.A., Almeida, Á.S. & Almada-Lobo, B., 2016. Forecasting the medical workforce: a stochastic agent-based simulation approach. *Health Care Management Science*.

Lopes, M.A., Almeida, Á.S. & Almada-Lobo, B., 2015. Handling Healthcare Workforce Planning With Care: Where Do We Stand? *Human Resources for Health*, 13(28).

Malgieri, A., Michelutti, P. & Hoegaerden, M. Van, 2015. *Health Workforce PLANNING*, Joint Action Health Workforce Planning and Forecasting.

Masum, H., Ranck, J. & Singer, P.A., 2010. Five promising methods for health foresight. *Foresight*, 12(1), pp.54–66.

Mestre, A., Oliveira, M. & Barbosa-Póvoa, A., 2012. Organizing hospitals into networks: A hierarchical and multiservice model to define location, supply and referrals in planned hospital systems. *OR Spectrum*, 34(2), pp.319–348.

Moreira, F.R., 2003. Linear programming applied to healthcare problems. *Einstein*, 1, pp.105–109.

National Institute for Public Health and the Environment, 2014. *A healthier Netherlands: Key findings from the Dutch 2014 Public Health Status and Foresight Report*, National Institute for Public Health and the Environment.

Nguyen, T.V.L. & Montemanni, R., 2016. *Integrated Home Health Care Optimization via Genetic Algorithms and Mathematical Programming*, Congress on Evolutionary Computation.

Ono, T., Lafortune, G. & Schoenstein, M., 2013. Health Workforce Planning in OECD Countries: A Review of 26 Projection Models from 18 Countries. *OECD Publishing, Paris*, 62.

Owen, S.H. & Daskin, M.S., 1998. Strategic facility location: A review. *European Journal of Operational Research*, 111, pp.423–447.

Rais, A. & Viana, A., 2011. Operations research in healthcare: A survey. *International Transactions in Operational Research*, 18(1).

Rhea, M. & Bettles, C., 2012. Four Futures for Dietetics Workforce Supply and Demand: 2012-2022 Scenarios. *Journal of the Academy of Nutrition and Dietetics*, 112.

Rhyne, D.M. & Jupp, D., 1988. Health care requirements planning: a conceptual framework. *Health Care Management Review*, 13(1), pp.17–27.

Rialland, A. & Wold, K.E., 2009. *Future Studies, Foresight and Scenarios as basis for better strategic decisions*, Marintek.

Ricci, A. et al., 2016. *Health Scenarios Stories*, Foresight and Modelling for European Health Policy and Regulation.

Roberfroid, D., Leonard, C. & Stordeur, S., 2009. Physician supply forecast: better than peering in a crystal ball? *Human resources for health*, 7(10).

Saúde, A.C. do S. de, 2012. *Duração dos Programas de Formação das Especialidades do Internato Médico*, Administração Central do Sistema de Saúde.

Scearce, D. & Fulton, K., 2004. *What if? The art of scenario thinking for nonprofits*, Global Business Network.

Sikken, B.J. et al., 2008. *The Future of Pensions and Healthcare in a Rapidly Ageing World: Scenarios to 2030*, World Scenario Series.

The Joint Research Centre - Institute for Prospective Technological Studies, 2015. Characteristics of Foresight. Available at: http://forlearn.jrc.ec.europa.eu/guide/1_why-foresight/characteristics.htm [Accessed September 15, 2017].

Thietart, R.-A., 2001. *Doing Management Research: A Comprehensive Guide*, SAGE Publications.

Wack, P., 1985. Scenarios: uncharted waters ahead. *Harvard Business Review*, pp.73–89.

Williams, H.P., 2013. *Model building in mathematical programming* 5th ed., Wiley.

Willis, G., 2014. *Robust workforce planning framework: An introduction*, Centre for Workforce Intelligence.

Willis, G. & Cave, S., 2014. *Scenario generation: Enhancing scenario generation and quantification*, Centre for Workforce Intelligence.

Winston, W.L., 2004. *Operations Research: Applications and Algorithms* 4th ed., Cengage Learning.
World Economic Forum, 2013. *Sustainable Health Systems: Visions, Strategies, Critical Uncertainties and Scenarios*, World Economic Forum.

Appendix

Appendix A – Classification of medical specialties

Table A.1: Medical classification in Portugal and their classification in clinical, surgical and diagnosis specialties.

Specialties	Clinical	Surgical	Diagnosis
Anatomia Patológica			x
Anestesiologia	x		
Angiologia e Cirurgia Vascular		x	
Cardiologia	x		
Cardiologia Pediátrica	x		
Cirurgia Cardiotorácica		x	
Cirurgia Geral		x	
Cirurgia Maxilo-Facial		x	
Cirurgia Pediátrica		x	
Cirurgia Plástica Reco. e Est.		x	
Dermato-Venereologia	x		
Doenças Infecciosas	x		
Endocrinologia e Nutrição	x		
Estomatologia		x	
Gastrenterologia	x		
Genética Médica	x		
Ginecologia/Obstetrícia		x	
Imunoalergologia	x		
Imunohemoterapia	x		
Hematologia Clínica	x		
Medicina Desportiva	x		
Medicina do Trabalho	x		
Medicina Física e de Reabilitação	x		
Medicina Geral e Familiar	x		
Medicina Intensiva	x		
Medicina Interna	x		
Medicina Nuclear			x
Medicina Tropical	x		
Nefrologia	x		
Neurocirurgia		x	
Neurologia	x		
Neurorradiologia			x
Oftalmologia		x	
Oncologia Médica	x		
Ortopedia		x	
Otorrinolaringologia		x	

Patologia Clínica			x
Pediatria	x		
Pneumologia	x		
Psiquiatria	x		
Psiquiatria da Infância e da Adolescência	x		
Radiologia			x
Radioncologia	x		
Reumatologia	x		
Saúde Pública	x		
Urologia		x	

Appendix B – Template of the email sent to experts

Assunto: Convite para participação em estudo como especialista

Caro(a) Prof.(ª) Dr.(ª),

No âmbito do estudo denominado "Construção de cenários para informar o planeamento de recursos humanos em saúde em Portugal", vimos por este meio convidá-lo(a) a participar num questionário online sobre a ***evolução futura*** *de um conjunto de variáveis associadas ao* ***planeamento de recursos humanos em saúde****.*

Este questionário encontra-se disponível em http://scenarios-hhrplan.weebly.com e visa recolher informação de peritos com conhecimento e experiência nas várias áreas associadas à prestação de cuidados de saúde e ao planeamento. Estamos a contactá-lo(a) como perito, e ficamos antecipadamente gratos pela participação prestada.

O tempo previsto de resposta a este questionário é de, no máximo, ***12 minutos*** *e todos os dados recolhidos são confidenciais. No momento em que iniciar o questionário é necessário que o complete até ao fim, uma vez que não é possível deixar a sua sessão a meio e continuar noutra altura. Os resultados, em forma de apresentação ou publicação, serão facultados a todos os participantes que assim o desejem.*

Por favor, complete o questionário através do link http://scenarios-hhrplan.weebly.com até ao dia ***31 de julho****.*

Agradecemos também que, caso considere pertinente, reenvie este email para outras pessoas que tenham interesse e conhecimento na área.

Note que não existem respostas certas ou erradas. Caso tenha alguma questão relativa a este questionário ou ao trabalho a ser desenvolvido pode contactar-nos através dos endereços: mariana.g.raposo@tecnico.ulisboa.pt; monica.oliveira@tecnico.ulisboa.pt; antonio.m.alvarenga@tecnico.ulisboa.pt ou mario.lopes@fe.up.pt.

Agradecemos desde já a sua participação.

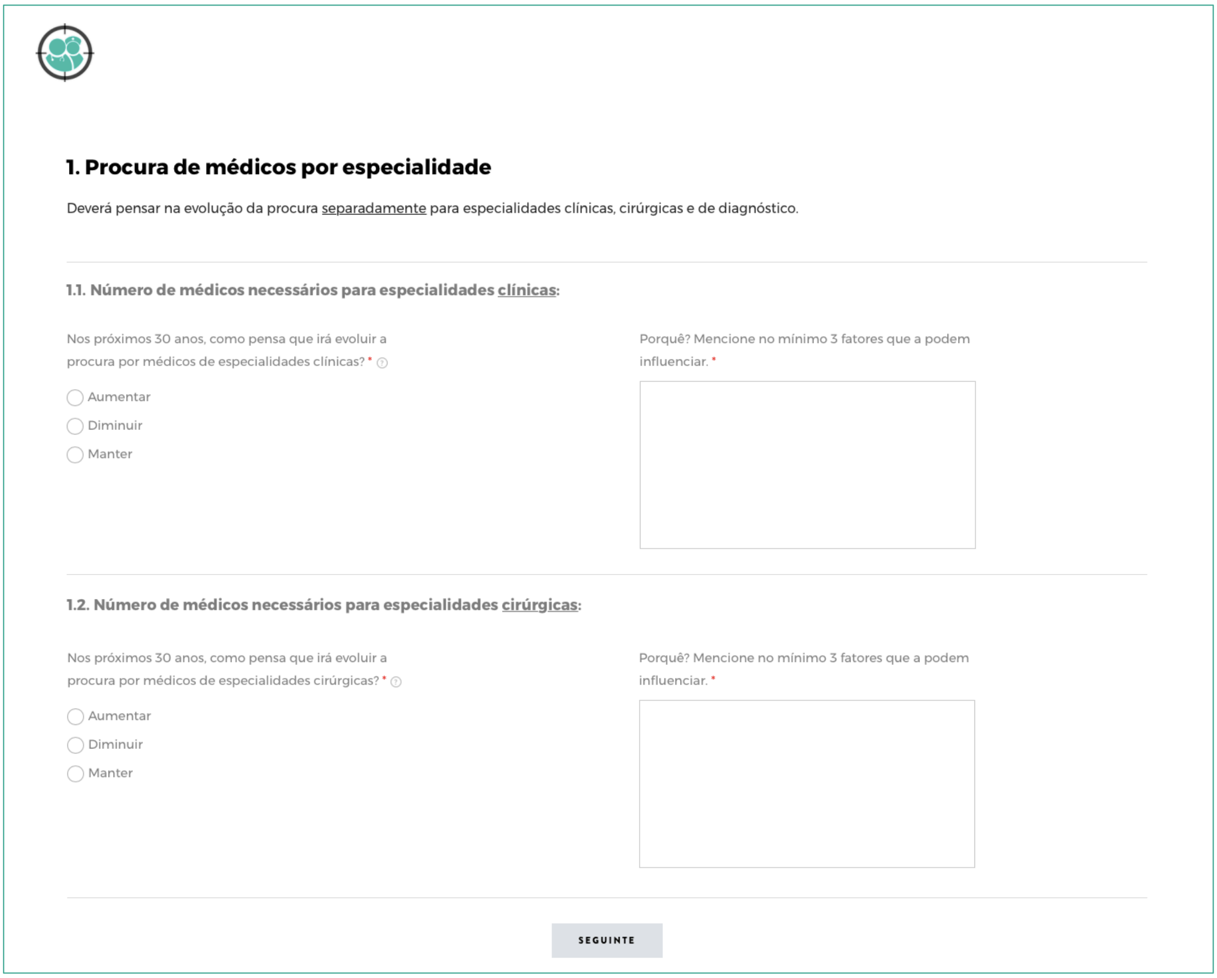
Melhores cumprimentos,

A equipa do projeto:

Mariana Raposo, Mónica Oliveira, António Alvarenga e Mário Amorim Lopes.

Centro de Estudos de Gestão do Instituto Superior Técnico e INESC-TEC

Appendix C – Web-based platform



1. Procura de médicos por especialidade

Deverá pensar na evolução da procura separadamente para especialidades clínicas, cirúrgicas e de diagnóstico.

1.1. Número de médicos necessários para especialidades clínicas:

Nos próximos 30 anos, como pensa que irá evoluir a procura por médicos de especialidades clínicas? *

- Aumentar
- Diminuir
- Manter

Porquê? Mencione no mínimo 3 fatores que a podem influenciar. *

1.2. Número de médicos necessários para especialidades cirúrgicas:

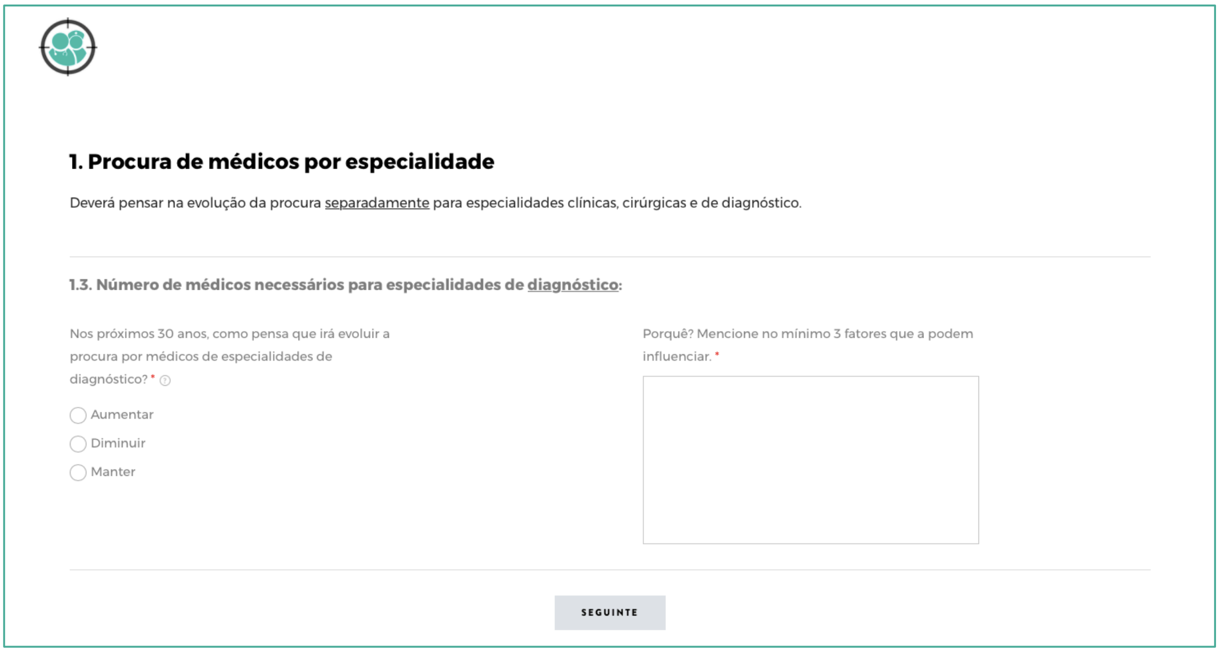
Nos próximos 30 anos, como pensa que irá evoluir a procura por médicos de especialidades cirúrgicas? *

- Aumentar
- Diminuir
- Manter

Porquê? Mencione no mínimo 3 fatores que a podem influenciar. *

SEGUINTE

Figure C.1: Webpage of the first and second parameters – physicians demand for clinical and surgical specialties – available at http://scenarios-hhrplan.weebly.com/1-demand-clin-surg.html.



1. Procura de médicos por especialidade

Deverá pensar na evolução da procura separadamente para especialidades clínicas, cirúrgicas e de diagnóstico.

1.3. Número de médicos necessários para especialidades de diagnóstico:

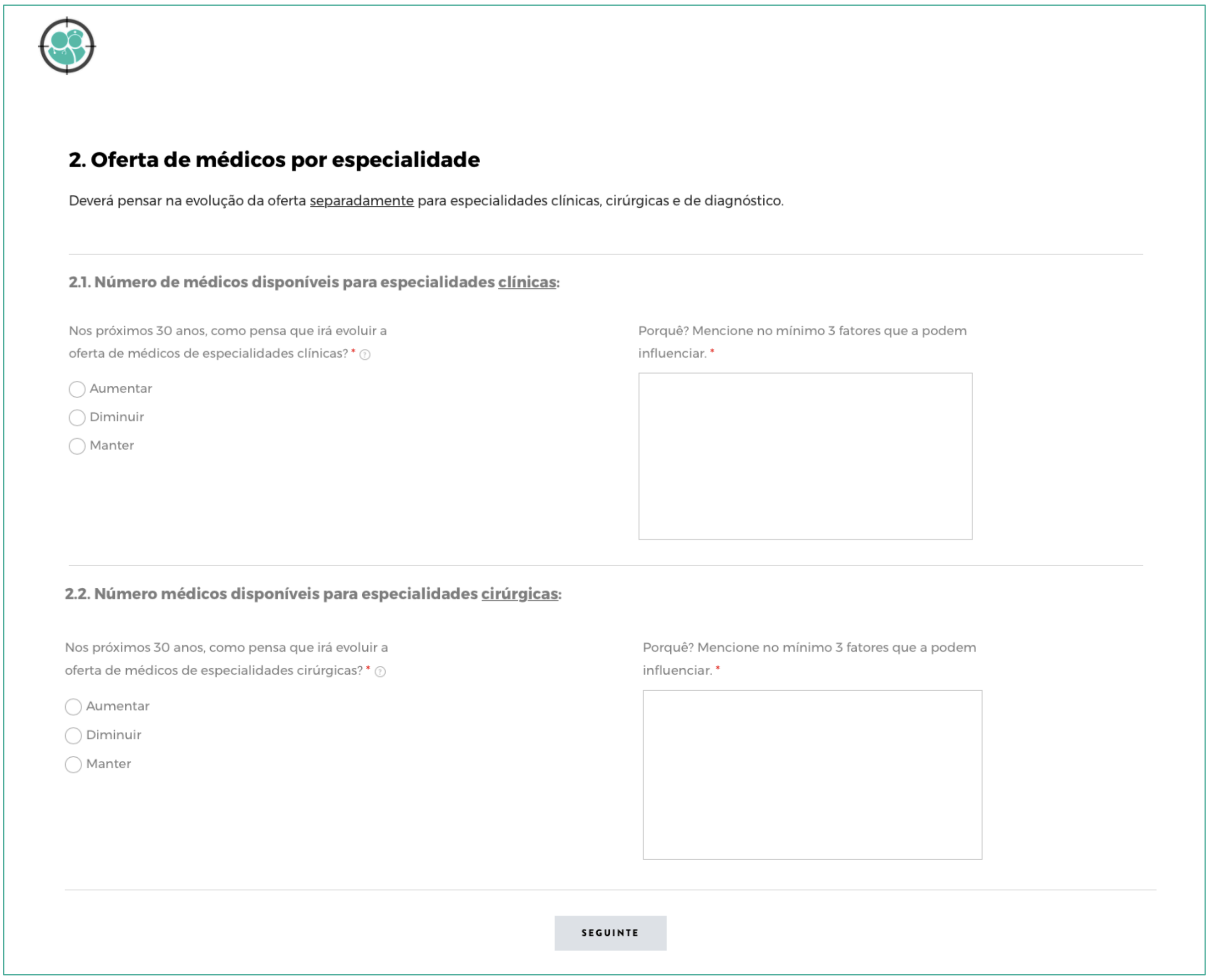
Nos próximos 30 anos, como pensa que irá evoluir a procura por médicos de especialidades de diagnóstico? *

- Aumentar
- Diminuir
- Manter

Porquê? Mencione no mínimo 3 fatores que a podem influenciar. *

SEGUINTE

Figure C.2: Webpage of the third parameter – physicians demand for diagnosis specialties – available at http://scenarios-hhrplan.weebly.com/1-demand-diag.html.



2. Oferta de médicos por especialidade

Deverá pensar na evolução da oferta separadamente para especialidades clínicas, cirúrgicas e de diagnóstico.

2.1. Número de médicos disponíveis para especialidades clínicas:

Nos próximos 30 anos, como pensa que irá evoluir a oferta de médicos de especialidades clínicas? *

- Aumentar
- Diminuir
- Manter

Porquê? Mencione no mínimo 3 fatores que a podem influenciar. *

2.2. Número médicos disponíveis para especialidades cirúrgicas:

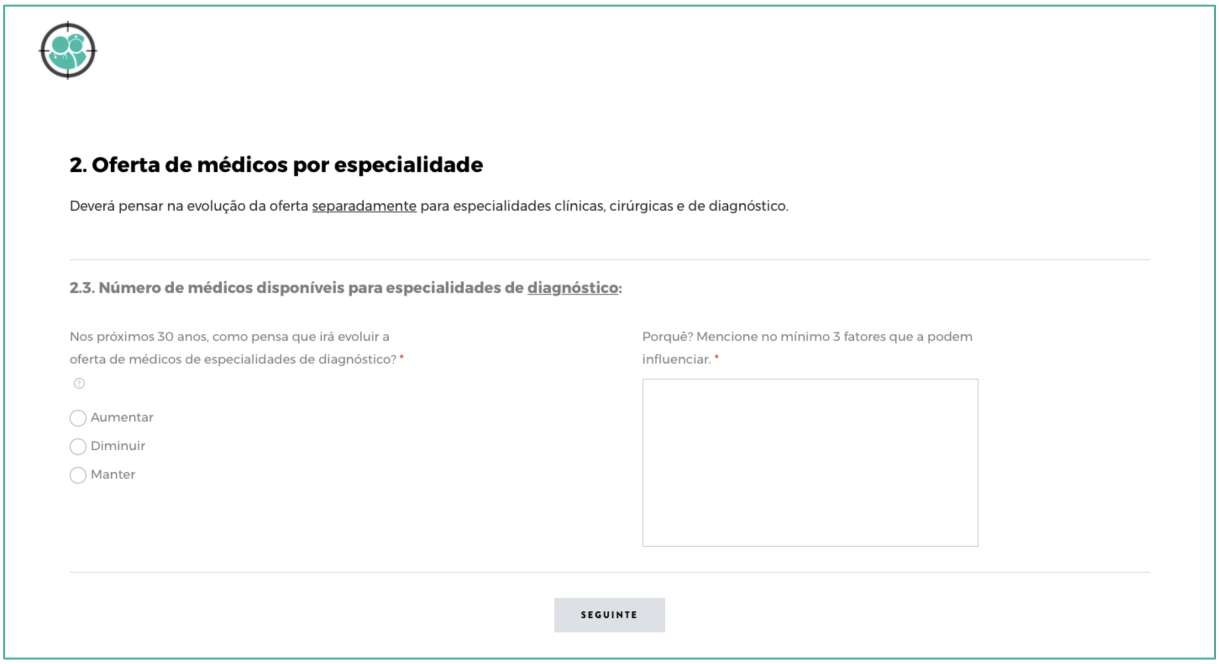
Nos próximos 30 anos, como pensa que irá evoluir a oferta de médicos de especialidades cirúrgicas? *

- Aumentar
- Diminuir
- Manter

Porquê? Mencione no mínimo 3 fatores que a podem influenciar. *

SEGUINTE

Figure C.3: Webpage of the fourth and fifth parameters – physicians supply for clinical and surgical specialties – available at http://scenarios-hhrplan.weebly.com/2-supply-clin-surg.html.



2. Oferta de médicos por especialidade

Deverá pensar na evolução da oferta separadamente para especialidades clínicas, cirúrgicas e de diagnóstico.

2.3. Número de médicos disponíveis para especialidades de diagnóstico:

Nos próximos 30 anos, como pensa que irá evoluir a oferta de médicos de especialidades de diagnóstico? *

- Aumentar
- Diminuir
- Manter

Porquê? Mencione no mínimo 3 fatores que a podem influenciar. *

SEGUINTE

Figure C.4: Webpage of the sixth parameter – physicians supply for diagnosis specialties – available at http://scenarios-hhrplan.weebly.com/2-supply-diag.html.

Figure C.5: Webpage of the eighth parameter – emigration rate – available at http://scenarios-hhrplan.weebly.com/4-emigration-rate.html.

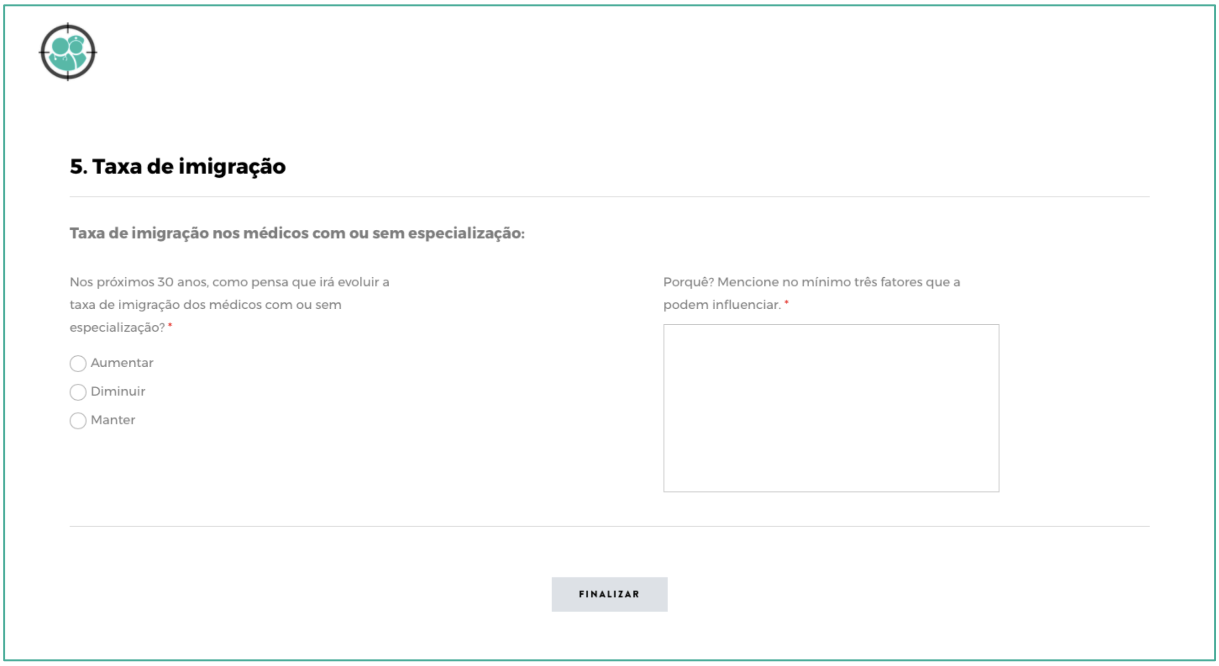


Figure C.6: Webpage of the ninth parameter – physicians demand for clinical and surgical specialties – available at http://scenarios-hhrplan.weebly.com/5-immigration-rate.html.

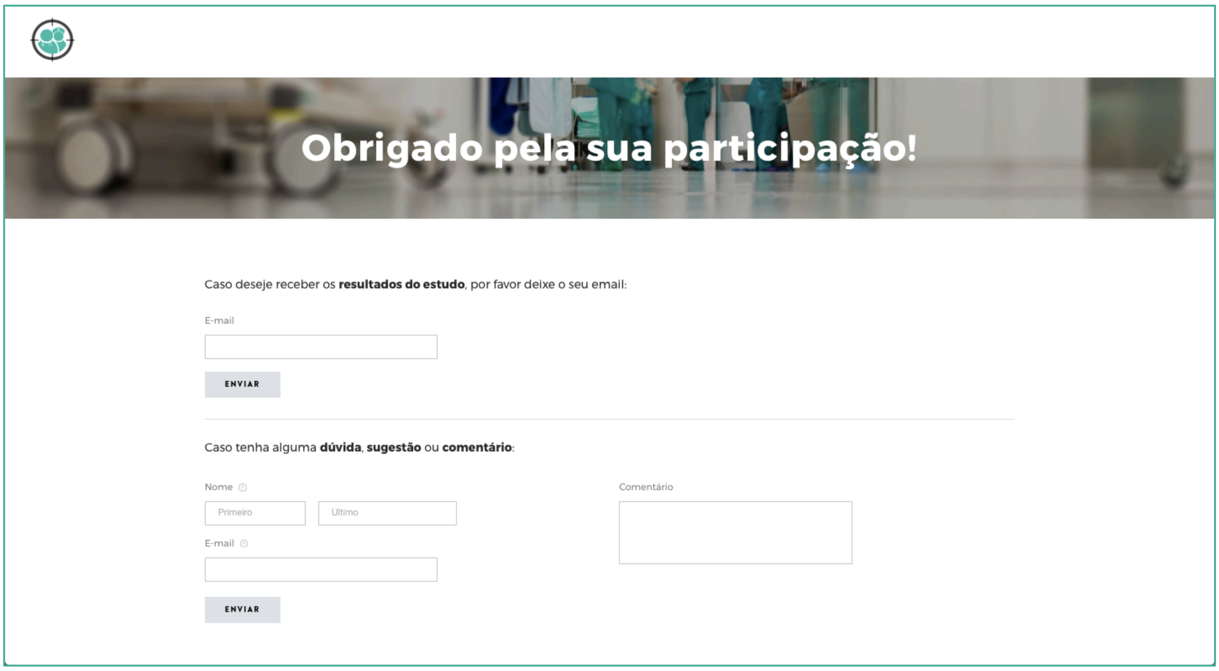


Figure C.7: End-page of the web-based platform, available at http://scenarios-hhrplan.weebly.com/end.html.

Appendix D – Cognitive Maps

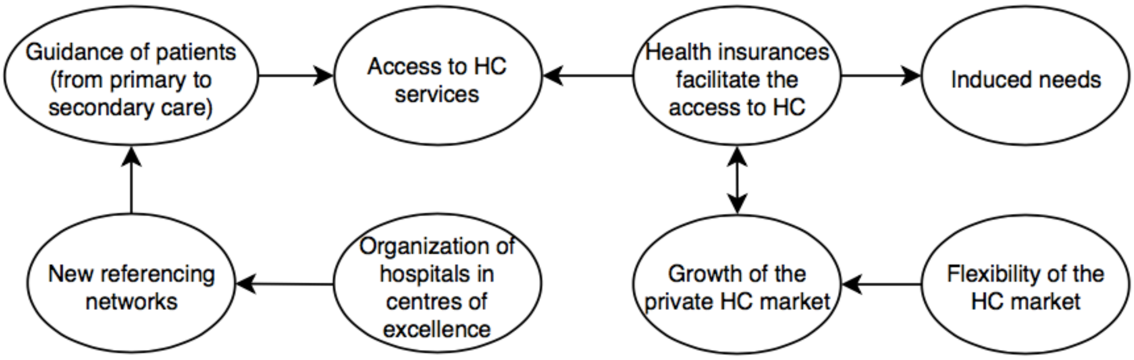


Figure D.1: Access to healthcare and evolution of the private healthcare market.

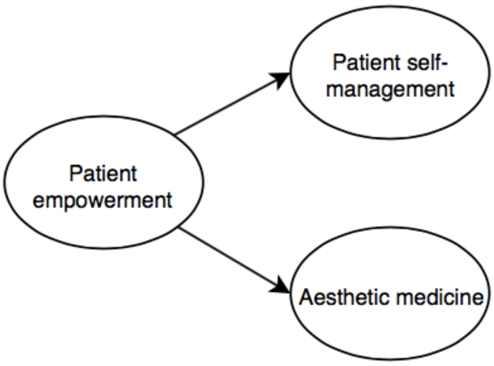


Figure D.2: Patient empowerment and self-management.

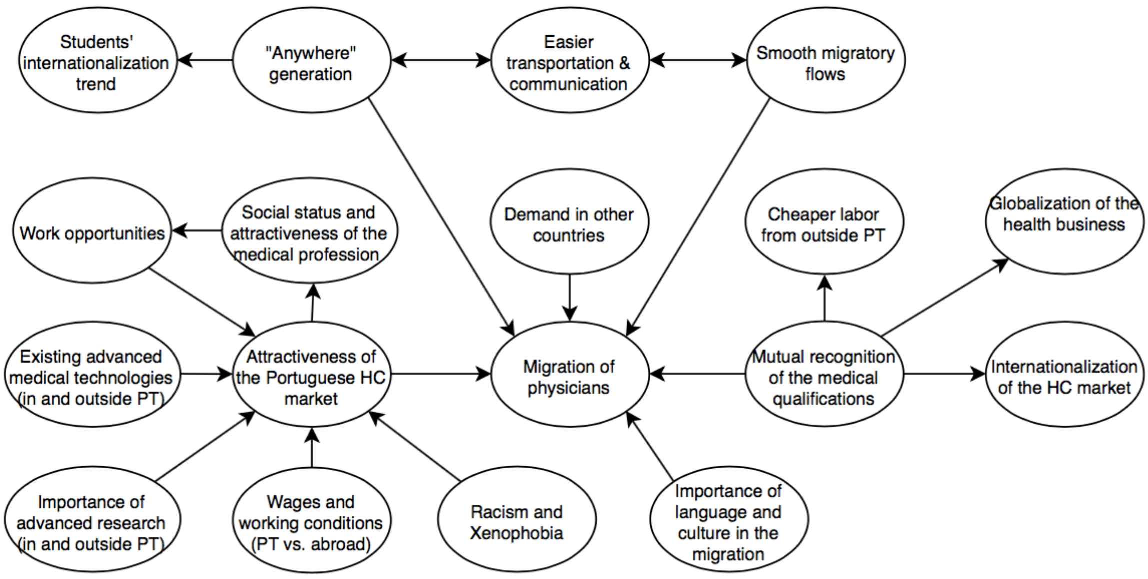


Figure D.3: Mutual recognition of medical qualifications and attractiveness of the Portuguese healthcare market.

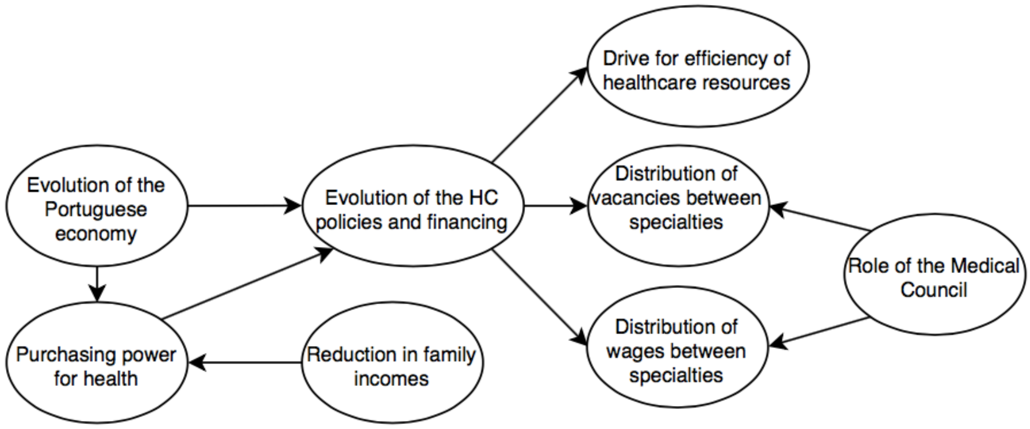


Figure D.4: Evolution of the Portuguese economy and of public funding in the health sector.

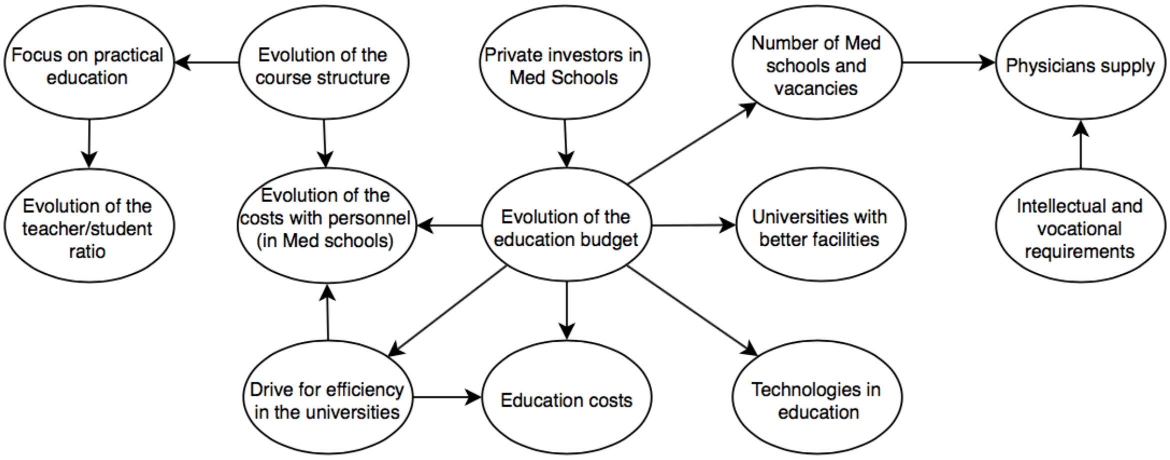


Figure D.5: Medical course structure and changes in medical schools.

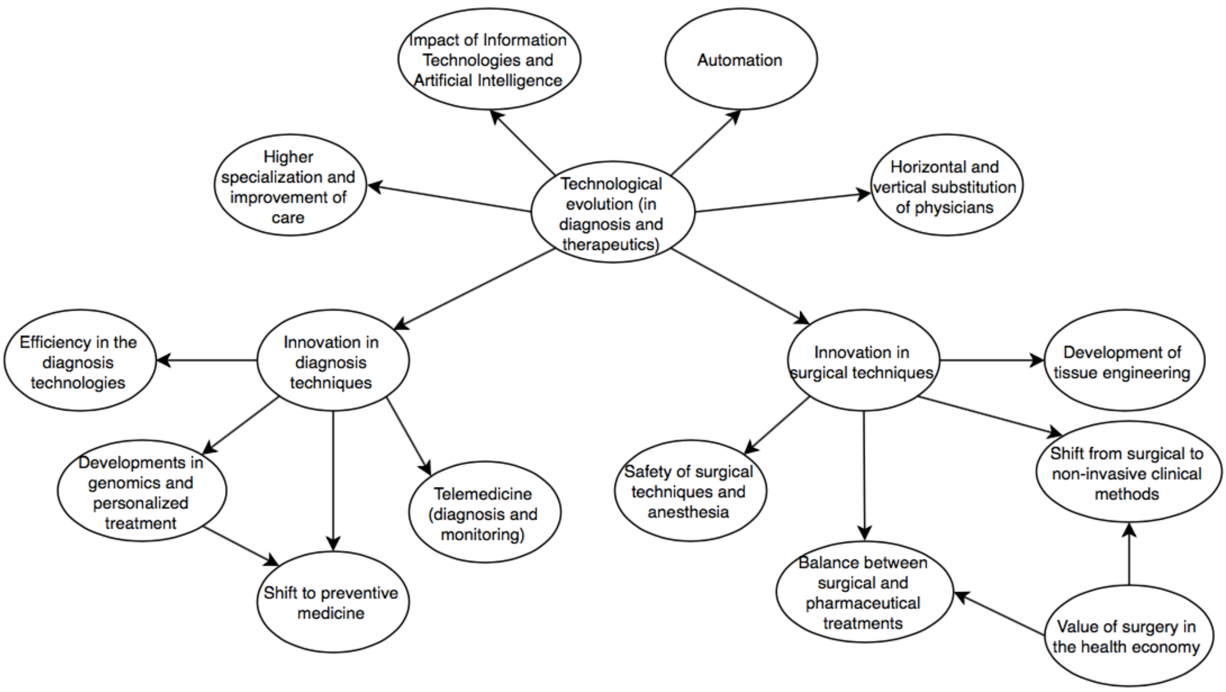


Figure D.6: Technological evolution in health

Appendix E – Exclusion constraints for the morphological analysis

Table E.1: Exclusion constraints obtained through a pairwise comparison of the hypothesis

D2E2	Medical qualifications recognized worldwide, allowing the migration of physicians. However, Portugal is not attractive enough to them due to low investment in advanced research and medical technologies, along with worse working conditions when compared to other countries.
	Recovery of the Portuguese economy and increased financing for health. New policies improve the management of the vacancies and wages between medical specialties.
D3E1	Medical qualifications recognized worldwide, allowing the migration of physicians who find the Portuguese market attractive due to the investment in advanced research and medical technologies and better working conditions.
	Low level of growth of the Portuguese economy, with increased restrictions in the health budget. Vacancies and wages between medical specialties unbalanced.
D3G1	Medical qualifications recognized worldwide, allowing the migration of physicians who find the Portuguese market attractive due to the investment in advanced research and medical technologies and better working conditions.
	Slow adoption of new technologies in the health sector, either because of financial or ethical constraints.
E1F2	Low level of growth of the Portuguese economy, with increased restrictions in the health budget. Vacancies and wages between medical specialties unbalanced.
	Increased efficiency in the universities and evolution of the medical course structure, with focus on practical education and the use of new technologies.
E1G2	Low level of growth of the Portuguese economy, with increased restrictions in the health budget. Vacancies and wages between medical specialties unbalanced.
	Technological evolution and fast introduction of new health technologies, with a big focus on automation, information technologies and artificial intelligence and telemedicine.
E2F1	Recovery of the Portuguese economy and increased financing for health. New policies improve the management of the vacancies and wages between medical specialties.
	The budget for medical universities and their autonomy do not allow for big changes in the teaching. Lack of new technologies and practical classes limited by old facilities.
F1G2	The budget for medical universities and their autonomy do not allow for big changes in the teaching. Lack of new technologies and practical classes limited by old facilities.
	Technological evolution and fast introduction of new health technologies, with a big focus on automation, information technologies and artificial intelligence and telemedicine.
F2G1	Increased efficiency in the universities and evolution of the medical course structure, with focus on practical education and the use of new technologies.
	Slow adoption of new technologies in the health sector, either because of financial or ethical constraints.

Appendix F – Results from the morphological analysis

Table F.1: Complete Cross-Coupling Table.

Scenarios		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	**1111111**	7	6	6	5	6	5	5	4	6	5	5	4	5	4	4	3	4	3	3	2	3	2	2	1	3	2	2	1	2	1	1	0
2	**2111111**	6	7	5	6	5	6	4	5	5	6	4	5	4	5	3	4	3	4	2	3	2	3	1	2	2	3	1	2	1	2	0	1
3	**1211111**	6	5	7	6	5	4	6	5	5	4	6	5	4	3	5	4	3	2	4	3	2	1	3	2	2	1	3	2	1	0	2	1
4	**2211111**	5	6	6	7	4	5	5	6	4	5	5	6	3	4	4	5	2	3	3	4	1	2	2	3	1	2	2	3	0	1	1	2
5	**1121111**	6	5	5	4	7	6	6	5	5	4	4	3	6	5	5	4	3	2	2	1	4	3	3	2	2	1	1	0	3	2	2	1
6	**2121111**	5	6	4	5	6	7	5	6	4	5	3	4	5	6	4	5	2	3	1	2	3	4	2	3	1	2	0	1	2	3	1	2
7	**1221111**	5	4	6	5	6	5	7	6	4	3	5	4	5	4	6	5	2	1	3	2	3	2	4	3	1	0	2	1	2	1	3	2
8	**2221111**	4	5	5	6	5	6	6	7	3	4	4	5	4	5	5	6	1	2	2	3	2	3	3	4	0	1	1	2	1	2	2	3
9	**1112111**	6	5	5	4	5	4	4	3	7	6	6	5	6	5	5	4	3	2	2	1	2	1	1	0	3	2	2	1	2	1	1	0
10	**2112111**	5	6	4	5	4	5	3	4	6	7	5	6	5	6	4	5	2	3	1	2	1	2	0	1	2	3	1	2	1	2	0	1
11	**1212111**	5	4	6	5	4	3	5	4	6	5	7	6	5	4	6	5	2	1	3	2	1	0	2	1	2	1	3	2	1	0	2	1
12	**2212111**	4	5	5	6	3	4	4	5	5	6	6	7	4	5	5	6	1	2	2	3	0	1	1	2	1	2	2	3	0	1	1	2
13	**1122111**	5	4	4	3	6	5	5	4	6	5	5	4	7	6	6	5	2	1	1	0	3	2	2	1	2	1	1	0	3	2	2	1
14	**2122111**	4	5	3	4	5	6	4	5	5	6	4	5	6	7	5	6	1	2	0	1	2	3	1	2	1	2	0	1	2	3	1	2
15	**1222111**	4	3	5	4	5	4	6	5	5	4	6	5	6	5	7	6	1	0	2	1	2	1	3	2	1	0	2	1	2	1	3	2
16	**2222111**	3	4	4	5	4	5	5	6	4	5	5	6	5	6	6	7	0	1	1	2	1	2	2	3	0	1	1	2	1	2	2	3
17	**1111222**	4	3	3	2	3	2	2	1	3	2	2	1	2	1	1	0	7	6	6	5	6	5	5	4	6	5	5	4	5	4	4	3
18	**2111222**	3	4	2	3	2	3	1	2	2	3	1	2	1	2	0	1	6	7	5	6	5	6	4	5	5	6	4	5	4	5	3	4
19	**1211222**	3	2	4	3	2	1	3	2	2	1	3	2	1	0	2	1	6	5	7	6	5	4	6	5	5	4	6	5	4	3	5	4
20	**2211222**	2	3	3	4	1	2	2	3	1	2	2	3	0	1	1	2	5	6	6	7	4	5	5	6	4	5	5	6	3	4	4	5
21	**1121222**	3	2	2	1	4	3	3	2	2	1	1	0	3	2	2	1	6	5	5	4	7	6	6	5	5	4	4	3	6	5	5	4
22	**2121222**	2	3	1	2	3	4	2	3	1	2	0	1	2	3	1	2	5	6	4	5	6	7	5	6	4	5	3	4	5	6	4	5
23	**1221222**	2	1	3	2	3	2	4	3	1	0	2	1	2	1	3	2	5	4	6	5	6	5	7	6	4	3	5	4	5	4	6	5
24	**2221222**	1	2	2	3	2	3	3	4	0	1	1	2	1	2	2	3	4	5	5	6	5	6	6	7	3	4	4	5	4	5	5	6
25	**1113222**	3	2	2	1	2	1	1	0	3	2	2	1	2	1	1	0	6	5	5	4	5	4	4	3	7	6	6	5	6	5	5	4
26	**2113222**	2	3	1	2	1	2	0	1	2	3	1	2	1	2	0	1	5	6	4	5	4	5	3	4	6	7	5	6	5	6	4	5
27	**1213222**	2	1	3	2	1	0	2	1	2	1	3	2	1	0	2	1	5	4	6	5	4	3	5	4	6	5	7	6	5	4	6	5
28	**2213222**	1	2	2	3	0	1	1	2	1	2	2	3	0	1	1	2	4	5	5	6	3	4	4	5	5	6	6	7	4	5	5	6
29	**1123222**	2	1	1	0	3	2	2	1	2	1	1	0	3	2	2	1	5	4	4	3	6	5	5	4	6	5	5	4	7	6	6	5
30	**2123222**	1	2	0	1	2	3	1	2	1	2	0	1	2	3	1	2	4	5	3	4	5	6	4	5	5	6	4	5	6	7	5	6
31	**1223222**	1	0	2	1	2	1	3	2	1	0	2	1	2	1	3	2	4	3	5	4	5	4	6	5	5	4	6	5	6	5	7	6
32	**2223222**	0	1	1	2	1	2	2	3	0	1	1	2	1	2	2	3	3	4	4	5	4	5	5	6	4	5	5	6	5	6	6	7

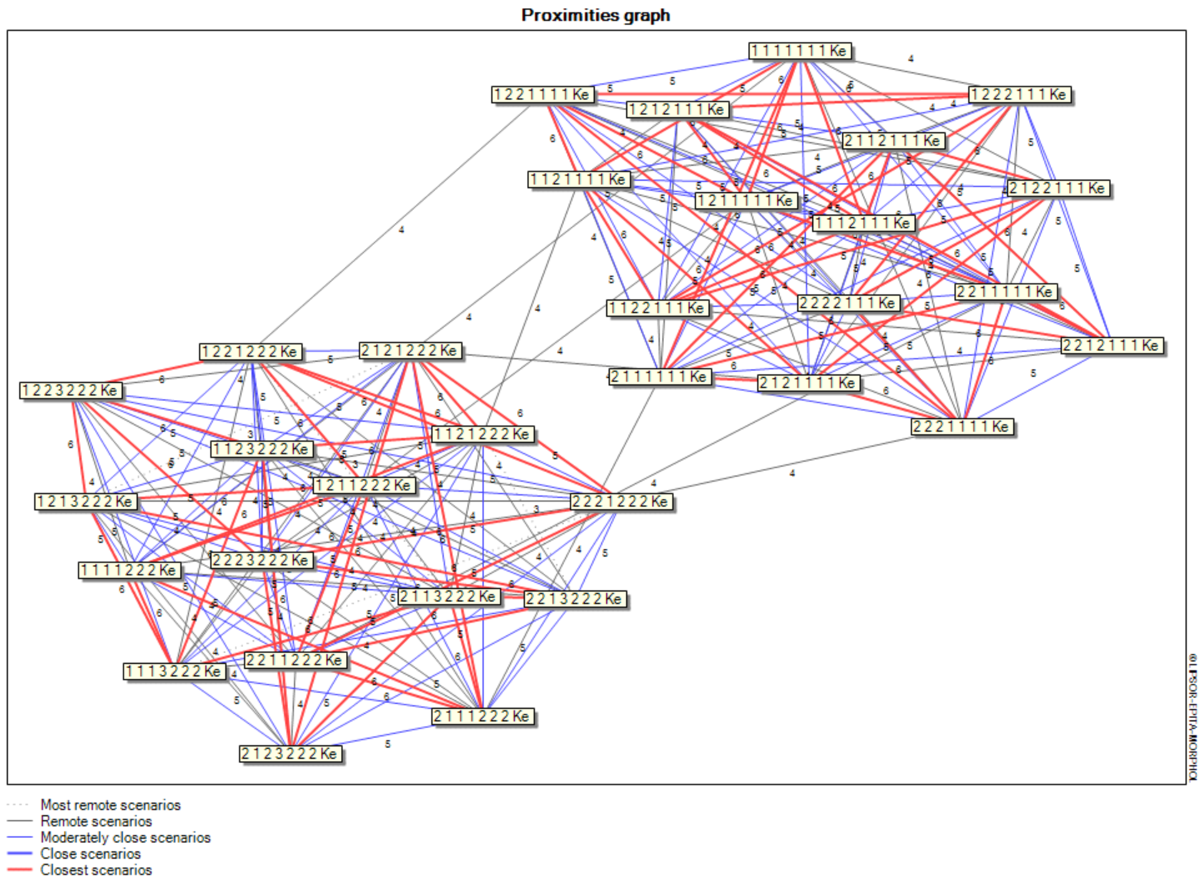


Figure F.1: Proximities Graph from the Morphol software. Only the linkages between scenarios with 4, 5 or 6 hypothesis in common are presented in here.

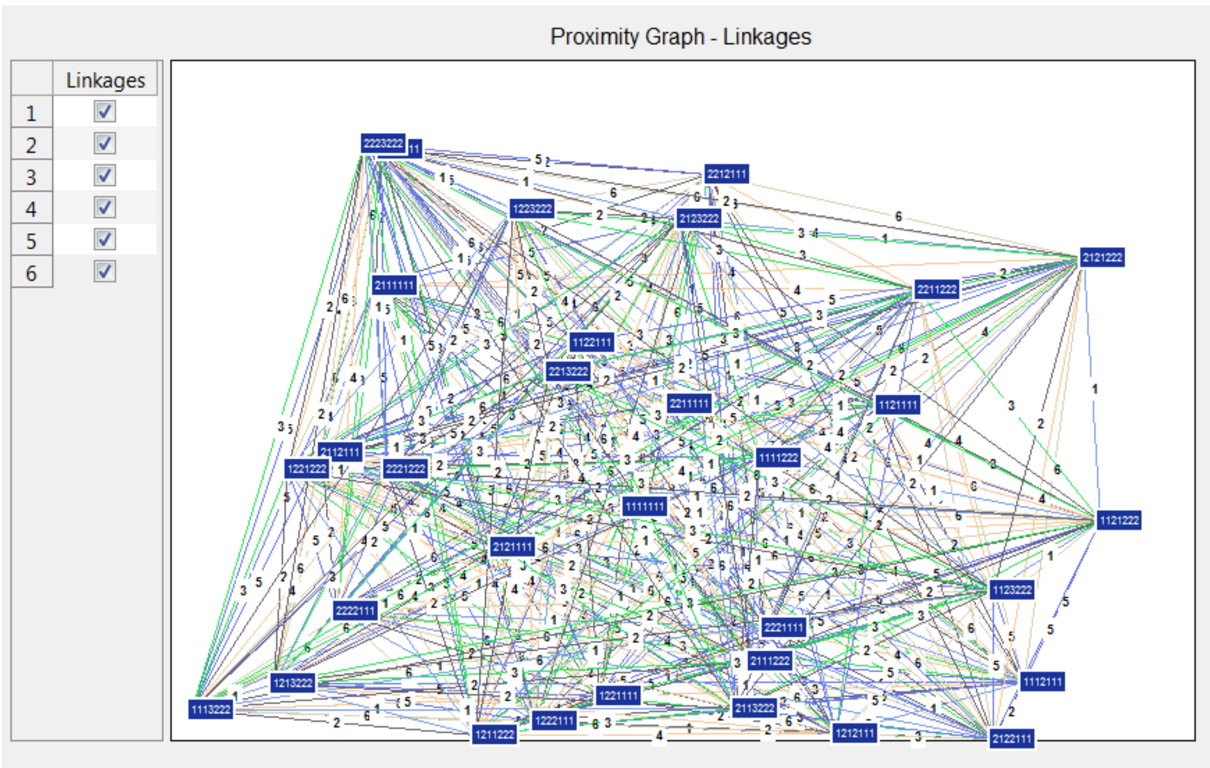


Figure F.2: Complete Proximities Graph from the FIL software.

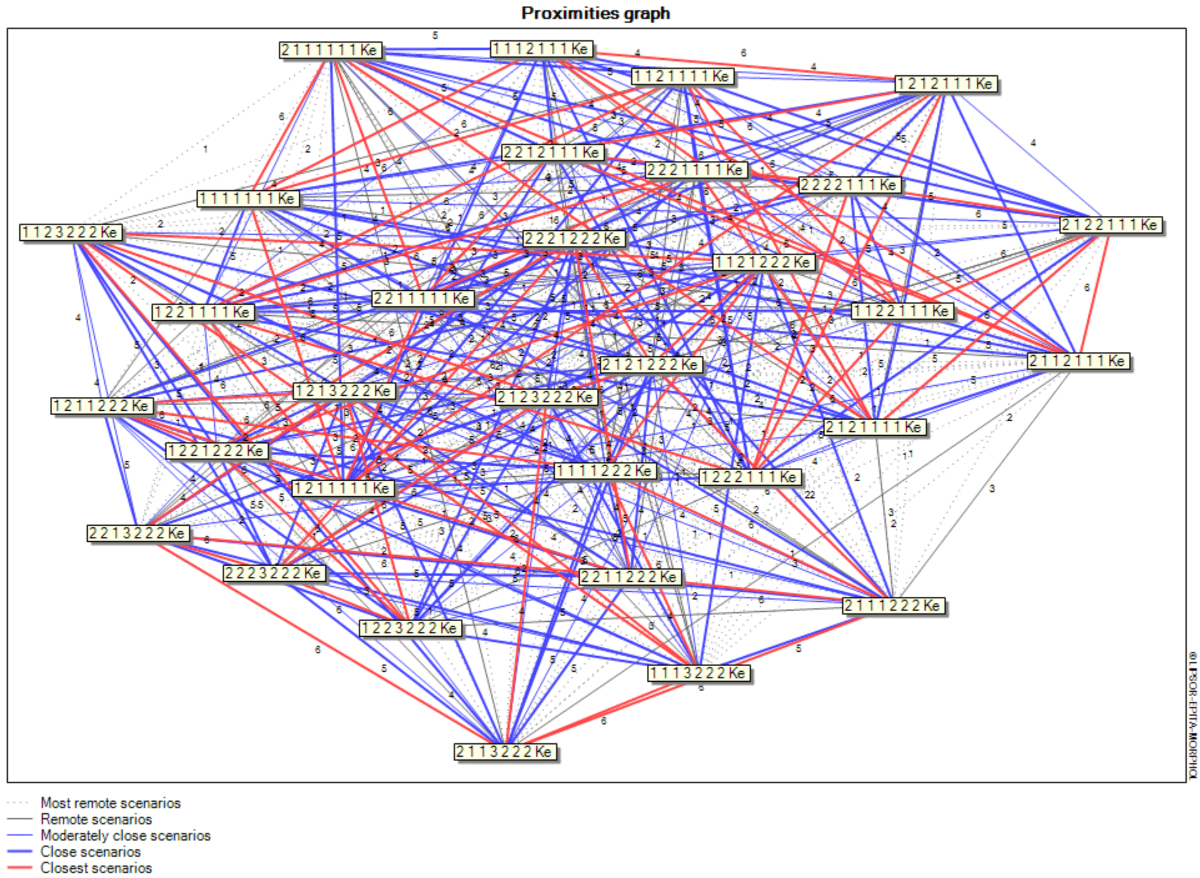


Figure F.3: Complete Proximities Graph from the Morphol software.

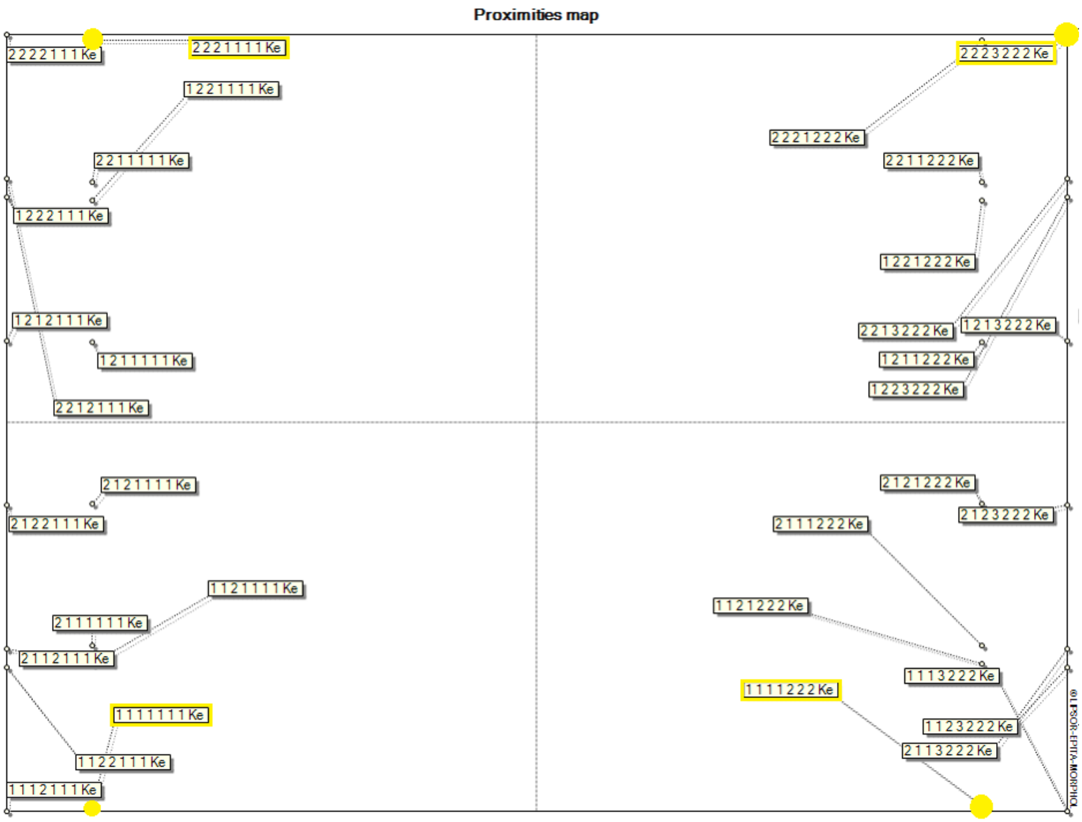


Figure F.4: Selected scenarios marked in the Proximities Map obtained by the Morphol software.