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

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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.

1. INTRODUCTION

There are several drivers that make planning in healthcare truly important nowadays [1]. In fact, one shall not forget the social and ethical responsibilities inherent to the health sector. Optimization problems related to healthcare have been developed for more than three decades to support planning [1]. 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 [1]. There is an inherent uncertainty in numerous healthcare optimization problems that should not be neglected, since it may influence significantly the quality and feasibility of the problem solution (Carello & Lanzarone 2014).

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 [2]. The healthcare sector is labor-intensive and human resources are the most important input for the delivery of healthcare (Bloor et al. 2003). In other words, the quantity and quality of the healthcare is strictly related to the quantity and quality of the existing human resources [3]. Therefore, being able to foresee the necessary amount of health professionals at some point in the future is both an ethical and economic goal [3].

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, which is higher than in most professions [3], [5]. 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, preventing self-adjustment [4], [5]. Thus, other mechanisms have to be used in order to match supply and demand and create equilibrium.

Effective workforce planning can be defined as achieving “a proper balance between the supply and demand for different categories of health workers, in both the short and longer-term” [6]. 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. 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 [7], [8]. On the other hand, a surplus may cause economic inefficiencies and misallocated resources [8], along with inflated costs through supplier-induced demand [7].

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. The uncertainty treatment within mathematical programming models is extremely important and is usually done 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 be reached with literature research together with input from experts, characteristic from scenario methodologies.

2. LITERATURE REVIEW

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. Healthcare planning is mostly done through forecasting models and, specifically for HHR planning, there are mostly supply-based and demand-based models. Operations Research methods are often used, including mathematical programming models, which always involves the optimization (either maximization or minimization) of the objective function [9]. This function is composed of a set of decision variables and subject to a set of constraints [10]. 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 [11]. 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 [12]. Another possible classification for the mathematical programming models is in deterministic and stochastic models, and the latter are used when some of the data in the model are uncertain and can be specified by a probability distribution [9]. In fact, when considering deterministic models, one way of addressing the problem of input data uncertainty is through sensitivity analysis, which 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.

2.2. Health Planning Models Dealing With Uncertainty

Mathematical programming models have widely been used in the health care planning literature, with various specifications [13]. 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. Only models that account for uncertainty were reviewed, as it is the focus of this study. We found models with a wide range of planning purposes, including the organization of hospitals into networks [14], the assignment of beds to hospital departments [15], nurses workforce planning [16]–[18], the planning of long-term care [19], [20] and the effective staffing plan for emergency departments [21].

Concerning the way these models account for uncertainty, it was possible to conclude that it is 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), being simply an adaptation of the neutral values, usually to cover a pessimistic and optimistic version of the future.

2.3. Foresight and Scenario Planning

Foresight, future studies and scenario-building are close definitions, often used as synonyms. There are several definitions for them in the literature: for instance, Godet 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" (Godet 2000). Indeed, scenarios are not predictions, but rather hypothetical stories about how the future might unfold [24]. There are four distinctive characteristics of foresight, when compared to other future studies such as forecasting, summarized in Figure 1 [25]. These differences are also highlighted in Figure 2 [26], where it is specified that, while forecasting uses data from the past to make assumptions and build a projection to a single future, scenario methodologies start from the current realities and create multiple futures that challenge assumptions. Moreover, in scenario thinking one should account for uncertainty about the future, making it explicit – we must "accept the uncertainty, try to understand it, and make it part of our reasoning" [27]. 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 [22]. 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 [28].
trends, together with a qualitative approach that is not using any mathematical algorithm, emphasizes the importance of the learning process [31], [32]. There are many variations of the intuitive logics methodology published and it is the approach that has received most of the attention in the literature [31].

The Intuitive Logics methodology, also referred to as the “Shell approach” to scenarios, was first proposed by Herman Kahn at the Rand Corporation and later used at Royal Dutch Shell by Pierre Wack and his colleagues [31], [32]. It is a reasonably flexible methodology, emphasizing the importance of the learning process, and is qualitative by nature, not using any mathematical algorithm [32].

Scenario building usually starts with an horizon scanning, which consist on the “exploration of potential challenges, opportunities, and likely future developments” [29]. Indeed, this leads to the identification of key external drivers, which are not controllable by the organization, and may be subject to its influence or entirely given factors. This scanning may include both desk research and inputs from experts.

**Scenario main methodologies**

It is widely recognized that scenarios emerged from two distinct geographical centers – the USA and France – almost simultaneous in the 1960’s [30]. The historical development of both centers has lead to the creation of 3 different methodologies/schools.

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The Probabilistic Modified Trends (PMT) school uses curve fitting of historical time series data to identify trends, together with expert judgment to gather potential high impact unprecedented future events. Indeed, it is a quantitative approach that includes two distinct matrix-based methodologies – Trend-Impact Analysis (TIA) and Cross-Impact Analysis (CIA) – both attempting to consider the probabilistic modification of extrapolated trends [31]. Each of these models generates a range of alternative futures and, when combined with expert judgments, they create scenarios.

The French approach to scenario planning – *La Prospective* – appeared with the philosopher Gaston Berger, who believed that the future is not predetermined, but rather something that can be modeled and created [31]. 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 [31].

Godet has developed several computerized tools to facilitate the process of scenario building, including Morphol for morphological analysis, which consists on a process to visually explore and analyze all the possible solutions, eliminating incompatible combinations of factors and creating plausible combinations [32].

### 2.4. Scenario Studies in Health

The review and comparison of the scenario studies in health aims to elucidate on what is being done in foresight for the health context, and where innovation can take place. 14 Scenario studies were reviewed, including scientific and grey literature [26], [29], [33]–[44]. These studies were all analyzed aiming to totally characterize their methodological design. A big effort was made to homogenize all the characteristics of each study 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. In fact, it appears that all of them followed the Intuitive Logics methodology, with some adaptations. 4 of the 14 scenario studies analyzed are focused on HHR planning, including both studies from The British Centre for Workforce Intelligence (CfWI), which followed the CfWI Robust Workforce Planning Framework [45]. This framework relies on four major steps – horizon scanning; scenario generation; workforce modeling and policy analysis – and thus is particularly interesting for this dissertation (Figure 3).
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. 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 is illustrated in Figure 4. 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 with the help of cognitive maps (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 latter be analyzed.

The proposed methodology was 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 [46].

![Figure 4: Overview of the proposed methodology (in orange) and its interrelation with an existing mathematical programming model (in blue). The scenario building includes 7 steps, both technical (in green) and social (in purple) and culminates in the generation of coherent combinations of parameters to be tested in the model.](image)

### 3.1. Key issue and input parameters refinement

To start with, the key issue of this study must be stated, appearing from the existing model. It is a multi-objective MILP model, deterministic and multi-period, receiving a set of inputs and predicting the number of vacancies to open/close both in the medical course and in each medical specialty, in several periods of the next 30 years. 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 is considered suitable for the scenario methodology.

The inputs of the model were divided, considering its uncertainty, into baseline data, assumptions, controllable parameters and intrinsically uncertain parameters. The last category includes the parameters that will be considered for the scenario generation, specifically the physicians’ supply and demand per specialty, education costs, emigration rate, and immigration rate. To facilitate the social steps, the medical specialties were grouped into clinical, surgical and diagnosis.

### 3.2. 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 was done through desk research on the field of study in combination with a participatory method, in particular a questionnaire within an online platform. Weebly¹ was the chosen platform to build the questionnaire, available at [http://scenarios-hhrplan.weebly.com](http://scenarios-hhrplan.weebly.com). The questioning protocol included two questions for each parameter and it took a maximum of 15 minutes to answer:

1. **“In the next 30 years, how do you think the parameter will evolve?”** (i.e. increase, decrease, or maintain);
2. **“And why?”** Mention at least 3 factors that will influence it.”

To avoid misunderstandings, both the email and the platform were developed 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. These emails included a brief description of the project and questioning protocol. It was also mentioned that they could forward the email to other people with interest and knowledge in the field of healthcare. The first email was sent on the 17th of July,

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¹ [https://www.weebly.com](https://www.weebly.com)
asking for answers until the 31st of July. A reminder was sent on that day with a final deadline of 11 of August. A total of 27 respondents were considered and their characteristics can be seen in Figure 5 and Table 1.

![Figure 5: (Left) Distribution of the sex of the respondents; (Right) Distribution of the work context of the respondents.](https://www.draw.io)

Figure 5: (Left) Distribution of the sex of the respondents; (Right) Distribution of the work context of the respondents.

<table>
<thead>
<tr>
<th>Table 1: Distribution of the respondents’ occupations.</th>
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<td>Doctor</td>
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3.3. Aggregating and Refining

All factors enumerated by the experts were analyzed individually. It was realized that only the group of factors mentioned by each expert could explain the respective future evolution and thus no correspondence could be made between the future evolution of each parameter and the individual factor. Indeed, the future evolution was not explicitly used forward on the methodology.

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 TEEPSE² framework.

3.4. Clustering

The 74 drivers were then clustered into 7 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, but were rather created by the researchers – using self-knowledge and desk research. The cognitive maps were built using draw.io³, which is a browser-based diagramming application. In cognitive maps each node (i.e. circle) represents a concept – in this case a driver – and the links/arrows symbolize the relationships between them which, in this case, may be either of causality or influence [32], [47]. The map corresponding to the first key variable is represented in Figure 6.

This process resulted in the following 7 key variables:

A. Aging and the rise in chronic disease;
B. Access to healthcare and evolution of the private healthcare market;
C. Patient empowerment and self-management;
D. Mutual recognition of medical qualifications and attractiveness of the Portuguese healthcare market;
E. Evolution of the Portuguese economy and of public funding in the health sector;
F. Medical course structure and changes in Med Schools;
G. Technological evolution in health.

![Figure 6: Example of a cognitive map that gave rise to the “Aging and the rise in chronic disease” key variable.](http://www.wavec.org)

Figure 6: Example of a cognitive map that gave rise to the “Aging and the rise in chronic disease” key variable.

3.5. 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 [31], [32]. 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 [32]. These hypothesis are described in Table 2 and form an initial morphological space of $2^6 \times 3 = 192$ scenarios.

The addition of exclusion constraints is indeed extremely important to reduce the morphological field, excluding the combinations that are in fact incompatible, in the sense that they are highly implausible together. 8 Pairwise exclusion constraints were then added: D2E2, D3E1, D3G1, E1F2, E1G2, E2F1, F1G2 and F2G1.

The key variables, respective hypothesis and exclusion constraints were then inserted in FIL – Future in Logic, a new software created by António Alvarenga and Marco Alves, resulting from the cooperation between ALVA Research and Consulting⁴ and WavEC Offshore Renewables⁵. Given that FIL is still under-development, its results were compared to the ones from Morphol, a well-known software reported in the literature.

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² Technological, Economic, Environmental, Political, Social, Ethical.
³ https://www.draw.io
⁴ http://www.alva-rc.com/index.html
⁵ http://www.wavec.org.
The Extreme World Method basically consists of selecting two group scenarios that the generated scenarios can easily be clustered into. An additional output, which is a Hierarchical Tree that helps in the process of clustering, is easy to conclude that the generated scenarios can easily be clustered into two groups, or even other powers of two (Figure 8).

It was decided that an adaptation of the Extreme World Method would be used to choose the scenarios. The Extreme World Method basically consists of selecting one scenario with all the positively resolved uncertainties, and another with all the negative ones [48]. Considering only this method, the two selected scenarios would be extremely goal-directed and may not be very representative. It was decided that an adaptation of the Extreme World Method would be used to choose the scenarios. The Extreme World Method basically consists of selecting one scenario with all the positively resolved uncertainties, and another with all the negative ones [48]. Considering only this method, the two selected scenarios would be extremely goal-directed and may not be very representative.

4. RESULTS

4.1. Results from the Morphological Analysis

32 Scenarios resulted form the reduction of the reduction of the morphological space. Each was characterized by three Proximity Indicators: “CT”, which is the sum of common hypothesis between the specific scenario and all the others; “CM”, corresponding to the number of scenarios that differ in only one configuration; and “CX”, equal to the number of scenarios that are completely different. To choose the representative scenarios, mainly two outputs were analyzed: the Proximities Map and the Hierarchical Binary Clustering Tree.

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, calculated from the number of common configurations between the different scenarios. Both FIL and Morphol obtained 2 similar maps, apart from a rotation. Visually speaking, the one from the second software is clearer and is presented in Figure 7. FIL offers an additional output, which is a Hierarchical Tree that helps in the process of clustering: it is easy to conclude that the generated scenarios can easily be clustered into two groups, or even other powers of two (Figure 8).

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disparities between supply and demand of physicians cannot be balanced by the migration of doctors.

“Healthy Country” (223222)
The last three decades have been good for Portugal, in particular for healthcare. To start with, there has been an increase in the birth rate and consequent rearrangement of the age pyramid. Patients are more aware of their needs than ever before and have been starting to have an active role in managing their health. They are interested in knowing more about their health status and have greater expectations for healthcare, increasing the demand for specialized care. Moreover, the Portuguese economy is clearly recovered and there is an increasing financing for health. New policies improved the management of the vacancies and wages of medical specialties, bringing them to a balance. 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, not forgetting 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 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 of disease, leading to a better patient diagnosis and personalized treatment. Besides, new diagnosis technologies, faster and more accurate, facilitate the practice of preventive measures, not to mention the use of IT and AI to aggregate information and support medical decision. The changes induced by technology, including the use of automation in diagnosis and therapeutics, lead to horizontal and 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 their immigration. This has been only possible given that the medical qualifications are recognized worldwide nowadays.

“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.

“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.

4.3. Final workshop
This section describes the design of the final workshop protocols, even though it was not possible to schedule it in time. This is a central step for foresight methodologies and so it will take place in a near future. This social step consists on a half-day workshop and must be conducted in Portuguese by a facilitator with strong knowledge in this field. It is based on a 4-steps protocol:

i. Summary of the work done, including the morphological analysis, 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 group elicitation, timelines may be used for each parameter with the present value already marked, where experts shall sign the future values under each scenario.

4.4. Results from the Optimization Model
To finalize the methodology we will need to go back to the MILP model and test it for the 4 scenarios, i.e. run it with the 4 coherent combinations of parameters elicited in the previous step, as illustrated in Figure 4. The differences in the solutions obtained must be analyzed 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.

5. 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 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 downsides of the proposed methodology, which can be used to adjust and improve it.

Concerning the Horizon Scanning, the number and variety on the backgrounds of the experts who accepted to take part in this study is remarkable (see Figure 5 and Table 1). 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. 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, the majority of experts were able to answer it easily. 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. The analysis of the answers should definitely be done by a team of researchers to diminish the dependency on a person’ judgment. Besides, the use of cognitive maps was very helpful to cluster drivers into key variables, 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). 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.

As the final workshop was not tested, the final steps of the methodology cannot be well discussed and indeed may need some adjustments.

6. CONCLUSION 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 scenario school, 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. 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 HHIRPLAN 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, which may be improved with further work. To start with, 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 second question may be changed from an obligation to a preference. 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. 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.

REFERENCES


[38] Centre for Workforce Intelligence, “The future pharmacist workforce: Scenario generation report,” Centre for Workforce Intelligence, 2013.


