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Enhancing optimization planning models for health human resources management with foresight

ABSTRACT

Achieving a balanced healthcare workforce requires health planners to adjust the supply of health human resources (HHR). Mathematical programming models have been widely used to assist such planning, but the way uncertainty is usually considered in these models entails methodological and practical issues and often disregards radical yet plausible changes to the future. This study proposes a new socio-technical methodology to factor in uncertainty over the future within mathematical programming modelling. The methodological approach makes use of foresight and scenario planning concepts to build tailor-made scenarios and scenario fit input parameters, which are then used within mathematical programming models. Health stakeholders and experts are engaged in the scenario building process. Causal map modelling and morphological analysis are adopted to digest stakeholders and experts' information about the future and give origin to contrasting and meaningful scenarios describing plausible future. These scenarios are then adjusted and validated by stakeholders and experts, who then elicit their best quantitative estimates for coherent combinations of input parameters for the mathematical programming model under each scenario. These sets of parameters for each scenario are then fed to the mathematical programming model to obtain optimal solutions that can be interpreted in light of the meaning of the scenario. The proposed methodology has been applied to a case study involving HHR planning in Portugal, but its scope far extends HHR planning, being especially suited for addressing strategic and policy planning problems that are sensitive to input parameters.

KEYWORDS

Mathematical Programming, Foresight, Scenario planning, Uncertainty Modelling, Health Human Resources, Planning.

1 Introduction

Healthcare systems are complex structures, serving economic, social and also other political goals that may sometimes conflict with one another. As such, problems in healthcare planning and organization are often modelled as being multi-objective, reflecting the different views and objectives held by different stakeholders. Moreover, most of the times, these problems require the use of future-related quantitative information, which is often generated through *forecasting*. Forecasting may be for instance required to anticipate the demand for urgent care at an Emergency Department of a new healthcare unit or to estimate how epidemiological trends may affect the demand for healthcare at the national or supra-national level.

Within such contexts, Operations Research and Management Science methods are often used, including mathematical programming models using optimization (either maximization or minimization) of a single or multiple *objective function* [1]. This function is composed of a set of *decision variables* and subject to a set of *constraints*, and is often used in solving networking [2], resource allocation [3], location-allocation [4], elective and emergency surgery capacity allocation [5], route planning problems [6], or planning the health workforce [7] in health contexts [8].

Considering the particular case of tactical and strategic decision-making, especially in healthcare settings, solutions from simulation or mathematical programming models largely depend on multiple input parameters [9]. If these parameters are well-known and the forecasts lie within tight intervals of confidence, it does not pose a significant problem to the robustness of the results. If, on the contrary, parameters are surrounded by uncertainty and are hard to predict, results may be less satisfactory. In such cases, stochastic programming, robust optimization and sensitivity analysis have been used to deal with parameter variability and as a means to understand the impact of parameters' changes [10].

The reality, however, may be more challenging than a variation in some parameters or the introduction of randomness. HHR planning, in particular, is highly dependent on a set of social, economic, environmental and political changes that affect future conditions for the demand and supply of HHR in an interdependent way. This means that there may even exist causal relationships between parameters that a sensitivity analysis or choosing statistical distributions within stochastic optimization will not capture [11]. And even robust and stochastic approaches may be subject to limitations, since these consider only a worst-case scenario (the case of robust approaches) or rely on the use of a large volume of data and of statistical distributions for the uncertain parameters, which is information not easily obtained and difficult to interpret by decision-makers (in the case of stochastic approaches); and in some cases existing information is incomplete or inexistent [11].

These approaches may, therefore, be inadequate for handling uncertainty in a structured and meaningful way when dealing with challenges such as HHR planning, which may well fit within the *wicked problems* category given its overarching implications and complexity [12]. Foresight, and specifically scenario planning, have been recalled to support decision making in addressing wicked problems and is considered "a useful tool in the OR practitioner's tool kit and that it can complement many of the established soft OR methods" [13], [14]. Given the challenges of dealing with uncertainty within mathematical programming, we propose the use of scenario planning concepts to enhance mathematical programming models in an integrated way, while also avoiding the difficulties found in existing scenario-based methods. In particular, we propose a multimethodology (in the sense defined by [15], as attempting to combine distinct methods for a common purpose) that uses a specifically designed scenario planning approach that builds tailored scenarios – for the specific context of mathematical programming planning models – while depicting the views of HHR stakeholders and experts. The approach adopted for scenario building is socio-technical by nature [16], as it combines several techniques with participatory processes to involve HHR stakeholders and experts in the construction of fit-for-purpose scenarios and in the elicitation of a coherent set of input parameters for those scenarios. Foresight, in contrast to forecast, assumes that the future may change dramatically from the past [17].

Also, our definition of scenario deviates considerably from its traditional application in the realm of operations research. Traditionally, a scenario is defined as a particular realization of the uncertain data [18], typically over parameters that affect uncertain constraints or over the role of distinct objectives; and more advanced cases assign a probability for each *scenario* to occur. For instance, if we were unsure about the emigration rate of physicians (which affects HHR planning considerably [9]), particular values likely to occur are instantiated. Most often, this likeliness is the result of either linear forecasts or the opinion of the research team. In contrast to this traditional approach, we use scenario as a realization of the future, and there may be several futures [19]. In these futures, uncertainty will be depicted by distinct parameter values that will be constructively built with stakeholders and experts. In this vein, a scenario is a narrative that describes a future situation, as well as the course of external events that cause the future to change [20]. Therefore, scenarios are not seen as outright predictions, but rather as hypothetical stories about how the future may unfold [21], with these possible futures and narratives leading to a coherent set of input parameters of a mathematical programming model.

Notwithstanding the technical components of the development of both the mathematical programming models and the scenarios, a strong emphasis is put on the design of participatory processes (online surveys, interviews and workshops) to capture the knowledge and expertise from health stakeholders and specialists in the scenario building process. Scenarios are fit-for-purpose for the planning context and are embedded within the mathematical programming planning model structure. Specifically, in the scenario building process online platforms are used to identify drivers expected to affect future changes to mathematical models inputs parameters; interviews are used to further discuss different drivers' configurations (i.e. their hypothesis for evolution) and for validating proposed scenario structures; and a workshop is used to further discuss scenarios and their narratives, and for involving stakeholders and experts in the elicitation of coherent combinations of input parameters (for the mathematical programming model) for each scenario.

The proposed multimethodology is fully applied to a case of HHR planning in Portugal, with the previous multi-objective mixed integer linear programming (MILP) model for setting medical vacancies from Cardoso-Grilo et al. [22] being taken as the starting model to be adapted, and with real HHR stakeholders and experts being involved in scenario building and in the elicitation of parameters. This involvement with HHR stakeholders and experts thus provides tailor-made scenarios to embed in the MILP model. Results from this paper are then compared to the ones previously reported, which were generated through deterministic programming [22]. We also show that the use of the mathematical programming model needs to be adapted for distinct scenarios (for instance, it only makes sense to pursue certain policy objectives in specific scenarios).

This work has two key contributions to the literature. First, we provide a novel approach for handling input parameter uncertainty within optimization models that avoids the difficulties found in existing scenario-based methods. Particularly, a new multimethodology that relies on foresight and scenario planning concepts to build tailor-made scenarios and input parameters together with stakeholders and experts that are specifically fit for mathematical programming models. The proposed methodology is transparent and can be adapted and replicated to other contexts (which is not usually the case for existing scenarios planning studies [23]). Second, we show how this multimethodology can be successfully employed by strategic planners dealing with HHR planning problems. We apply it to a real-world case of HHR planning, in which the aim is to plan the number of vacancies in medical schools and in residency programs for coming years, inviting HHR stakeholders and planners with distinct views to join the process and think about the future. A critical aspect of the case is that it shows that HHR planning objectives may change under distinct possible futures (i.e. under a specific scenario, it may not make sense to pursue some policy objective).

It should be noted that scenario building processes have been acknowledged as key for policy-making purposes [24], with literature recognizing that building scenarios through participatory approaches and thereby engaging with relevant stakeholders and promoting an effective communication strategy and partnerships are some premises that must be followed in order to build meaningful and useful scenarios [25], which is a path that we uptake in this study.

The remainder of this paper is organized as follows: Section 2 provides an overview of HHR planning and foresight in the context of healthcare. Section 3 describes the multimethodological approach, detailing each step of the process. Section 4 reports the application of the multimethodology to a case study of HHR planning in Portugal and presents the results from its application. Scenarios, scenario narratives, as well as how these scenarios influence the planning of future medical residency vacancies with HHR mathematical programming models (requiring an adaptation of the use of MILP models) are shown. Finally, in Section 5 we discuss the results from applying and testing the proposed methodology, as well as draw insights from its application to the real case study.

2 Background

2.1 Health human resources

Healthcare is still to this date a labor-intensive sector, with HHR being the most important input in the delivery of healthcare [26]. As a consequence, the quantity and quality of the healthcare delivered is highly dependent on the quantity and quality of the existing HHR [27], including the physicians and nurses who undertake the clinical tasks, but also of clinical assistants and other administrative staff [9]. Therefore, being able to foresee the necessary number of health professionals at some point in the future is paramount to effective HHR planning, and can also be seen as an ethical and an economic goal [28].

HHR planning is unlike most other fields and industries. First, improper planning may lead, in the limit, to patient deaths—an extreme but possible outcome [29]. Second, the health labor market is highly idiosyncratic, especially concerning the time required to train qualified staff, which is higher than in most professions [27]. Furthermore, strong state regulation over healthcare delivery but also over medical training and access to profession, along with licensing and professional regulations, prevents self-adjustment of the market [27].

Effective workforce planning can then 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*" [30]. This is, in fact, equivalent to ensuring 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 [27]. It certainly is a complex task, and a mismatch is likely to result in severe consequences. 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 of the available clinicians and increase of the waiting lists [27]. On the other hand, a surplus may cause economic inefficiencies and misallocated resources, along with inflated costs through supplier-induced demand [27], [31].

Therefore, workforce planning requires information on a wide range of future healthcare supply and demand parameters.

2.2 Healthcare planning models dealing with uncertainty

Several techniques have been used to assist healthcare planning. Simulation has been a key tool of the OR praticioner's toolkit, being frequently used to tackle operational, tactical but also strategical problems. There are three main simulation approaches [32]: Discrete Event Simulation (DES), System Dynamics (SD), and the more recent Agent-based Modelling (ABM). These approaches have been used for patient scheduling [33], resource allocation [34], capacity planning and management [35], staff scheduling, modelling patient flows in emergency care [36], healthcare capacity and delivery [37], forecasting the medical workforce [9], studying migration of physicians and policy implications [38], or health policy [39]; and these approaches enable performing deterministic and stochastic analyses and present key advantages when one needs to model complex and nonlinear problems [3]. Optimization has also been widely used and preferred to simulation when reaching an optimal solution is a strong requirement, with several studies exploring a combination between simulation and optimization, although entailing a high level of modelling complexity [3]. Again, these combinations of methods enable the modelling of uncertainty in several formats.

For contexts like the one uptaken in this paper—the planning of medical vacancies to be opened in the future, when several policy objectives are pursued, and when a wide range of future healthcare demand and supply variables are uncertain and critical—, mathematical programming models may be favoured in the face of this type of uncertainty.

Distinct modelling approaches have been recalled for handling uncertainty within mathematical programming. Deterministic models are often used as the starting point before incorporating uncertainty considerations, while stochastic and robust programming and sensitivity analysis explicitly incorporate uncertainty within mathematical programming modelling. Looking into detail to these approaches, stochastic programming handles the unknown parameters as a realization of random parameters, usually sampled from a probability function [40]. These parameters are commonly incorporated in a single-, two or multi-stage stochastic problem [41]. As most applications of stochastic programming have focused on operational problems in healthcare, stochastic programming is especially suited to contexts in which planning problems are well-defined and entail clear inputs, and where the probability distribution of uncertain parameters is known (theoretically or empirically) [42]. For instance, stochastic programming has been used to reduce patient waiting times and overtime in an outpatient infusion center [43]; for scheduling in laboratory facilities of healthcare delivery systems [44]; and also, for modelling kidney exchange problems [45]. Since these problems can become quite large and therefore computationally expensive, heuristic formulations have been sometimes used [46].

Another option for modelling uncertainty within mathematical programming is robust optimization, which does not require the specification of the underlying probability distributions [41]. Instead, it uses uncertainty sets and provides a worst-case guarantee for the solution. It has been used for capacity allocation in elective and emergency surgery [5] or for devising operating room schedules, while factoring in unknown surgery durations or patients arriving randomly to the emergency department [47].

A simpler but commonly used approach for addressing the problem of input data uncertainty is running a sensitivity analysis (for instance one- or two-way sensitivity analyses), whose purpose is to measure the impact of varying a parameter on the optimal objective function, in this way analyzing at the end of modelling the robustness of a solution [48]. Albeit similar in nature and frequently used in replacement, sensitivity analysis differs substantially from stochastic and robust programming. While stochastic programming or robust optimization assess the uncertainty in model outputs resulting from uncertainty in several inputs altogether and leading to an optimal solution, sensitivity analysis tries to capture the contribution of the inputs to the variation of the optimal solution, without taking data uncertainty into account at the modelling stage.

Although widely used for planning purposes in the healthcare sector, these different methods do suffer from several weaknesses that can seriously hinder the achievement of useful planning results in real contexts [11], [49]: sensitivity analysis does not typically capture the inter-relationships between input parameters; robust approaches are criticized by its conservativeness because they only consider the worst-case scenario; and stochastic programming requires details about the probability of occurrence of those scenarios, which is information not easily obtained, and also depends on the use of an acceptable number of scenarios that gives a good representation of the uncertainty, which often results in computationally intractable problems. Stochastic programming tends to be also associated with a black-box, as it is difficult for the planner to understand how the optimal solution is generated.

It is thus clear that scenarios and uncertain parameters can be further explored and play a key role when developing mathematical planning models to support the decision-making process under uncertain conditions. In fact, bearing in mind the need to consider changes in multiple parameters of a mathematical programming model, several planning studies have explored the use of instruments reported as *scenario-like* by resorting to stochastic programming or sensitivity analysis, but without using a structured, scientifically-based methodology to construct these *scenarios*. Indeed, what researchers typically do is to select a set of parameters of interest and assume changes to those parameters in an *ad hoc* way (examples on the organization of hospitals into networks [2], assignment of beds to hospital departments [50], nurse workforce planning [7], long-term care planning [4], [51], or in the effective staffing plan for emergency departments [52]). Nevertheless, the *scenarios* adopted in these studies do not respect the definition of scenarios from the foresight literature, as defined in the next section. In fact, these *scenarios* are typically elaborations of the researchers to reflect a change in one or several input parameters (for instance, a *scenario* where the retirement age increases or decreases by a year when doing HHR planning [53]). Moreover, these scenarios do not result from a structured construction process to obtain meaningful and sound scenarios (aligned with scenario definitions in the foresight literature), and do not depict coherent combinations of all the relevant input parameters for those scenarios.

Additionally, when dealing with high-level planning problems, in which the planning horizon is long, causal links between input parameters are hard to identify, and hidden endogeneity between parameters may exist, there being a need to use methods that account for these aspects. Further to these aspects, scenarios to be used within mathematical programming models should also be built to be tractable and to enable an understanding about planning consequences. Moreover, it is critical to ensure that unlikely and unrealistic combinations of input parameters are used.

As such, proper scenarios can be generated with adequate techniques to capture the views (and stimulate the involvement) of relevant stakeholders and experts, and to produce coherent combinations of parameters for those scenarios that can be interpreted, with foresight and scenario planning providing concepts and a path to enhance mathematical programming modelling. Also, the construction of scenarios is expected to have implications for the practical use of mathematical programming models as there is an association between possible futures and policy objectives. For instance, in scenarios of economic recession, cost containment can be modelled as a key constraint in HHR planning, while under economic growth there is usually scope for governments to pursue other policy objectives such as equity in the distribution of medical vacancies to distinct specialties and to different locations. As a consequence, the formulation of the model, including its objectives, may vary depending on how the future unfolds, a fact most research does not address.

2.3 Foresight and scenario planning

Foresight and futures studies are often used interchangeably. Foresight has been described using multiple definitions; one of the most common is as follows: "the term refers to approaches to inform decision-makers, by inputs concerning the longer-term view and by drawing on wider social networks that have been used in much futures studies or long-range planning" [54]. In short, foresight is about thinking, debating and shaping the future [19], [55]. Foresight is, therefore, a much more overarching activity than simply projecting the future using data from the past and making assumptions, which is the task forecasting aims to achieve (cf Figure 1). There are multiple foresight methods and techniques, with scenarios being among the most widely used [56]. Scenario methodologies start from the current realities and create multiple futures that may challenge assumptions altogether [57]; hence, scenarios are not taken as predictions, but rather as hypothetical stories about how the future may unfold [21]. One can think of scenarios as a long-term macro view that invites experts not only to think about the future but also to explicit their assumptions while doing so (cf Figure 1); and building such scenarios has shown to improve the quality and effectiveness of policy-making [58].

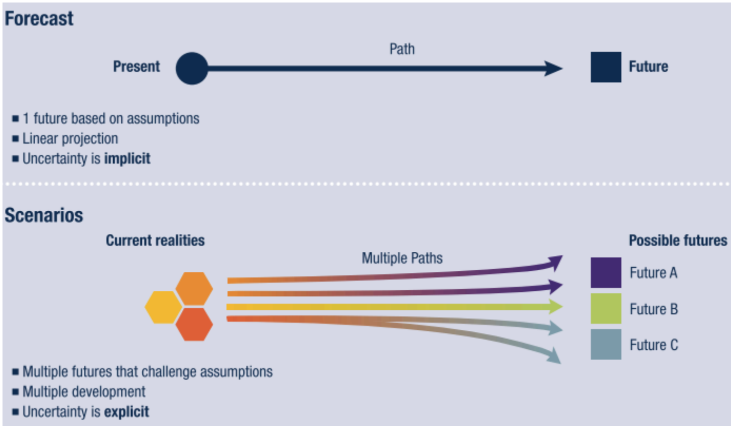

Figure 1: Forecasting versus scenario thinking (source: [59]).

Scenarios emerged from two distinct geographical centres—the USA and France—almost simultaneously in the 1960's [60], with 3 schools of thought being recognized: Intuitive Logics, *La Prospective* and Probabilistic Modified Trends. The Intuitive Logics school was based on the work by Herman Kahn at the Rand Corporation and later used at Royal Dutch Shell by Pierre Wack and his colleagues [60]. It is deemed as a flexible methodology that emphasizes the importance of the learning process and is qualitative by nature, not using any mathematical algorithms [61]. There are many variations on methodologies recalled within this school, and it has received most of the attention in the literature [60]. Following the Intuitive logics scenario development methodology, Wright et al. present eight stages for scenario building: 1) set the agenda; 2) determine the driving forces; 3) cluster the driving forces; 4) define the cluster outcomes; 5) impact/uncertainty matrix; 6) frame the scenarios; 7) scope the scenarios; and 8) develop the scenarios. The purpose of these steps is to identify the driving forces of the future that are present in context environment and will impact the topic of concern; consider the range of possible and plausible outcomes of each of these forces; and understand how the forces interact with each other in terms of cause and effect, and chronological order (adapted from [62]);

The French school to scenario planning, *La Prospective*, is the product of the philosopher Gaston Berger, who believed that the future is not predetermined, but rather something that can be modelled and created [60]. What started as the creation of normative scenarios of the future to guide policy-makers and provide a basis for action was soon expanded by

Michael Godet to a mathematical and computer-based approach to assist experts in scenario building [60]. Godet has developed several computerized tools to facilitate the process of scenario building, including Morphol for morphological analysis, which consists of a process to visually explore and analyze all possible solutions, eliminating incompatible combinations of factors and creating plausible combinations [61]. And again, expert judgment is required for scenario building. One of the main objectives of the use of such tools is to ensure the internal consistency of the scenarios being built [63], as consistency (immediately followed by plausibility) is one of the most important criterion for scenario validation [61].

In this paper, we propose enhancing optimization in the context of HHR planning by embedding scenario building within the mathematical planning models. Previous studies have already employed scenarios in strategic HHR planning problems [64]-[67], including to assist in the planning of community pharmacists in Portugal [68], but not as a means to deal with uncertainty in MILP models for health planning in general, and for HHR planning in particular. In addition, some of the scenario-based methods suffer from several weaknesses that can seriously hinder the achievement of useful planning results (see section 2.2).

3 Methodology

The specific features of the novel multimethodology proposed in this study are detailed in this section. An overview of the proposed multimethodology, which is divided into 8 steps, is represented in Figure 2. Steps 1-7 are part of a fit-for-purpose scenario building (socio-technical) approach to build tailor-made scenarios, which are developed for the context and embedded into a mathematical programming model. In Step 8, the MILP model is then run according to the scenario specifications that are relevant to HHR stakeholders and experts.

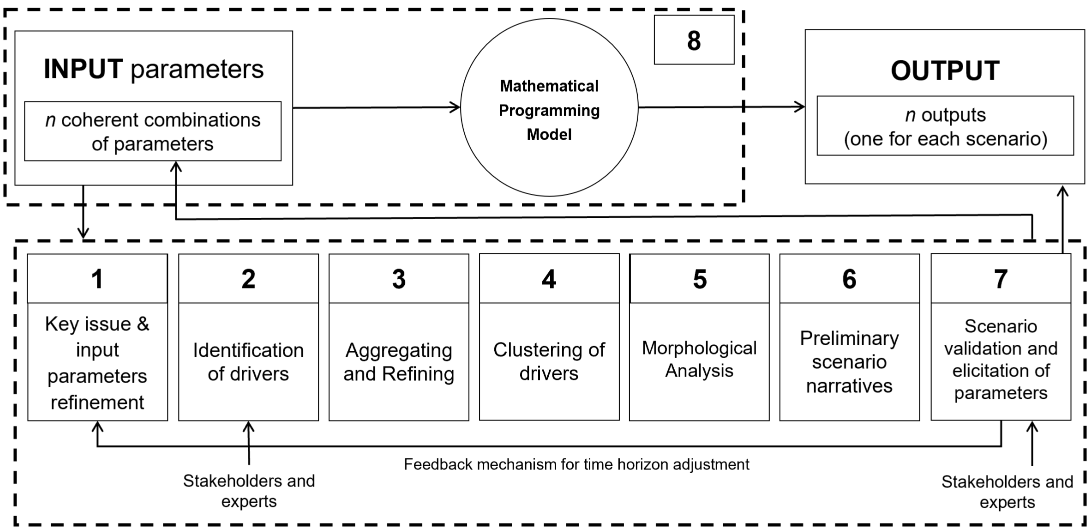

Figure 2: Overview of the technical steps of the proposed methodology embedding scenario building within mathematical programming modelling. Some steps also entail a social component, with an involvement of health stakeholders and experts.

This new multimethodology is adapted from recent developments from the "intuitive logics" school [55] by adopting a constructive and learning process in which constructivism [69], [70] is ensured by involving stakeholders and experts in a process for building scenarios fit for the mathematical programming HHR planning model. It also makes use of concepts from La Prospective, namely morphological analysis, for analysis of the relevance, coherence and plausibility of the scenarios being built [56].

Similar to most works that deal with uncertainty in mathematical programming modelling, the process starts with an identification and definition of the input parameters (Step 1). However, our methodology goes beyond such analysis by encompassing a thorough procedure that builds on the knowledge of health stakeholders and experts to build scenarios in the planning context. It begins with explaining the key issue under analysis (in this case, planning physicians requirements in Portugal) and refining the input parameters that may be relevant. Next, a panel of health stakeholders and experts are invited to explain the driving forces that may affect how parameters will evolve in the future (in line with identifying the drivers) (Step 2). Since it is appropriate to involve multiple stakeholders and experts in the process, their answers need to be organized, aggregated and refined, with causal relationships being considered (Step 3). Next, similar drivers identified using different terms but sharing the same ontological meaning have to be clustered (Step 4), being followed by a morphological analysis, which will give origin to all possible combinations of the drivers and with information to select representative and contrasting combinations of drivers to be taken as the relevant scenario structures (Step 5). The final stages consist of writing preliminary scenario narratives for the scenario structures previously built (Step 6); and finally, to involve stakeholders and experts to test, adjust and validate the scenarios narratives, as well as to elicit estimates for the parameters resulting from each scenario (Step 7). The sets of input parameters – with a set of parameters being defined for each scenario that entails a possible future with a substantive interpretation – are then used as an input to the mathematical programming model (Step 8). The mathematical programming model needs to be first adjusted to better reflect the policy context of the scenario under analysis, with such an adjustment involving the selection of a meaningful set of objectives and constraints, before running the model and obtaining outputs.

The proposed methodology is aligned with the generic CfWI Robust Workforce Planning Framework [28] from the British Centre for Workforce Intelligence that relies on four major steps for workforce planning: horizon scanning, scenario generation, workforce modelling, and policy analysis (see representation in Figure 3). Hence, our methodology is not only aligned, but it also addresses concerns from those working in workforce planning.

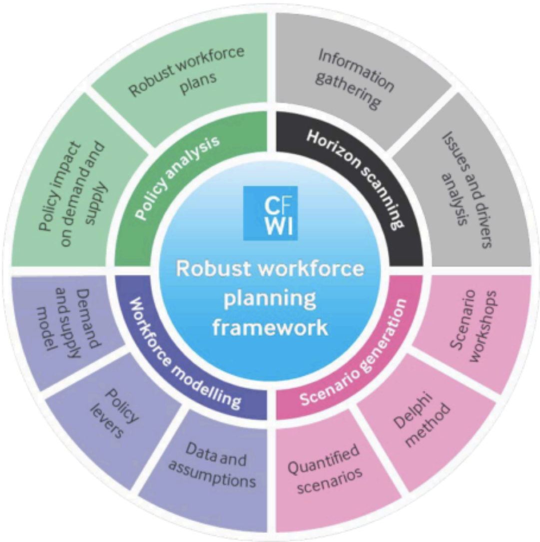

Figure 3: The CfWI Robust Workforce Planning Framework (source: [28]).

3.1 Methodology steps

The starting point is the modelling of the planning problem through mathematical programming, followed by:

Step 1 – Key issue and input parameters refinement. The first step is about identifying the key issue in scenario building, and ensuring stakeholders and experts clearly understand the planning context. Second, it is important to define the time horizon of the planning problem. Finally, researchers need to identify the input parameters of the mathematical programming model that are intrinsically uncertain in the context of the planning problem. These parameters can be of the following types:

i. **Baseline data**: present facts that are known;
ii. **Assumptions**: make use of estimated parameters that are not likely to change over time;
iii. **Controllable parameters**: identify the parameters that entail policy choices;
iv. **Intrinsically uncertain parameters**: identify parameters that are likely to change over time.

We propose that the most relevant parameters for scenario building are this last type of parameters – intrinsically uncertain parameters – which will vary per scenario.

The output of this step is then one or more clear statements framed in a well-defined time horizon, which are critical for those participating in model building to be fully cognizant of the subject matter, therefore explicating their assumptions about the future.

Step 2 – Identification of drivers. Having clearly identified the intrinsically uncertain input parameters, the next step is meant to collect a wide range of perspectives from an array of stakeholders and experts on why the uncertain parameters previously identified may vary along the time horizon. The goal is to gather information about the main driving forces with an impact on the uncertain parameters, asking questions such as «In the next 30 years, how do you think parameter A will evolve»? to health stakeholders and experts. Given the specificity of the topic, we are interested in obtaining specialized feedback, in the sense that the participant should be a stakeholder or expert and understand at least the general principles of the problem. One can ask qualitatively whether the parameter is expected to increase/decrease/maintain, and then ask for the rationale behind that answer. Hence, questions such as «Why will it change? Mention at least 3 factors that may influence it» will help to disclose the drivers behind that prediction, so that drivers are identified, and causal links between drivers can be inferred at a later stage.

Step 3 – Aggregating and refining. Answers from experts are then collected, and an individual analysis of all factors enumerated by the health stakeholders and experts is performed. The objective is now to identify and aggregate the same drivers and frame them within TEEPSE (Technological, Economic, Environmental, Political, Social and Ethical) terms. This is a very technical and laborious process, yet it is a necessary step to eliminate redundancies and combine factors that refer to the same ontological entity. Not to be confused with clustering, Step 3 consists of identifying terms that may be used to refer to the same thing. We suggest the workflow detailed in Table 1 for conducting this step, which is conducted by researchers/analysts.

Table 1: Workflow suggested for aggregating and refining the information collected from the stakeholders and experts in horizon scanning in Step 2.

1.	Assign an ID to each expert.
2.	Organize the answers of experts – the potential drivers – by input parameter, and for each, group the ones referring to the same ontological entity.
3.	Name each group of potential drivers with a word or expression that clearly identifies the underlying concept, and which is taken as a scenario driver.
4.	Build a table containing drivers as rows and parameters as columns to summarize all the information. Fill the table with information linking drivers with input parameters as captured by stakeholders and experts' answers.
5.	Organize the drivers according to TEEPSE taxonomy (Technological, Economic, Environmental, Political, Social and Ethical).

Step 4 – Clustering of drivers. This step is concerned with clustering drivers so as to diminish the admissible set of key drivers. The idea is to separate independent from interrelated drivers and obtain one key driver in the second case. This is done by first listing all the drivers, and by establishing causality and influence relationships. Unless an ontology already exists, which is very unlikely given the dimensionality and specificity of planning problems, semantic networks need to be generated manually to relate the drivers and the way they are interconnected, implying that the process is mostly manual and may require extensive desk research. We suggest using cognitive maps to assist the mapping of relations and then the clustering of drivers: in cognitive maps, each node represents a concept/driver, while arrows symbolize relationships between nodes, which may be of causality or influence [44]. Afterwards, one tests for independence and creates clusters of drivers. Such clusters can then be reduced into a single key driver. This process results in a list of key drivers that will be the basis for the remaining steps. Similar to the previous step, this can be conducted by the researchers/analysts and does not necessarily require the participation of the health stakeholders and experts (although these can be involved). This step will sound familiar to those experienced in doing causal loop diagrams for System Dynamics models.

Step 5 – Morphological Analysis. In this step, a morphological analysis is conducted by the researchers/analysts to expand the set of plausible evolutions of key drivers (also known as scenario structures, the backbone of scenarios), which should be contrasting and challenging and in a small number, so as to reduce the scenario space [61]. Morphological analysis is a structured and systematic way of obtaining all the combinations of the plausible evolutions of the key drivers that lead to hypothetical scenarios [60], [61]. If there are n key drivers with two options each, then 2^{n-1} combinations are virtually possible. For problems with a significant number of key drivers, this may result in an overwhelming set of admissible combinations, which may be substantially reduced by adding exclusion constraints (for instance, capturing impossible combinations between evolutions), and more reductions may be obtained by running software applications, such as FIL[1] or Morphol, that help to narrow results further by grouping similar items [71]. These software packages execute methods, such as Proximities Map and Hierarchical Binary Clustering Tree [72], in order to help reducing the scenario solution space. The Proximities Map is a two-dimensional representation of the morphological space in which the relative location of each possible scenario is given by the Euclidean distance calculated from the number of common configurations between the different scenarios. The Hierarchical Binary Clustering Tree is a very similar method that also uses the distance to group configurations in pairs of two. This process consists of combining two by two the nearest scenarios on each level of pairing, up to a level that ends with the two most distant scenarios (see Figure 6). One should however note that although this scenario reduction may be performed by analysts (such as is the case in this

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[1] FIL is a software package developed by ALVA Research and Consulting and WavEC Offshore Renewables.

study), involving health stakeholders and experts can be valuable for the selection of more relevant and meaningful scenarios.

The final result in this step is the selection of a set of contrasting scenario structures deemed as relevant for planning – rather than using a complete set of scenarios, as it is typically the case in most stochastic programming studies [49], [73] (although these scenarios are typically generated with probability distributions of a few input parameters, and not as a coherent combination of a wide range of input parameters), here the aim is to identify and select plausible scenario structures with a meaningful interpretation and that help understanding the impacts of HHR planning in practice. We suggest using the extreme world method [74] to derive two extreme but plausible scenarios, and additionally, we propose considering also some in-between realities (note that distinct logics of scenario selection can be adopted depending upon the planning context and according to the views of stakeholders and experts). Usually, the use of a number of scenarios between 3-5 is recommended for strategic decision-making [61].

Step 6 – Preliminary scenario narratives. It then follows the generation of scenario narratives for each scenario, i.e. a descriptive story that entails a world where these variations happen to take place [75]. Scenario narratives are appropriate to communicate the meaning of scenarios and to make stakeholders and experts to be in the right frame in the next steps of the methodology. This is a technical endeavor usually performed by researchers/analysts, with scenarios and narratives being afterwards adjusted and validated by health stakeholders and experts.

Step 7 – Scenario validation and elicitation of parameters. Step 7 aims at conveying the scenarios to the stakeholders and experts, adjusting and validating the scenarios, and once this is concluded, to involve stakeholders and experts in the elicitation of input parameters. This step also includes a feedback mechanism for readjusting the time horizon, if experts are unease with very long time horizons. This change has no impact on the previous steps and does not require repeating any of the stages, but it will impact the estimates obtained in the next participatory processes.

Several participatory processes can be adopted, and for illustrative purposes we propose a final round of interviews with a larger group of stakeholders and experts, and a workshop with a smaller group of health stakeholders and experts with the objective of using these scenario narratives to elicit their guesses that will then be incorporated in the mathematical programming model. The individual interviews are intended for scenario adjustment, validation and for increasing the knowledge about the variation of uncertain parameters in the time horizon, and may be led as follows: participants are first reminded of the key issue, of the planning context, and with the parameters under study; next, each scenario is thoroughly presented and discussed to ensure clarity; finally, each stakeholder and expert reflects upon whether each parameter will increase, decrease or stay constant in each scenario. Once the individual interviews are performed and depending on results, scenarios can be adjusted for clarity.

In the workshop, a group of stakeholders and experts starts by accessing the results of the individual interviews, by reflecting about the scenarios, and afterwards think about how the parameters may evolve under each scenario. Next, a group discussion takes place and the participants elicit future levels of input parameters for each scenario and confront each other's views on the subject. Finally, the participants elicit the group input parameters for each scenario. The outcome of this demanding process is the generation of coherent input parameters that accurately describe what will happen with input parameters in each of the scenarios posited by the experts. These parameters are then used to run the mathematical programming planning model for each scenario. Future oriented evidence can be provided to experts when available.

Step 8 – Mathematical Programming model. Finally, Step 8 makes use of the scenarios built in the previous steps as input to the MILP model. To illustrate the implementation of the proposed methodology, we depart from the mathematical programming model from Cardoso-Grilo et al. [22] that informs about which medical vacancies should be opened to anticipate future healthcare needs (the complete mathematical formulation is presented in Annex A). Figure 4 shows in a generic format how the MILP model is to be used in different scenarios, with the model needing to be adapted to each scenario context to answer to relevant planning questions.

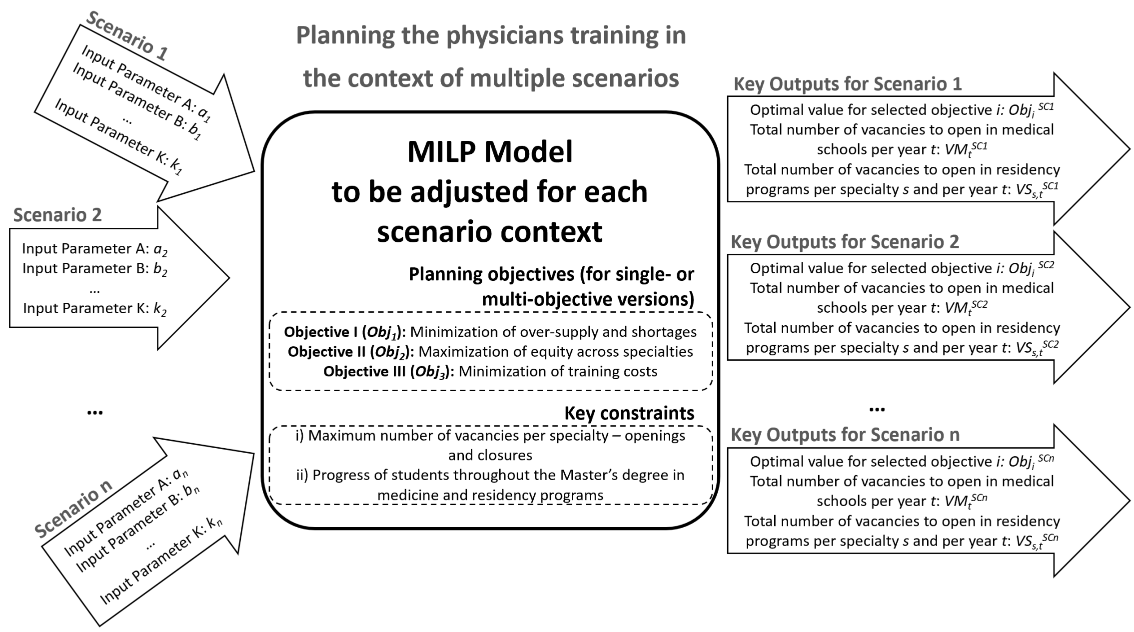

Figure 4. General representation of the use of the MILP model to inform the planning of physicians' vacancies for the different scenarios built based on steps 1-7 of the multimethodology.

Interpreting Figure 4 for the HHR context, the model is set to inform about the training of physicians, specifically regarding on how many vacancies should be opened per year in medical schools and per specialty – decision variables VM_t and VS_{st}, respectively (see

Annex A) – while accounting for multiple objectives and respecting key planning constraints. Depending on the analysis to be performed, one or more of the following objectives may be considered, and the use of the model requires adaptations: i) minimization of over-supply and shortages in the provision of care (objective I), ii) maximization of equity in the distribution of physicians across specialties (objective II), and iii) minimization of costs incurred in the training process (objective III). Key constraints include the imposition of a maximum number of vacancies that can be opened or closed per specialty, as well as the modelling of the medical training pathway of students throughout the Master's degree in medicine and residency programs.

Concerning the use of the scenarios built following Steps 1-7 of the multimethodology, the MILP model is run for each scenario individually (with a meaningful policy context), and different outputs will be obtained for the objectives selected for analysis and also for the vacancies to be opened in medical schools (numerus clausus) and residency programs. These different outputs will depend on:

i. The combination of input parameter values (obtained following Steps 2-7) characterizing the set of uncertain input parameters (herein represented as input parameters A-K, identified under Step 1) that define each scenario;

ii. The combination of objectives and constraints selected for running the model coherently with each scenario, since each scenario could give origin to different objectives and constraints (for instance, if the economic outlook is negative, reducing brain drain/physician emigration may be one objective, while if the country is performing well, emigration tends not to be an issue). Accordingly, the mathematical programming model needs to be adjusted for each scenario and for the planning questions set for each scenario.

4 Case study: planning the Portuguese physician workforce

The methodology detailed in the previous section was used to build scenarios to support the planning of physicians in Portugal. The case comprised the several steps defined in the methodology, with the starting point being the MILP model proposed by Cardoso-Grilo et al. [22], which was adapted for use with the tailored scenarios and to answer relevant and related planning questions. As above described, the scenarios reflect the views of a group Portuguese health stakeholders and experts.

4.1 Step 1 – Key issue and input parameters refinement

The key issue of our case was taken from the context of the multi-objective MILP model [22], which is a multi-period model that receives a set of inputs and aims at assisting planners in defining the number of vacancies to open/close both for medical school and for all medical residencies, in several periods for the next 30 years. Since the *right* number of vacancies is the result of a balance between the supply and the demand for physicians, both have to be projected into the future. Therefore, the key issue of our case was reframed as follows: "*How will the HHR evolve in the next 30 years in Portugal?*".

The inputs of the mathematical programming model were divided, based on their uncertainty, in baseline data, assumptions, controllable parameters and intrinsically uncertain parameters. The last category included the parameters to be considered for the scenario generation, which are: (i) supply of and (ii) demand for physicians of all specialty types (clinical, surgical and diagnostic); (iii) education costs; (iv) emigration rate; and (v) immigration rate.

4.2 Step 2 – Identification of drivers

The step to identify the driving forces with impact on the future of HHR for the intrinsically uncertain parameters was done through desk research on the field of study, in combination with an online questionnaire (available at http://scenarios-hhrplan.weebly.com). The questioning protocol included two questions for each input parameter. The questions were:

1. The closed question "In the next 30 years, how do you think the *parameter* will evolve?" with possible answers being increase, decrease, or maintain;
2. The open question "And why? Mention at least 3 factors that will influence the *parameter* evolution."

The parameters under study are the ones listed in Step 1. A personalized email was sent to a total of 53 HHR stakeholders and experts, along with an email to the Portuguese Central Administration of the Health System, the governmental entity that is in charge of planning the HHR in Portugal. These emails included a brief description of the project and questioning protocol. It was also indicated that the email recipients could forward the email to other people with interest and knowledge in the field of healthcare. Participants were told that the questionnaire would take an average of 12 minutes to answer (this figure was based on a pilot in which a few individuals answered). A few questions regarding socio-professional characteristics of participants were included.

A total of 27 responses were considered, out of which 78% were male and the remaining 22% female (invitations were sent irrespective of gender). Most of the respondents (55%) reported working in the public sector, while 30% worked in the private sector and 15% worked in both. The occupation of the respondents is shown in Annex A, Table A.1. The information collected from the open question, written in free text form, was then used as the driving factors from which both global trends affecting the evolution of the parameters (increase/decrease/maintain) and the drivers explaining such variations were extracted (see Annex D).

4.3 Step 3 - Aggregating and refining

All driving factors enumerated by the participants were analyzed individually and aggregated manually by one of the authors using simple hermeneutics [76]. The driving factors, or drivers, were named with a word/expression meant to be easily understood and organized according to the TEEPSE taxonomy, earlier described. Expressions such as «increase in life expectancy», «population ageing» or «population longevity» were synthetized to one single driver called *ageing population*. Similarly, expressions such as «greater incidence of multimorbidity and chronic diseases» or «increase in chronic diseases» were reduced to a driver termed *incidence of chronic diseases*. In the end, the aggregation procedure of driving factors gave origin to 74 *drivers*.

4.4 Step 4 – Clustering of drivers

The 74 drivers were clustered into 7 key drivers. This was achieved by looking for causal relationships or influences between the different drivers and by gathering this information within a cognitive map representation. These relationships were created by the researchers through self-knowledge and desk research.

In the cognitive maps, each node (i.e. circle) represents a concept—in this case a driver—and the links/arrows symbolize the relationships between them, with relationships capturing causality or influence [61]. The map corresponding to the first key variable (Aging and increase in chronic diseases) is represented in Figure 4. As a result, we obtained 7 key drivers deemed as critical to influence the input parameters of the mathematical programming planning model:

A. Ageing and increase in chronic diseases;
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 to the health sector;
F. Medical course structure and changes in medical schools;
G. Technological evolution in health.

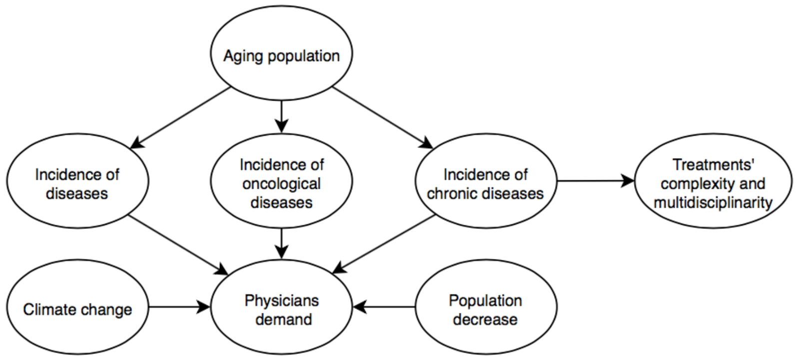

Figure 4: Example of a cognitive map that originated the "Aging and increase in chronic diseases" key driver.

4.5 Step 5 - Morphological analysis

The step following the derivation of the key drivers under Step 4 is the generation and selection of scenarios through a morphological analysis. As depicted in Table 2, the analysis led to six key drivers taking two possible configurations (i.e. hypothesis of evolution) each, and one taking three, which led to an initial morphological space composed of $2^6 \times 3=192$ scenario structures. Exclusion constraints were then considered excluding incompatible (i.e., highly implausible) combinations, leading to a reduction of the morphological space. For instance, if the Portuguese economy is doing well and increased public sector funding is secured (E2, Table 2), then it is not likely that medical schools will see no improvements or a deterioration in their budget (F1, Table 2). Eight pairwise exclusion constraints were considered relevant, corresponding to the following cases (nomenclature as presented in Table 2: D2E2, D3E1, D3G1, E1F2, E1G2, E2F1, F1G2 and F2G1. This process led to a reduction of the morphological space from 192 to 32 scenarios.

Table 2: Key drivers and respective hypothesis.

Key drivers and hypothesis		
A	1	Aging, rise in chronic diseases and consequent increase in the complexity and multidisciplinary of the pathways.
	2	Increase in the birth rate and consequent beginning of the rearrangement of the age pyramid.
B	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	1	Maintenance of the information asymmetry on health services: patient awareness and empowerment remains the same.
	2	Increase of patient's awareness and expectations, starting to have an active role in managing their health.
D	1	Mutual recognition of medical qualifications at international level is very limited, along with the closure of borders and troubled migratory flows.

Key drivers and hypothesis		
	2	Medical qualifications recognized worldwide, allowing the migration of physicians. However, Portugal is not attractive enough IMGs 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.
E	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	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	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.

Key drivers legend: A. Ageing and increase in chronic diseases; 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 to the health sector; F. Medical course structure and changes in medical schools; G. Technological evolution in health.

Departing from these 32 scenarios, we could then proceed to choosing the final set of scenario structures. To do so, we used the Extreme World method, which consists of selecting one scenario with all the best-case resolved uncertainties, and another with all the worse-case, yet plausible, scenarios [77]. Within this setting, the scenarios selected were "1111111" and "2232222". Note that each scenario is represented by a *n*-digit number in the Morphol software, with *n* representing the number of key variables (7 in this case), and each digit can assume a value up until 2 or 3, as coded in Table 2. In order to include in-between realities, we extended the set by choosing two additional scenarios by analyzing the results in the Morphol and FIL software. This selection was based on the following two criteria:

i. Selected scenarios cannot belong to the list of "closest scenarios" from the two extreme scenarios (list of closest scenarios obtained from the FIL and the Morphol Software);
ii. Use of the Proximity Indicator – the CT indicator – to depict representative scenarios. The CT indicator represents the sum of common hypothesis between the specific scenario and the remaining ones, thereby identifying which scenarios have similarities.

Taking these criteria into account, and analyzing further both the Proximities Map (Morphol Software; Figure 5) and the Hierarchical Binary Clustering Tree (FIL

Software; Figure 6), the scenarios “2221111” and “1111222” were chosen. These two scenarios are distant from each other, represent a set of representative scenarios according to the Proximities Map (visual representation in Figure 5, with the selected scenarios highlighted in yellow), and together with two extreme scenarios we obtained a set of four scenarios to be analyzed in the following step. There is no rule specifically pointing to four. The scenarios were selected to ensure both representativity, i.e. the scenarios that best cover the morphological space; and manageability, i.e. build the smallest set of scenarios to facilitate both the workshops and the analysis.

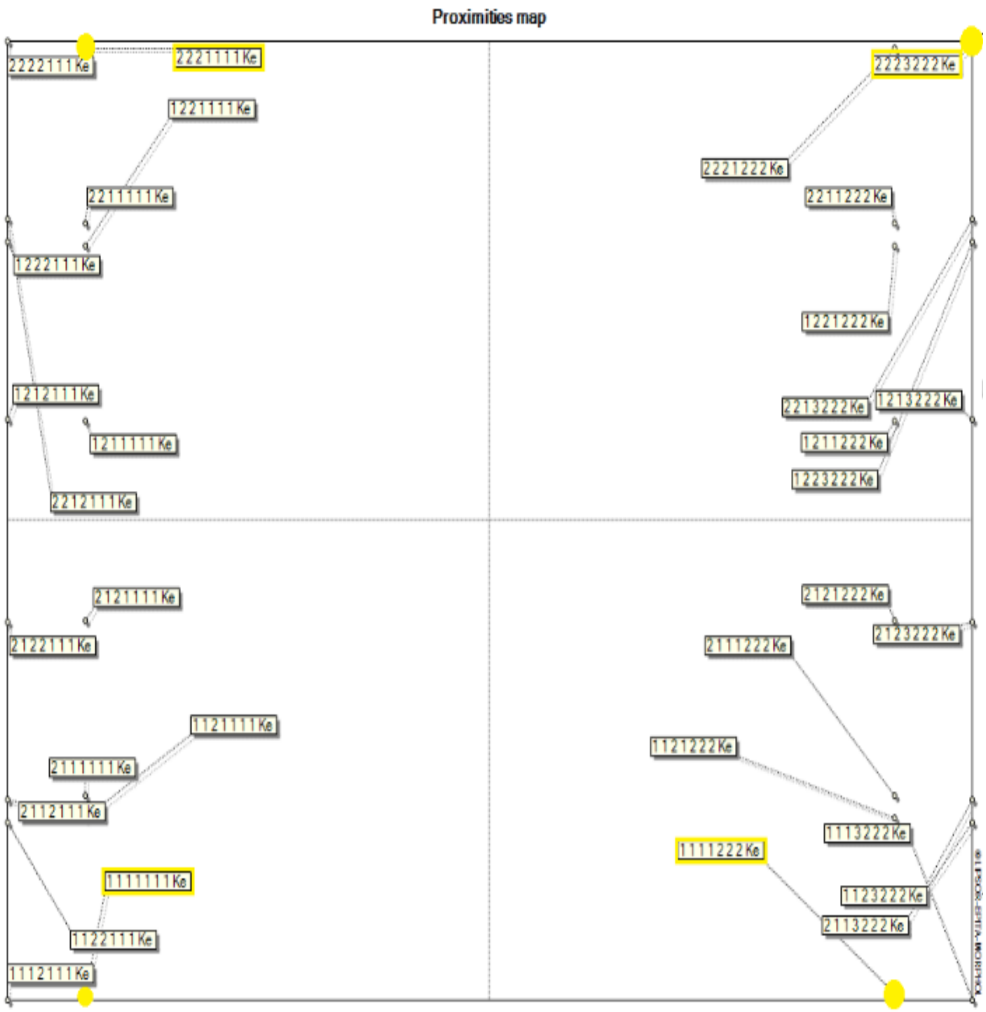

Figure 5: Selected scenarios marked in the proximities map obtained by the Morphol software [71].

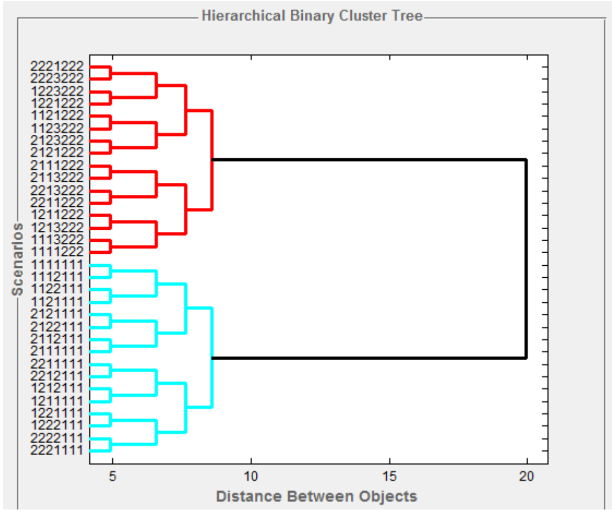

Figure 6: Hierarchical Binary Clustering Tree: output from FIL software.

4.6 Step 6 – Preliminary scenario narratives

The scenarios previously obtained reflected a combination of different drivers and configurations. Although the meaning of each configuration is clearly defined, the scenarios can be better conveyed through short story narratives that tell about a future where this reality holds and where today's decisions can be played out [78] and help health stakeholders and experts visualizing how such future may unfold, facilitating the discussion in the last round of interviews and in the final workshop. Shorter versions of the scenarios were constructed by trying to find interrelations between the different final key drivers in order to reduce the complexity of the narratives.

The first scenario narrative, detailed in Box 1, depicts the evolution of a healthy and booming Portugal, exhibiting strong economic growth, a healthy and young population. The second scenario narrative (Box 2) builds a future where the Portuguese population is informed and aware of their health status, in which ageing is decreasing, but the economy of the country is still struggling. In the third scenario narrative (Box 3), Portugal is growing steadily, but the population is old and facing a heavy burden of disease. Finally, the fourth story (Box 4) presents the worst-case scenario: the economy is not doing well, the population is sick and getting older. The scenario structures are available in Table B.1 in Annex B.

Box 1 - Scenario 1 (1111111): Healthy country (HC)

The last three decades have been good for the healthcare sector in Portugal: the increase in the birth rate led to a less constrictive population pyramid. Moreover, patients' awareness and expectations have increased, so they have a more informed and effective oversight of their health. Alongside, the economy recovered, and health spending increased, providing citizens with increased access to healthcare. Furthermore, medical qualifications are recognized worldwide, increasing the migration of physicians, since Portugal is now an attractive market. Lastly, investment in education also increased substantially. Gains in efficiency driven by technological evolution allowed for a significant improvement in universities, and medical schools in particular. Additionally, the fast introduction of new health technologies has enhanced advances in the prevention and treatment of diseases.

Box 2 - Scenario 2 (2232222): Population one, technology zero (POTZ)

We are now in 2047. Socially, there have been improvements starting in 2020: the increase in the birth rate diminished the effects of an ageing population. Now, patients want to know more about their health status and the use of self-diagnosis techniques. More recently, there has been a growth of the private healthcare market. These developments facilitated the access to healthcare but are also associated with a possible increase in supply-induced demand for healthcare services.

Nevertheless, the low level of growth of the Portuguese economy put a curb to the public sector, namely in the allocation of healthcare resources. The disparities between supply and demand, along with the slow adoption of medical technologies cannot be balanced with the migration of doctors. Additionally, the budget of medical schools is still severely constrained, impeding a higher degree of autonomy or the use of new technologies in education.

Box 3 - Scenario 3 (2221111): New technology meets old habits (NTMOH)

Demography in 2040 is not that of a rosy picture. Increased life expectancy comes also with an ageing population suffering from chronic diseases and multi-morbidities. There is still a significant gap in information between patients and doctors that could be diminished using new technologies. However, it is important to consider that an older population is more averse to the use of new gadgets.

In the public sector, due to a recovered economy more investment in healthcare has been possible. Nevertheless, the access to healthcare remains the same, the organization of public hospitals and current referral networks cannot keep up with the development of clinical pathways and the growth of the private healthcare market.

Another positive impact of a stronger economy is a reinforced budget for education. Gains in efficiency at universities and the evolution of the medical course has been partially driven by technological evolution, especially due to the widespread use of advanced computer software and simulation equipment. Furthermore, the fast introduction of new health technologies has improved advances in the prevention and treatment of diseases.

Box 4 - Scenario 4 (1111222): Sick system (SS)

We are now in 2047. Rising life expectancy along with a lower birth rate and an improved healthcare has resulted in an ageing population. Therefore, chronic diseases abound, leading to an increase in the demand for several medical practices. Additionally, the information asymmetry between patients and physicians is still significant. Patient empowerment has not increased as expected.

The access to healthcare remains the same: organization of hospitals and referencing networks cannot keep up with the development of clinical pathways and the growth of the private healthcare market. In fact, the low growth of the Portuguese economy caused a lower purchasing power/access for health services.

The budget for medical universities and their autonomy do not allow for big changes to teaching practices. Therefore, there is a slow adoption of new technologies.

4.7 Step 7 – Scenario validation and elicitation of parameters

In order to adjust and validate scenarios and to obtain the elicitation of input parameters from each scenario, we first performed semi-structured individual interviews with six health stakeholders and experts. These interviews allowed a detailed discussion, and adjustments towards validation of the scenarios, as well as to obtain a qualitative guess of how different parameters may evolve (increase, decrease or stay constant) in the time horizon.

All the feedback obtained during the individual interviews was digested and then used to prepare the final workshop in which four health stakeholders and experts further validated the scenarios and elicited a coherent set of parameters for each scenario that varies along time. We herein detailed how the interviews and workshop took place.

Semi-structured individual interviews

Six semi-structured interviews with experts took place between March and May 2018, and each had a duration of nearly one hour. The following institutions assigned a health stakeholder or expert to be interviewed: Independent Medical Union (SIM), Institute of Hygiene and Tropical Medicine (IHMT), National Association of Medical Students (ANEM), Medical Council (OM), European Association of Hospital Physicians (AEMH) and the Central Administration of the Health System (ACSS). These institutions are unions, public health schools, medical councils, and governmental health authorities with a strong interest and/or with policy responsibilities in HHR.

During each interview, after a discussion on the scenarios, each set of parameters (at the current level) was analyzed for each scenario. Experts were asked to predict how much the parameters were expected to change under each scenario according to their own view. Table C.1 depicts the results obtained on a qualitative scale, where a smooth variation means a maximum 5% change from actual values, a moderate variation a 5% to 10% change, and a sharp variation implies a variation larger than 10%. Following the interviews, small adjustments were made to the scenario narratives, to improve their intelligibility.

Final Workshop

The final workshop gathered three of the previously interviewed experts. Its main purpose was to quantify the uncertain parameters under each scenario, with the group being provided with final scenario narratives and with a summary of the results from individual interviews. Taking into consideration the feedback of the experts provided in previous steps, who claimed that 30 years was too far into the future and would make things extremely complex to discuss, for the purposes of eliciting input parameters and running the mathematical programming planning model the time horizon was decreased to 12 years. As a consequence, stakeholders and experts envisioned the future until 2030, and not until 2048 as initially defined. This change to the time horizon does not have any implication on the previous stages, as it only affects the elicitation of the quantitative estimates within the scenario building process (also requiring adjustments to the implemented MILP model). The need to readjust the horizon arose from a clear difficulty the experts had in envisioning such a distant future.

Both a numerical elicitation of input parameters, as well as qualitative considerations, were obtained through discussion along the workshop regarding the evolution of input parameters for the four scenarios. In cases of differences in opinion, the members of the group discussed and evolved towards a compromise parameter. Table 3 reports the numerical estimates for input parameters elicited by the experts in the workshop, while Table 4 details the main qualitative considerations that emerged in the session and that should be taken into consideration when using the input parameters within the mathematical programming model.

Table 3: Group estimates for each parameter for 2030 under each scenario.

	Estimated (simulated) current value	Healthy country	Population One Technology Zero	New technology meets old habits	Sick system
Supply of physicians (specialists)	32 893	38 000	36 000	38 000	34 000
Demand for physicians	39 762	40 000	40 000	43 000	44 000
Education costs (per student/year)	12 750€	20 000€	13 000€	20 000€	13 000€
Emigration flow (per year)	151	200	300	200	400
Immigrant stock	1858	1858	1500	2000	1800

Table 4: Qualitative considerations from experts at the workshop.

a)	It is essential to have access to more recent and accurate information about the human resources working in the health system and the Portuguese National Health Service to inform the elicitation of values.
b)	The demand and supply of physicians depends on the aging of the society, on technological evolution, on the possibility of doctors assuming other roles (e.g. as hospital managers), or on the increasing need for quality of life of doctors.
c)	Education costs are related to the technological evolution and to wages of the faculty staff.
d)	The inexistence of barriers and the valorization of new experiences encourage emigration, which makes it difficult to calculate the actual flow of emigrants.
e)	The stock of immigrants does not account for the number of Portuguese doctors who worked and/or studied abroad and return, only the number of IMGs.

4.8 Post-foresight: running the scenarios in the MILP model

The MILP model was run for the four scenarios considering the necessary adaptations, i.e., considering the objectives and constraints deemed as relevant for meaningful policy analyses (more details follow below), as well as adapting to the time horizon. Specifically, two planning settings were considered for policy analysis (there being however many other relevant planning settings), with each setting being defined to better represent an example of policy context behind each scenario.

Particularly, when considering scenarios in which it is possible to foresee a strong economic growth, which is the case for a Healthy Country and New Technology Meets Old Habits scenarios, a full demand satisfaction may be possible to achieve and the training of HHR should be planned accordingly (Planning Setting I). Under such setting, the model can be applied by imposing that all the required physicians need to be trained to ensure full demand satisfaction while ensuring the minimization of costs. Accordingly, a single-objective version of the MILP model focused in the minimization of training costs (objective III) and with an additional constraint forcing a full demand satisfaction (by replacing objective II by an additional constraint that forces equity to be the maximum possible) can be run.

On the other hand, when considering future contexts of no economic growth, which is the case for Population One Technology Zero and Sick System scenarios, it is key to understand how to plan HHR training without incurring in extra costs, which can be achieved by redistributing existing vacancies across specialties (Planning Setting II). Under these circumstances, the model can be applied by imposing that existing vacancies should be redistributed across specialties so as to minimize the oversupply and shortages of physicians (objective I), while simultaneously minimizing medical training costs (objective III). A multi-objective version of the model can be thus run for such a planning setting.

The details related to the adaptation and application of the MILP model under the four different scenarios crossed by relevant planning questions are depicted in Figures 7 and 8. These figures show: i) details about the uncertain input parameters characterizing each scenario, ii) the objectives and key constraints considered for running the model under each scenario, and iii) key results obtained based on that application. Key results may include a single optimal solution for the *numerus clausus* in medical schools and residency vacancies per year when a single-objective version of the model is used, or a Pareto frontier with multiple solutions characterized by different *numerus clausus* and residency vacancies when a multi-objective version is used. These results are detailed in the following sub-sections.

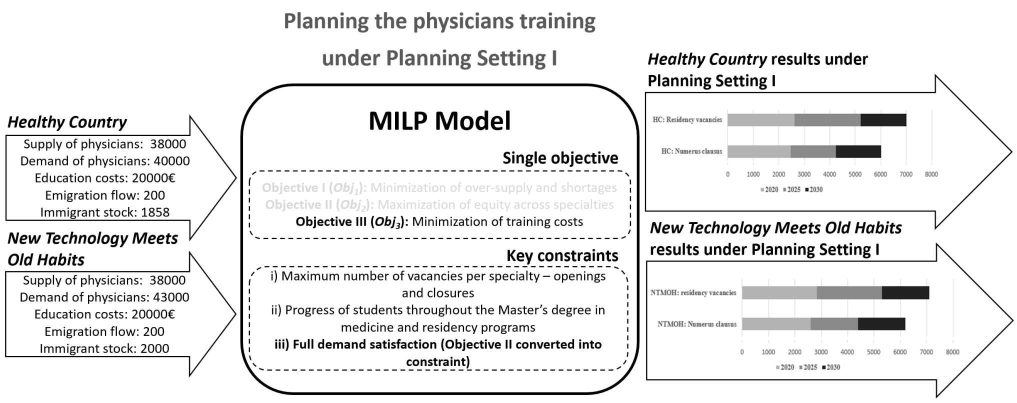

Figure 7: Key components of the MILP model used for planning the physicians training under Planning Setting I and while considering possible futures characterized by Healthy Country (HC) and New Technology Meets Old Habits (NTMOH) scenarios.

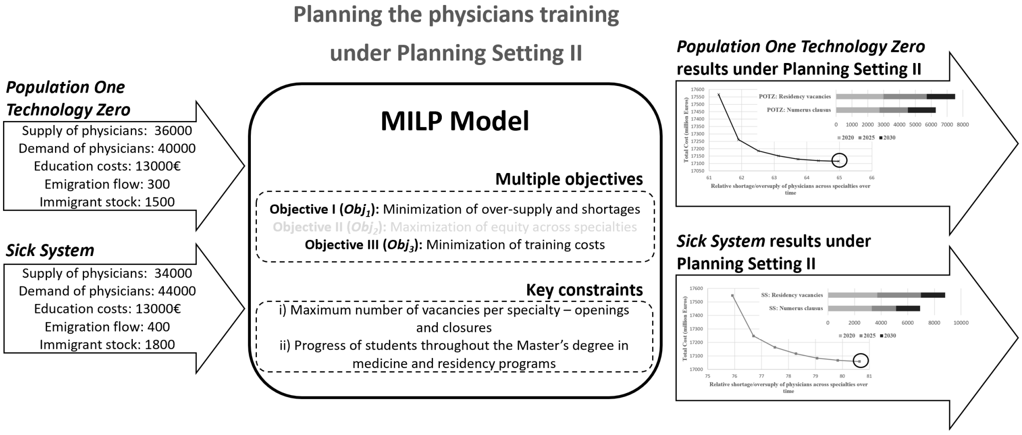

Figure 8: Key components of the MILP model used for planning the physicians training under Planning Setting II and while considering possible futures characterized by Population One Technology Zero (POTZ) and Sick System (SS) scenarios.

To illustrate the use of the proposed approach, we present results organized into two subsections. In a first analysis, **Analysis I,** the MILP model is run for each combination of scenario and planning setting, and compared with the results obtained when no uncertainty is accounted for (hereafter referred to as Deterministic Analysis, and using current estimates as input parameters). This comparison aims to show the impact of accounting for uncertainty when planning the supply of HHR. In **Analysis II,** the results obtained when modelling the distinct planning settings are compared, showing the type of policy analyses enabled by the use of scenarios. Combination of scenarios and planning settings considered for both analysis follows Figures 7 and 8.

4.8.1 Analysis I

In this analysis we rely on two different types of Deterministic Analysis:

i. In Deterministic Analysis I (DA I) a single-objective version of the MILP model is used in which the aim is to fully satisfy demand for the minimum cost, i.e., when Planning Setting I is considered as a basis. DA I is then compared with scenarios considered within Planning Setting I, i.e. for scenarios characterized by a strong economic growth (Healthy Country, and New Technology Meets Old Habits scenarios) (see Figure 7);
ii. In Deterministic Analysis II (DA II) a multi-objective version of the MILP model in which existing vacancies should be redistributed across specialties so as to minimize the oversupply/shortages of physicians and costs is used, i.e., Planning Setting II is considered as a basis. DA II is then compared with scenarios run under Planning Setting II, i.e. for scenarios characterized bylimited and slow economic growth (Sick System, and Population One Technology Zero scenarios) (see Figure 8).

Both DA I and DA II are evaluated when no uncertainty is accounted for, i.e., when considering the current parameter values shown in Table 3.

Table 7 and Figure 9 show the results obtained when evaluating the HHR training problem under Planning Setting I, both when considering uncertainty and when no uncertainty is considered. These results make it clear that accounting for uncertainty is crucial for an adequate workforce planning. And this happens because significant differences are found either in terms of costs (Table 7), numerus clausus and residency vacancies (Figure 9). Not accounting for uncertainty would suggest the need for a reduced number of vacancies (both numerus clausus and residency vacancies), which would then translate into a lower level of healthcare provision, with potential negative impacts to the health status of the Portuguese population in general.

Table 7: Costs incurred with the medical training process (in million Euros) under DA I and Healthy Country and New Technology Meets Old Habits scenarios over the 2018-2030 period under Planning Setting I.

	Deterministic Analysis I	**Healthy Country**	**New Technology Meets Old Habits**
Master's degree	1681	2847	2879
Salaries paid to physicians doing specialties	3931	3989	4142
Salaries paid to physicians giving medical training	4693	4763	4946
Closing existing vacancies	0,081	0,134	0,161
Total cost	10304,3	11599,1	11967,6

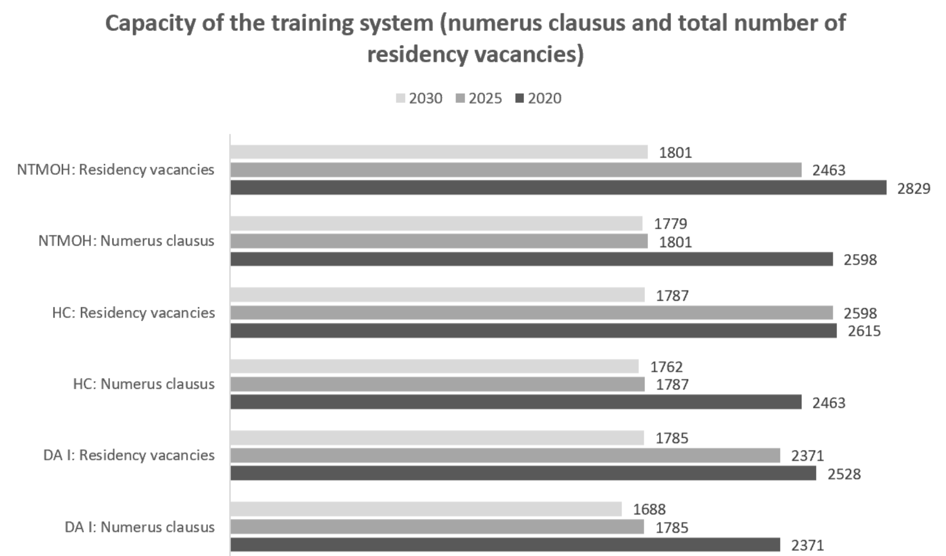

Figure 9: Capacity of the training system, in terms of numerus clausus and total number of residency vacancies under a Deterministic Analysis (DA I) and a Healthy Country (HC) and New Technology Meets Old Habits (NTMOH) scenarios evaluated under Planning setting I over the 2018-2030 period.

A common behavior was however found between scenarios characterized by economic growth (i.e., under a Healthy Country and New Technology Meets Old Habits scenarios) and when no uncertainty is accounted for (i.e., for DA I) - the number of vacancies is higher until 2020, and from this point onwards it is diminished. This is an expected result because the shortage of physicians after 2020 will be reduced as soon as physicians are trained.

Figure 10 now compares the results obtained when Portugal is facing a limited and slow economic growth (i.e., under a Sick System and Population One Technology Zero scenarios) when no public resources are available to dedicate to extra vacancies. The results obtained for both scenarios are compared with the results obtained under a Deterministic Analysis within similar planning circumstances (i.e., DA II).

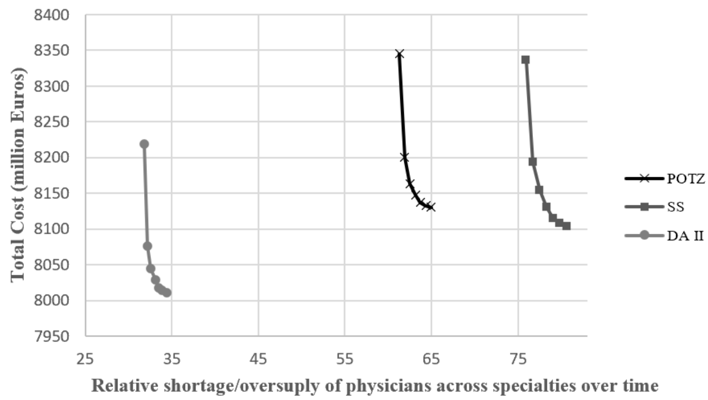

Figure 10: Pareto frontier obtained when running the multi-objective MILP model when simultaneously minimizing training costs and the shortages/oversupply of physicians across specialties over the 2018-2030 period. Legend: POTZ: Population One Technology Zero; SS: Sick System; DA II: Deterministic Analysis

The Pareto frontiers shown in Figure 10 indicate that significant differences arise when comparing the Deterministic Analysis with the results obtained when uncertainty is accounted for – both in terms of costs and distribution of vacancies across specialties. Particularly, informing HHR planning without considering for uncertainty and disregarding the possible occurrence of scenarios in which the country is struggling from an economic point of view would provide a wrong sign that it is possible to redistribute existing vacancies so as to achieve an exaggerated reduction of shortages of physicians at unattainable low costs.

4.8.2 Analysis II

Results from using the four scenarios in distinct planning settings are now compared in Figures 11 and 12, showing that significant differences arise when one considers different combinations of scenarios and planning settings (combinations described in Figures 7 and 8).

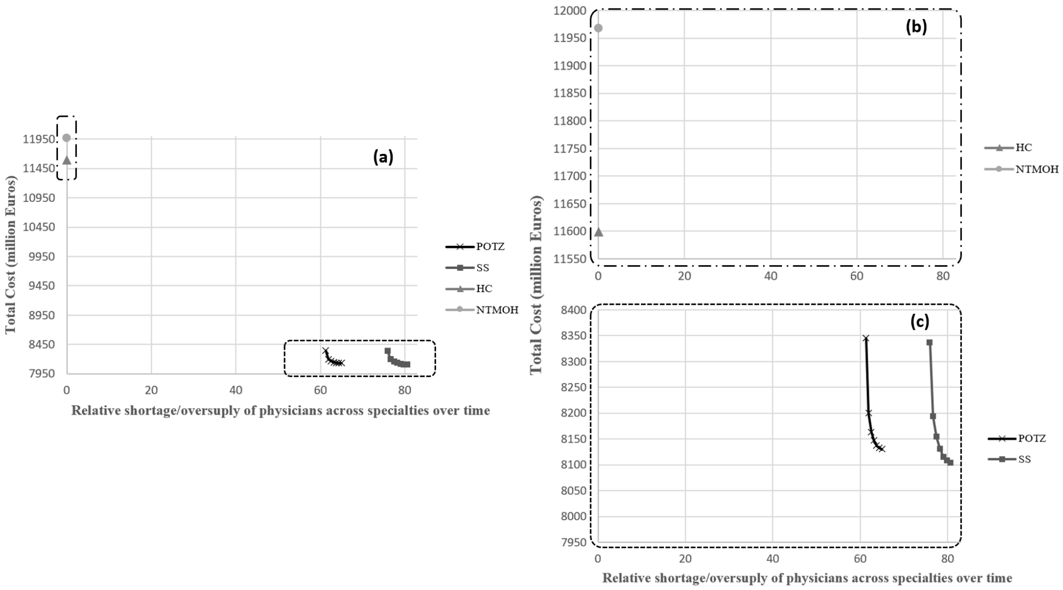

Figure 11: (a) Cost and relative shortage/oversupply of physicians characterizing the solutions obtained over the 2018-2030 period for all the combination of scenarios and planning settings in analysis, where it is possible to identify (b) minimum cost solutions obtained when a full demand satisfaction is imposed under HC and NTMOH scenarios (Planning Setting I), and (c) pareto frontiers obtained when simultaneously minimizing training costs and the shortages/oversupply of physicians across specialties under POTZ and SS scenarios (Planning Setting II). Legend: HC: Healthy Country; NTMOH: New Technology Meets Old Habits; POTZ: Population One Technology Zero; SS: Sick System

Visible differences are observed when comparing scenarios depicted in Planning Setting I and characterized by a strong economic growth (Healthy Country and New Technology Meets Old Habits), in which a full demand satisfaction aims to be achieved (see Figure 7), with scenarios assessed under Planning Setting II and facing limited and slow economic growth in which no public budget is available for further investments in medical vacancies (Sick System and Population One Technology Zero) (see Figure 8). These differences are directly related to the capacity required for the training system, both in terms of numerus clausus and total number of residency vacancies – see Figure 12.

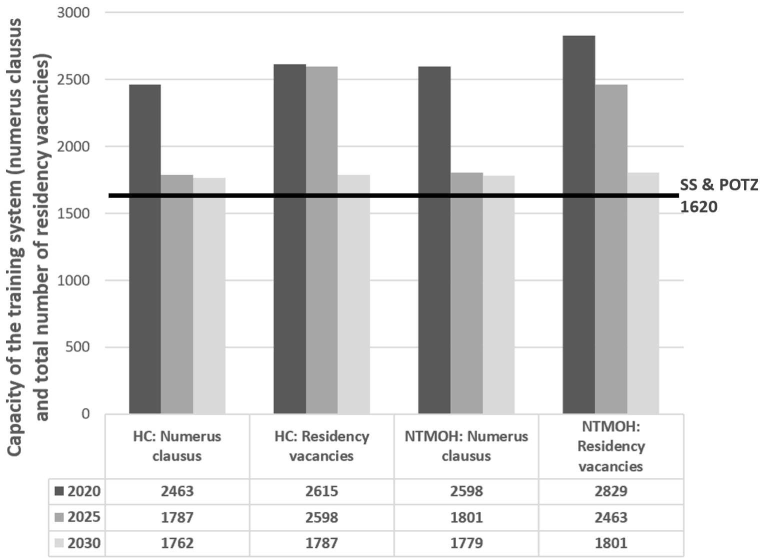

Figure 12: Capacity of the training system, in terms of numerus clausus and total number of residency vacancies under an Healthy Country (HC) and New Technology Meets Old Habits (NTMOH) scenarios evaluated under Planning Setting I, and under a Sick System (SS) and Population One Technology Zero (POTZ) scenarios evaluated under Planning Setting II over the 2018-2030 period.

Particularly, Figure 12 shows that under the Healthy Country and New Technology Meets Old Habits scenarios there are higher requirements in terms of numerus clausus and residency vacancies, which directly results in the higher costs shown in Figure 11. This is an expected result due to the full demand satisfaction that is imposed under scenarios in which the country is growing steadily from an economic perspective – the costs shown in Figure 11 represent the costs to be incurred when additional investments take place so as to increase the capacity of the training system, and this capacity should be enough to train all the physicians required to ensure a full demand satisfaction of the population until 2030. And this full demand satisfaction results in no shortages/oversupply of physicians, as depicted in Figure 11. The higher costs characterizing an Healthy Country and New Technology Meets Old Habits scenarios is also a result of the higher education costs characterizing such scenarios – 20000€ per student per year, which is significantly lower than the 13000€ associated with SS and POTZ scenarios (see Table 3).

On the other hand, Figure 12 shows that only 1620 vacancies can be used under a Sick System and Population One Technology Zero scenarios, because no budget is available for investments in extra medical vacancies. This number of vacancies corresponds to the current capacity of the system that should be redistributed so as to minimize the shortage/oversupply of physicians across specialties. Limiting the investment to the current capacity levels, together with the lower education costs, then translates into lower costs for the system when compared with scenarios facing an economic growth (see Figure 11).

An extra analysis concerns the comparison of scenarios within the same policy and economic context, i.e., scenarios evaluated within the same planning setting – comparison of an Healthy Country and New Technology Meets Old Habits scenarios, both facing a strong economic growth; and comparison of a Sick System and Population One Technology Zero scenarios, both characterized by a much-limited economic growth. The differences found are not consequence of differences in education costs (see Table 3), but rather of differences in the levels of supply and demand.

Starting with scenarios facing a significant economic growth, it is possible to verify that an Healthy Country is associated with lower costs. In fact, if an Healthy Country scenario takes place, it means that Portugal will not only face a strong economic growth, with more resources being available for the public sector together with a more healthy and young population (i.e., with a lower demand for HHR, as it can be confirmed in Table 3). Under those circumstances, the planning model informs that there should be a lower investment in terms of numerus clausus and residency vacancies when compared to a scenario in which the population is getting older and facing a heavy burden of disease (such as happens under a New Technology Meets Old Habits scenario) (see Figure 12). On the other hand, if the country turns to be characterized by a higher level of demand for HHR, mainly due to an older population facing (sometimes multiple) chronic diseases, higher total costs will be incurred – this is the case of a New Technology Meets Old Habits scenario, as shown in Figure 11.

Concerning the results obtained for scenarios in which the Portuguese economy is struggling, these are represented by the different Pareto Frontiers shown in Figure 11(c). Particularly, if on the top of such a limited economic growth one adds a sicker and older population, such as the case of a Sick System scenario, the country should be prepared to have a higher relative shortage of physicians across specialties. This is an expected result since a such a scenario is characterized by a higher level of demand for HHR (when compared to a Population One Technology Zero scenario), meaning that a higher amount of demand will be left unsatisfied because no further investments are allowed to increase the training capacity (both scenarios are evaluated in a context in which the numerus clausus and vacancies should be limited to the current capacity of the system, i.e., 1600 vacancies).

Summing up, accounting for uncertainty shows to be crucial for well-informed HHR planning. Also, since significant differences in planning decisions arise when different scenarios are considered, it becomes clear the relevance of scenario building with the involvement of experts that better know the reality of the sector. In light of the constructed scenarios, one obtained coherent parameters for meaningful scenarios, which enable running and interpreting the MILP model in light of distinct future circumstances that can be analysed.

5 Discussion and Conclusions

Scenario-building methodologies appear to be underrated in Operations Research literature judging by the very small number of articles handling uncertainty from the lens of foresight, as an alternative to classical approaches such as stochastic or robust programming. For operational problems where randomness plays a relevant yet well-bounded role, this may not be a severe limitation. However, for more strategic problems where the future is very uncertain and may change dramatically, it may narrow down possible outcomes.

HHR planning is one such strategic, multidimensional and multidisciplinary problem that falls in the basket of *wicked* problems. Hence, estimating how much one parameter may change in the future—for instance, the emigration of physicians—is a complex and overarching exercise, requiring a prediction spanning over fields such as economics, sociology and politics [38]. It is very unlikely that a single researcher or even a team of researchers is able to capture all the different perspectives from so many distinct fields of knowledge, which is precisely why foresight brings in the contribution of experts. Furthermore, it should be highlighted the role that participatory and collaborative approaches (e.g. interviews, Delphi, decision conferences, for some discussion see [79]) have in collecting and synthesising individual perspectives from a (sometimes) large number of participants.

In fact, these contributions are sometimes so relevant they may enforce a reformulation of the problem, as new perspectives shed light on the problem. The optimization model we considered had already been formulated by applying the CATWOE methodology, which tries to factor in the sometimes-conflicting perspectives of the different stakeholders, and therefore, we did not cover how the scenario building exercise may indeed affect the formulation of the optimatization model and how it reflects strategic decisions, but there is a growing body of literature that suggests coupling methods, such as resource-based view, to further enhance the model specification [80]. This is particularly applicable in the context of strategic and policy decision-making, such as is the case of HHR planning, where the evidence of positive benefits arising from the use of scenarios to help policy makers envisioning long term implications of their choices (past the legislature) has been accruing [81]. However, the literature is scarce on examples of the incorporation of scenario planning into processes of policy design, choice and implementation [24]. Further work can be pursued to clarify the benefits of building the scenarios pari passu with the optimization model.

On the downside, scenario-building methodologies may be time-consuming and subjective, in the sense that results are highly dependent on the choice of experts or on the way participatory and collaborative processes are conducted. Some of the limitations may be overcome by increasing the pool of experts, in this way ensuring more heterogeneous and diverse results. Of course, when considering approaches such as interviews and workshops, this comes at the cost of more time and resources spent on. In such cases, participation can be enhanced by decision support technologies (see [82], [83])

Existing approaches for dealing with long-term planning under uncertainty and based upon mathematical programming are adequate up to a point. Past the point where the planning horizon becomes long, input parameters are defined at the macro level and are interrelated, with causal links hard to establish, there is scope for developing new tools. Our aim was to leverage the power of optimization models by coupling them with a sound and structured process of building internally consistent and plausible scenarios that are embedded within the mathematical modelling process. Although the proposed methodology was developed for HHR planning, it may be generalized for other areas.

In this work, we devised a multimethodology for building tailor-made scenarios together with experts within the scope of a mathematical programming model. The proposed multimethodology thus contributes to the literature in the area by either providing a novel approach for handling input parameter uncertainty within optimization models, and also by employing this approach together with health authorities and decision-makers involved in HHR planning problems in which the aim is to plan the number of medical vacancies for coming years. Concerning the methodological contribute in particular, a new multimethodology that relies on foresight and scenario planning concepts to build tailor-made scenarios together with stakeholders and experts, with scenarios being developed and embedded for a MILP model. The especially designed scenario building process integrates expert knowledge for building meaningful scenarios for the future, and also guides the process of building estimates of critical input parameters under each scenario.

The contribution of this methodology is particularly relevant to strategic and political problems, such as HHR planning, where decision processes are often made on an *ad hoc* basis, in which information is fragmented, and in which the decision-making process is often unstructured [84]. In such cases, where uncertainty is the norm and outcomes so frail, it is necessary to gather a comprehensive overview of the problem, and such feat is only possible with the contribution of a diverse set of stakeholders and experts. In fact, as problems are becoming ever more complex and transdisciplinary, knowledge from one single discipline or field will not be enough to provide a satisfactory answer [85]. Our methodology harnesses on the knowledge and information dispersed among the many to devise more robust and overarching planning tools.

The proposed multimethodology can be replicated to planning contexts other than HHR planning and can be applied in a couple of months without compromising on thoroughness and scientific rigor—all steps of an established scenario-building protocol are considered. Also, the application of the methodology to an actual case study, in particular to a wicked problem, brought to light its ups and downs, which we discuss next. With regards to Step 2 of the multimethodology (Identification of drivers), the use of a web-based platform proved to be very time-efficient and easy to implement. An additional positive aspect is that experts did not have to reveal their identities and could, therefore, express themselves freely without the bias of their institutional or corporative views. On the downside, information collected is potentially not as rich as with a face-to-face methodology, where clarifications can be made, and the answers may be further detailed per request of participants. Some participants rose concerns about the need to compulsory present three drivers for explaining a future variation of the parameter, arguing that it was both time-consuming and that in some cases they could only come up with less than three reasons. This can be overcome easily by not requiring a minimum number of drivers.

Aggregating and refining the answers is also a time-consuming yet mandatory step. To the best of our knowledge, the literature on foresight does not report any structured or semi-automatic way of doing it. Perhaps some text mining/information retrieval software could simplify the task of synthetizing results, but they are unavailable for this purpose to this date. Also, cognitive maps were critical for clustering drivers into key variables. However, the process lacks objectivity as not all information required to execute the clustering is provided by the experts, and some information needs to be obtained through desk research.

In what concerns the output of the proposed methodology, four different scenarios were devised reflecting different possible futures. Different results were in fact obtained when running the MILP model under each scenario, thus translating into significantly different policy directions. With such a variety of possible directions to follow, it becomes clear why scenario-planning methodologies should be followed to devise future scenarios taking into account the multiplicity of views and perspectives of different experts.

When we further compare the scenarios built with the help of the experts to the *scenarios* devised previously [9], it becomes evident that skipping scenario-building would disregard futures bringing radical changes, scenarios which were not previously envisioned by the researchers. In particular, the most extreme scenarios (Healthy Country and Sick System) had not been previously envisioned in the aforementioned research, and the uncertainty included in the model did not account for such extreme changes. However, Eastern European countries, as well as Ireland, have shown that quick and robust economic growth is possible, and with it a fast improvement in the health status of the population.

The contribution of this methodology is particularly relevant to strategic and political problems, such as HHR planning, where information is ad hoc, external, infrequent and very speculative, and the decision-making process is less structured than typical operational problems. In such cases, where uncertainty is the norm and outcomes so frail, it is necessary to gather a comprehensive overview of the problem, and such feat is only possible with the contribution of a diverse set of stakeholders and experts. In fact, as problems are becoming ever more complex and transdisciplinary, knowledge from one single discipline or field will not be enough to provide a satisfactory answer. Our methodology harnesses on the knowledge and information dispersed among the many to devise more robust and overarching planning tools.

Indeed, this work comes forth as an attempt to strengthen public policies, in particular in the field of HHR planning, by building upon a notion of Futures that moves away from deterministic forecasting, leaning towards a broader concept that encompasses probable futures, possible futures, and more relevant to policy-making, preferable futures, where policy proposals and agendas fit [86].

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Annex A

Table A.1: Distribution of the respondents' occupations.

Physician		11
University professor		3
Economist		3
Public healthcare	Hospital administrator	2
	Manager	2
Health technologies company	CEO	2
	Director	1
	Technical consultant	1
Private healthcare	Clinical information manager	1
	Hospital manager	1

Annex B

Table B.1: |Scenario narratives generated based on the evolution of each key driver.

Code and scenario name	**Scenario configuration**
"1111111" **Healthy country (HC)**	Aging, rise in chronic diseases and consequent increase in the complexity and multidisciplinary of the pathways. 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. Maintenance of the information asymmetry on health services: patient awareness and empowerment remains the same. Mutual recognition of medical qualifications at international level is very limited, along with the closure of borders and troubled migratory flows. Low level of growth of the Portuguese economy, with increased restrictions in the health budget. 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. Slow adoption of new technologies in the health sector, either because of financial or ethical constraints.
"2232222" **Population one, technology zero (POTZ)**	Increase in the birth rate and consequent beginning of the rearrangement of the age pyramid. Increase of patient's awareness and expectations, starting to have an active role in managing their health. 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. Recovery of the Portuguese economy and increased financing for health. New policies improve the management of the vacancies and wages between medical specialties. Increased efficiency in the universities and evolution of the medical course structure, with focus on practical education and the use of new technologies. Technological evolution and fast introduction of new health technologies, with a big focus on automation, information technologies and artificial intelligence and telemedicine.
"2221111" **New technology meets old habits (NTMOH)**	Increase in the birth rate and consequent beginning of the rearrangement of the age pyramid. 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. Increase of patient's awareness and expectations, starting to have an active role in managing their health. Mutual recognition of medical qualifications at international level is very limited, along with the closure of borders and troubled migratory flows. Low level of growth of the Portuguese economy, with increased restrictions in the health budget. Vacancies and wages between medical specialties unbalanced. 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.
"1111222" **Sick system (SS)**	Aging, rise in chronic diseases and consequent increase in the complexity and multidisciplinary of the pathways. 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. Maintenance of the information asymmetry on health services: patient awareness and empowerment remains the same.

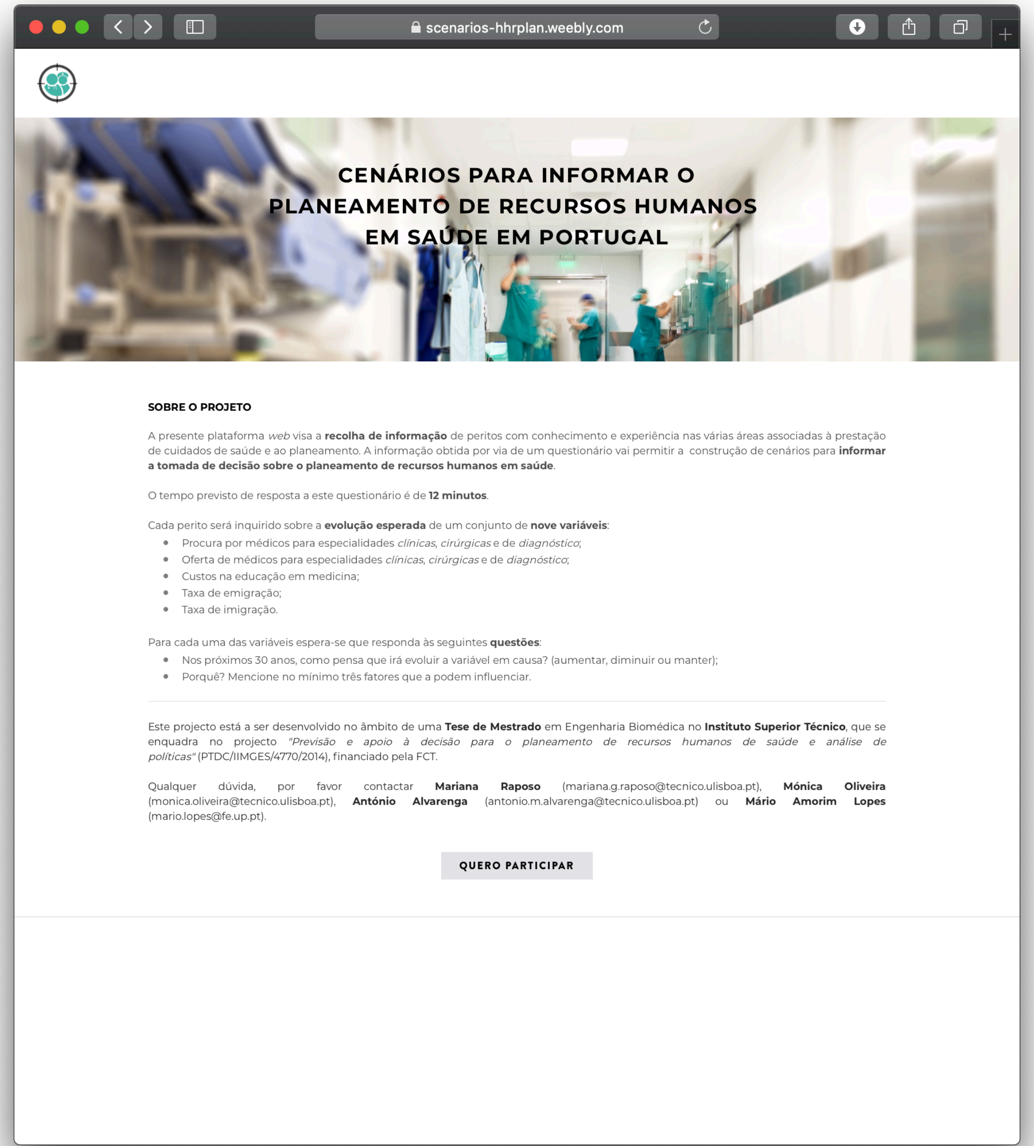
	Mutual recognition of medical qualifications at international level is very limited, along with the closure of borders and troubled migratory flows. Recovery of the Portuguese economy and increased financing for health. New policies improve the management of the vacancies and wages between medical specialties. Increased efficiency in the universities and evolution of the medical course structure, with focus on practical education and the use of new technologies. Technological evolution and fast introduction of new health technologies, with a big focus on automation, information technologies and artificial intelligence and telemedicine.

Annex C

Table C.1: Feedback obtained after the interview round for each parameter under each scenario.

	Supply of physicians	**Demand for physicians**	**Education costs**	**Emigration rate**	**Immigration rate**
Healthy country	n = 3/5 Smooth increase	n = 3/4 Moderate increase	n = 3/6 Increase	n = 4/6 Moderate reduction	n = 4/6 Moderate increase
Population One Technology Zero	n= 3/5 Moderate reduction	n = 3/4 Smooth increase	n = 4/6 Smooth reduction	n = 4/6 Sharp increase	n = 4/6 Smooth increase
New Technologies meet old habits	n= 3/5 Smooth reduction	n = 3/4 Moderate increase	n = 3/6 Increase	n = 3/6 Sharp increase	n = 4/6 Moderate increase
Sick system	n = 3/5 Smooth reduction	n = 3/4 Sharp increase	n = 4/6 Moderate reduction	n = 6/6 Sharp increase	n = 4/6 Sharp reduction

Annex D


scenarios-hhrplan.weebly.com
CENÁRIOS PARA INFORMAR O PLANEAMENTO DE RECURSOS HUMANOS EM SAÚDE EM PORTUGAL
SOBRE O PROJETO
A presente plataforma web visa a recolha de informação de peritos com conhecimento e experiência nas várias áreas associadas à prestação de cuidados de saúde e ao planeamento. A informação obtida por via de um questionário vai permitir a construção de cenários para informar a tomada de decisão sobre o planeamento de recursos humanos em saúde.
O tempo previsto de resposta a este questionário é de 12 minutos.
Cada perito será inquirido sobre a evolução esperada de um conjunto de nove variáveis:
Procura por médicos para especialidades clínicas, cirúrgicas e de diagnóstico;
Oferta de médicos para especialidades clínicas, cirúrgicas e de diagnóstico;
Custos na educação em medicina;
Taxa de emigração;
Taxa de imigração.
Para cada uma das variáveis espera-se que responda às seguintes questões:
Nos próximos 30 anos, como pensa que irá evoluir a variável em causa? (aumentar, diminuir ou manter);
Porquê? Mencione no mínimo três fatores que a podem influenciar.
Este projecto está a ser desenvolvido no âmbito de uma Tese de Mestrado em Engenharia Biomédica no Instituto Superior Técnico, que se enquadra no projecto "Previsão e apoio à decisão para o planeamento de recursos humanos de saúde e análise de políticas" (PTDC/IIMGES/4770/2014), financiado pela FCT.
Qualquer dúvida, por favor contactar Mariana Raposo (mariana.g.raposo@tecnico.ulisboa.pt), Mónica Oliveira (monica.oliveira@tecnico.ulisboa.pt), António Alvarenga (antonio.m.alvarenga@tecnico.ulisboa.pt) ou Mário Amorim Lopes (mario.lopes@fe.up.pt).
QUERO PARTICIPAR