Robust workforce planning for the English medical workforce

Authors: Dr Graham Willis*, Dr Andrew Woodward*, Dr Siôn Cave**

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Centre for Workforce Intelligence (CfWI)

Graham.Willis@cfwi.org.uk

209 – 215 Blackfriars Road

London

SE1 8NL

**

Decision Analysis Services Ltd (DAS)

SionCave@das-ltd.co.uk

Grove House

Lutyens Close

Chineham Court

Basingstoke

Hampshire

RG24 8AG

Abstract

This paper describes the use of system dynamics in a major project for the UK Department of Health to inform a review of the intake to medical and dental school. It takes many years to train these professionals (typically 15 years or more for a hospital consultant), so an under or over-supply cannot be corrected quickly or easily. The cost of training and employing an individual is significant so the decisions to be made are highly important.

The system dynamics approach meant that robust, evidence-based supply and demand models could be created to test potential policies and their impact. It also meant that the model was "transparent" and enabled the expertise of several hundred stakeholders from the healthcare system to be captured and synthesised.

Significant decisions were made as a result of this work, including:

- *A 2% reduction in medical school intakes to be introduced with the 2013 intake, with a further review in 2014*
- *No immediate change to dental school intakes because of issues over data quality highlighted by the modelling, with another review in 2013*
- *A rolling cycle of reviews of medical and dental student intakes should be established; to be undertaken every three years.*

Key Words: System dynamics, workforce planning, workforce training, doctor, dentist, healthcare, health policy, Centre for Workforce Intelligence

1. Introduction

This paper describes a major project that has directly influenced decisions taken by the Department of Health (DH) and the Higher Education Funding Council for England (HEFCE) to adjust the numbers of doctors and dentists being trained in order to prevent a future under or over-supply. The work was carried out by the Centre for Workforce Intelligence (CfWI) with support from Decision Analysis Services Ltd (DAS).

The CfWI is an independent agency working on specific projects for the Department of Health and is an operating unit within Mouchel Management Consulting Limited. The CfWI is the UK's national authority on workforce planning and development, providing advice and information to the health and social care system. The aim of the CfWI is to produce quality intelligence to inform better workforce planning, in order to improve people's lives. The CfWI are supported by DAS who provide specialist system dynamics consultancy. DAS is a team with a shared vision of solving strategic challenges facing government and industry decision makers using systems modelling and simulation methods.

This paper describes the work undertaken to model the future supply and demand of doctors and dentists for the Health Education National Strategic Exchange (HENSE) review group. The NHS in England employs 1.35 million staff, including over 145,000 doctors (NHS Information Centre, 2013). Supply of a single specialist doctor costs the UK Government approximately £250K to £550K in training (University of Kent, 2011) and over £2Million in lifetime salary[1], so over-supply is expensive. Equally, under-supply has a considerable, if harder to quantify, impact on the health and well-being of the population.

The purpose of the work was to provide intelligence to inform recommendations of the HENSE review group on future student intakes to medical and dental schools. The work was carried out from winter 2011 to the autumn of 2012. The work was acknowledged as making a major contribution to this review (Department of Health. 2012).

Implementing the recommendations of the HENSE review group for a 2% reduction in trainee doctors will lead to a reduction in training costs to the NHS of approximately £50 million per year. These recommendations were informed by the modelling, and have been agreed by the DH and HEFCE, who share responsibility for determining medical and dental school intakes.

A completely new approach to workforce planning was developed by the CfWI for this project, which we call *Robust Workforce Planning*. This is a method for identifying potential future issues that need to be addressed by workforce planners. It allows them to assess the impact of workforce policy options and reduce risk. This approach is new for health and social care workforce planning in England. We first think about what health and social care may look like in the future, including the workforce needed to provide it. We then focus on policies to deliver the required workforce, and test them

[1] http://www.ic.nhs.uk/workforce, Staff earnings. 25 years of GP or Consultant salary of approximately £108k pa. (NHS Information Centre, 2013a).

across a range of futures defined by a set of scenarios. This allows robust decisions to be made that recognise the uncertainty of the future.

Central to the approach are system dynamics (SD) models that calculate workforce supply and demand – in this project the medical and dental workforce. These models are referred to in this paper as the MDSI models. The models were grounded in empirical data and evidence. The MDSI models enabled analysis against a range of potential futures and policy interventions. The models allow the rapid assessment of the implications of scenarios and policies across the whole of the medical and dental training systems and workforce.

1.1. Contents

Section 2 describes the challenge of health and social care workforce planning.

Section 3 provides an overview of the *Robust Workforce Planning* framework, which is used by the CfWI to inform workforce planning decisions. The role of system dynamics in the framework is described.

Section 4 describes the systems dynamics models that were developed during the application of the *Robust Workforce Planning* Framework to provide projections of future supply and demand of doctors and dentists.

Section 5 discusses the impact of the system dynamics modelling and the next steps for the application of system dynamics in the CfWI.

2. The challenge – Health and social care workforce planning

2.1. Introduction to workforce planning with a health care focus

Effective workforce planning has been described as ensuring "The right people, with the right skills, in the right places, at the right time" (Taylor, 2005). This is a challenge in health care due to a complex mix of staff and staff functions, the large geographic area that is covered and the changing policies that influence the supply and demand of care. The risks of poor workforce planning are to put patient lives at risk, increase morbidity, and spend huge sums of money to correct sub-optimal systems. Employees can suffer from the stresses of understaffing, or in the case of oversupply, livelihoods can be put in jeopardy if jobs are not available. To mitigate risk it is important to have foresight of the key issues, and flexibility within the workforce and the training pipeline to adapt when necessary.

2.2 The medical and dental workforce

The medical and dental workforce in England is large and very highly qualified. Characteristics of training are long and varied training paths that take well over ten years from starting university to becoming a trained specialist. There are over 60 medical specialties and 11 dental specialties that trainees compete to specialise in. Progression through the training pipeline is subject to delays as trainees often take time out for research, maternity or other experiences. When qualified there are many different contracts available to doctors, such as consultant, GP, speciality doctor, and many more. Attrition occurs throughout education, training and employment.

2.3 Why health workforce planning is difficult

Health workforce planning is very difficult because of the size of the workforce (over one million), the number of professions and different skills involved, and the complexities of estimating the requirements to meet the future health needs of the population.

There are many routes through training, flows between these routes, and also migration in and out of England and the UK. Behaviours of the workforce vary by age, gender and the type of doctor or dentist. Transfer between contracts and training areas complicates the system. The long timescales for training make it hard to measure the impact of policy changes and to make corrections. The inertia, delays and complex influences in the system mean that modelling is complicated.

3. CfWI workforce planning framework

Rather than attempt to predict the future, the CfWI has developed a scenario-based approach that recognises the complexity of factors influencing demand and supply and the intrinsic uncertainty of the future. This framework is referred to as the *Robust Workforce Planning* framework. The key benefits of this approach are to support longer-term planning, here looking out to 2040; to support more robust decision making, taking account of the uncertainties of the future; and to help decision makers be more alert to emerging risks as the future unfolds.

The study into the medical and dental workforces described in this paper is the first time an approach of this kind has been used in healthcare workforce planning. The high-level framework is illustrated in Figure 1. The framework consists of four linked stages, the outputs from each stage feeding into the next. A major feature of the framework is the high degree of stakeholder involvement, which is critical to arrive at a shared view of future challenges, and in making policy decisions.

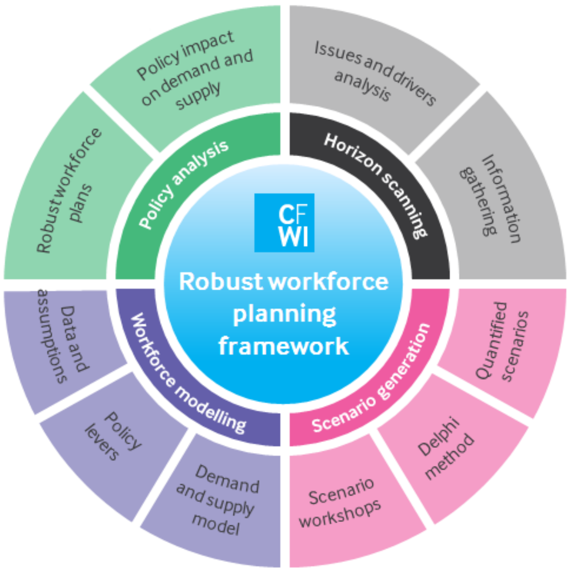

Figure 1 – Robust Workforce Planning framework

3.1 Stage 1 - Horizon scanning

Horizon scanning explores the potential challenges, opportunities and likely future developments that could influence workforce planning. These include technological, economic, environmental, political, social and ethical (TEEPSE) influences on an unfolding future. Some of these influences may be viewed as predetermined, such as an ageing population, and some may be more uncertain, such as technology advances.

The horizon scanning can be broad or focused on specific areas. A web site is used to collate a wide range of expert opinions and present key factors[2]. Reports are avaialble on the horizon scanning conducted for the MDSI project (CfWI, 2012 and 2012a).

3.2 Stage 2 – Scenario generation

Scenario thinking focuses on how the future might evolve (Van der Heijden et al, 2002). Scenarios are essential for workforce planning since it is not possible to predict the long-term future accurately. Scenarios are particularly useful since a range of plausible futures can be generated and demand and supply projections made. Workforce plans can then be assessed against the scenarios for robustness. A baseline or 'business as usual' scenario is included to illustrate what might happen if trends continue as at present.

Scenarios are based around high impact and high uncertainly driving forces which shape the future. The method used (Wright & Cairns, 2011) creates plausible stories about the future that capture what might happen in a memorable way. Facilitated workshops are used to get wide involvement and agreement.

Following the scenario generation, the narrative stories need to be quantified. A unique feature of the framework is the use of a Delphi process (Dalkey & Helmer, 1963) to quantify key workforce variables. Experts make quantitative judgments and share the reasoning behind them over several rounds to decrease uncertainty and refine the values.

3.3 Stage 3 – Workforce modelling

The purpose of workforce modelling is to project demand and supply for a range of plausible futures, as described by the scenarios. Further modelling is then conducted to determine the robustness of policy options for achieving a sustainable balance of demand and supply. System dynamics modelling is used, since it is most appropriate to complex systems with feedback, like health and social care workforce planning, and can easily be extended or revised to address additional issues as they arise.

The model takes several kinds of input:

- **Facts we know** – baseline data to populate the model, including current training and workforce numbers
- **Assumptions we make** – predictable trends and assumptions needed where key data is not available or of poor quality
- **Parameters that we can control** – that define the policy choices needed to secure adequate supply to meet forecast demand
- **Uncertainties we can quantify** – intrinsically uncertain parameters that may vary by scenario.

[2] www.horizonscanning.org.uk

The model is formally tested and documented. Sensitivity analysis is conducted to help understand the impact of changes in data on model outputs, and thus which are the most important for accuracy.

3.4 Stage 4 – Policy analysis

Policy analysis focuses on analysing future uncertainties and the impact of policy options, and presenting the findings. By considering multiple future scenarios, different options can be tested to see which one is the most robust. There will be some which lead to favourable outcomes across all futures and others where the outcome is less clear. In these situations the relative probability of scenarios may need to be assessed, and scans made for signals that might indicate a particular scenario unfolding.

4 MDSI system dynamics model

The *Robust Workforce Planning* framework described in Section 3 was applied in 2012 to the future supply and demand of doctors and dentists for the HENSE review group. A fundamental part of the framework during the workforce modelling stage was the development of models to calculate the change in supply and demand for the medical (doctors) and dental workforces through to 2040. This Section provides a description of the system dynamics models.

4.1 High-level requirements

The workforce models were required to:

- Calculate the supply and demand for the medical and dental workforces from now through to 2040
- Segment the workforce by age and gender
- Represent the training pipeline from entering university through to delivering service as fully qualified doctors and dentists
- Represent the complex career paths for doctors and dentists following qualification
- Integrate with large datasets from a variety of NHS and other official data sources
- Use the data from the Delphi workshops that define the attributes of the four scenarios
- Enable policy analysis to be carried out to determine the impact of different policies on the different scenarios
- Execute rapidly and produce outputs that can be readily analysed
- Be fully tested and documented, with an audit trail for all assumptions
- Allow the sensitivity of the input assumptions to be determined.

Due to the complexity of the model scope and scale it was decided that the system dynamics approach was best suited to meeting the modelling requirements. Not only does the method allow the complex processes to be represented and to integrate with the complex datasets, but as it is based on a graphical representation of the system the stakeholders can be more readily involved in the model validation.

Two models were developed, one for the medical workforce and the other for the dental workforce. The models were built using Vensim DSS and Microsoft Excel. A user interface was developed using Excel to enable non-SD analysts to more easily use the model and carry out policy analysis.

4.2 Model description

This section provides a high level description of the MDSI models, and the approach adopted to develop them. The standard development process, as illustrated in Figure 2, was followed for the models:

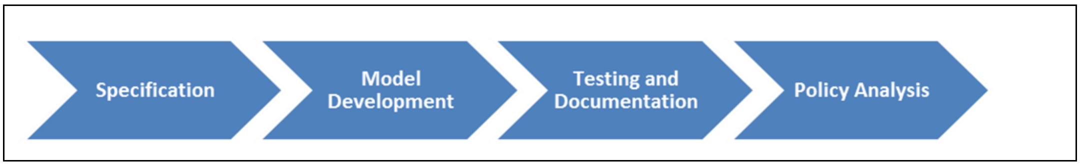

Figure 2 – Simulation development process

Each of the stages is described below, along with further detail regarding the model structure and functionality.

4.2.1 Specification

The model specification clearly defined the purpose of the model, and what was in scope, and equally importantly what was out of scope. The specification was based on the initial model requirement outline in Section 4.1 and ensured that the developed models only represented what was needed for the purposes of the HENSE review, thus preventing scope creep and mitigating against the risk of late delivery.

4.2.2 Development

The initial stages of model development were to map out the relevant processes of the training and career pathways with appropriate stakeholders from the medical and dental systems.

The maps were created in Vensim and printed out to be shared with the stakeholders. In addition, the process maps were presented at a series of national road shows hosted by the CfWI, which enabled over 80 people to comment and amend the process maps.

Numerous stakeholders helped to sense-check the accuracy of the models themselves or helped to provide or sense-check the data and modelling assumptions used. Key sources of help were the DH’s Workforce Data and Analysis Team, the Health and Social Care Information Centre, the British Medical Association (BMA), the General Medical Council (GMC) and specific deaneries, University and Colleges Admissions Service (UCAS), NHS Pensions, and members of the medical and dental project reference groups.

The large degree of stakeholder engagement throughout the process mapping stage ensured high levels of stakeholder buy-in to the modelling process.

Sample career path stock and flow diagrams are given in Figures 3 and 4 below:

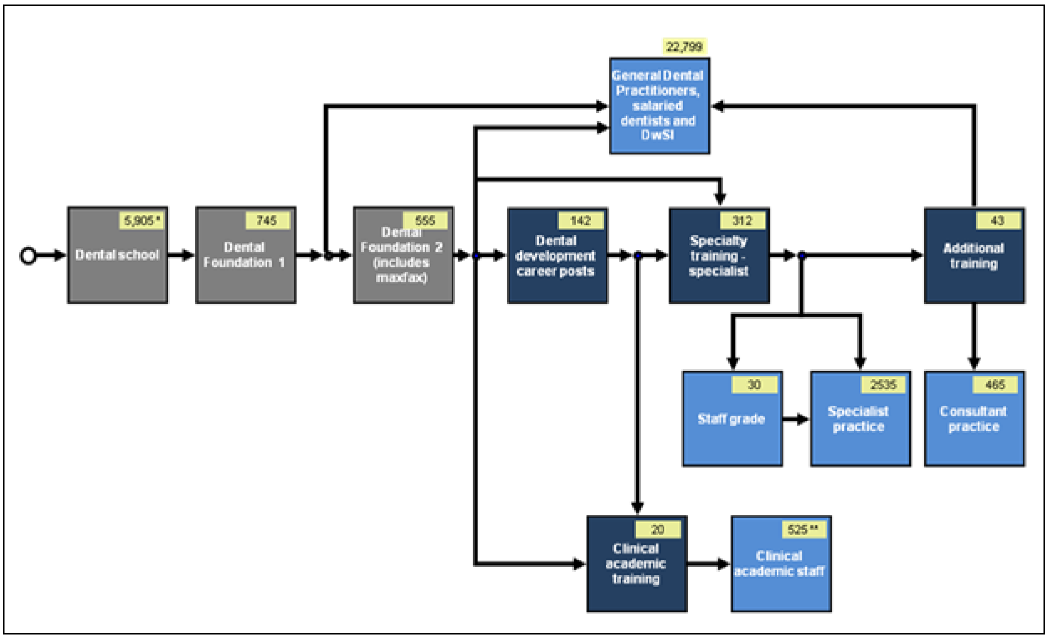

Figure 3 – Dental model career pathway stock and flow diagram

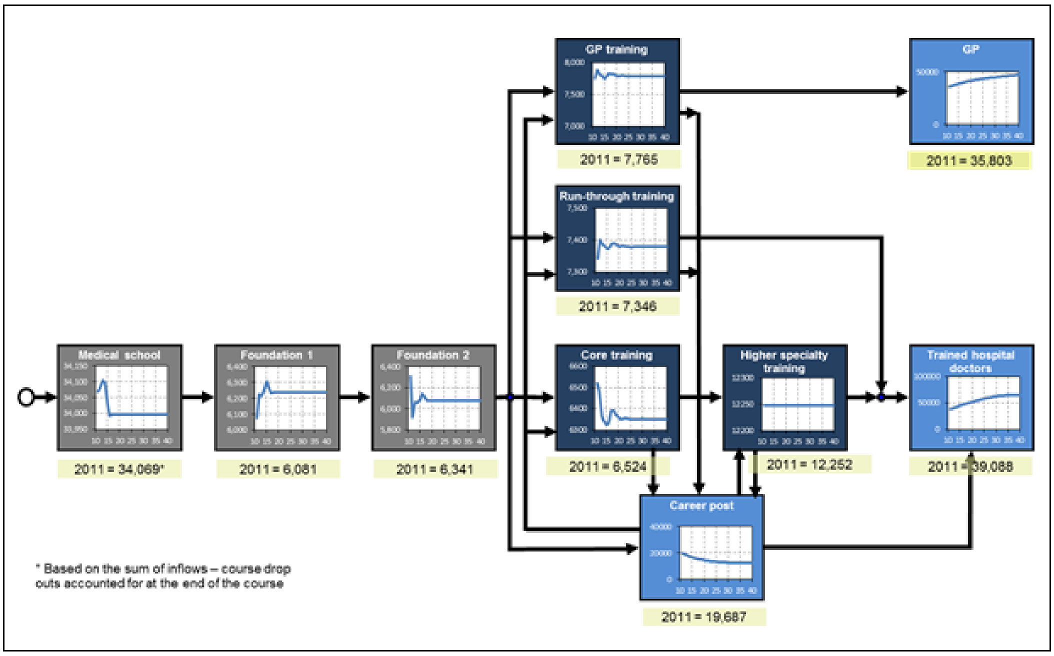

Figure 4 – Medical model career pathway stock and flow diagram

Following process mapping, the process maps were converted into a quantitative model. The model was developed using a combined Vensim and Excel architecture. Excel was used to create a user interface so that multiple scenarios and policies could be specified and then simulated with Vensim.

The model was developed iteratively. As each functional area was completed the model results were shared with experts to determine whether the behaviour for that functional area was sensible and explainable.

The medical and dental models contain similar calculation structures. In both models the future demand is calculated based on the current demand for service, future population projections, changes in levels of need and changes in productivity (for example through technological advances) and changes in service delivery. The demand calculation is based on a framework from the Canadian research programme on health human resources (Birch et al, 2011).

In both models the future supply is calculated based on the simplified career pathways shown above in Figures 3 and 4. The actual career pathways represented within the models are in fact much more complicated, and include attrition from the stocks, exits out of the system, inflows from overseas, workforce re-joiners and re-sits. The workforce levels are also broken out into more detailed career progression pathways. Figure 5 provides a more detailed view of the complexity of the medical training and career pathway as implemented in the Vensim SD model.

In addition, the supply is segmented by age (from 16 to 80 years) and gender. This enables age and gender dependent impacts to be taken into account, for example attrition and participation rates[3]. The models have been developed so that additional segmentation can be added if required.

Finally, the models contain training allocation algorithms and capacity constraints at each stage of the training pipeline. These enable the preference between types of training to be included (for example there is a female gender preference for GP Training). This allows the changes in future demography to be considered within the model.

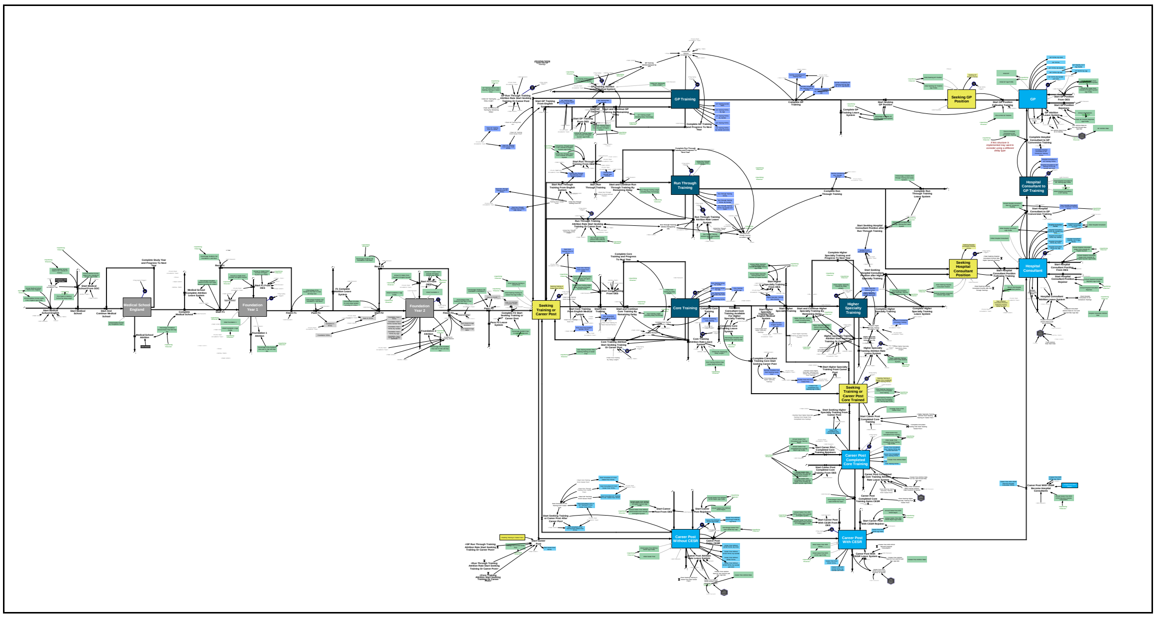

Figure 5 – Detailed stock and flow diagram for medical model

[3] The extent to which the workforce work full or part time

The medical model contains 15 separate influence diagrams, 997 distinct variables and is initialised with 903,525 items of data. This model takes approximately 10 seconds to simulate. The dental model is of similar complexity

Each Vensim system dynamics model is linked to an Excel spreadsheet. The Excel spreadsheet contains all the input data used by the Vensim model, including all data references and a complete data audit trail. The table below provides a snapshot of some of the data integrated into the MDSI models:

Type	Historic range	Source
Accepted applicants to preclinical dentistry	2007 –11	UCAS
Medical school intakes	2007–11	Higher Education Funding Council for England
Foundation programme data	2011	UK Foundation Programme Office Annual Report
Medical and general practice (GP) workforce census for England	2008–11	Health and Social Care Information Centre
National population projections	2010	Office for National Statistics
Hospital episode statistics for England	2010 –11	Health and Social Care Information Centre

The Excel spreadsheet also acted as a user friendly model interface and allowed the user to:

- Create, store and edit future scenarios
- Create, store and edit potential policies
- Select scenarios and policies to simulate
- Simulate the SD model
- Store the results of multiple simulations
- View and analyse the results of multiple scenarios.

4.2.3 Documentation and testing

The models were fully documented and tested prior to use for formal policy analysis. This was carried out to ensure that all model assumptions were formally documented and signed off, and that the model had been implemented correctly.

Each model was documented in the following ways:

- A Technical Description was developed that described the model architecture, model assumptions and how the model is used for analysis
- The Excel spreadsheet made extensive use of comments to describe the purpose of the cells and contained audit trail cells so that references could be included for each data item

- Each variable in the Vensim model was documented using the equation editor, and the units were fully defined.

A robust, formalised approach to testing was adopted. The purpose of model testing was twofold:

- To ensure that the model design has been transformed into a simulation model with sufficient accuracy
- To ensure that the simulation model is sufficiently accurate for the required purpose.

A test specification was developed based on the model documentation. The test specification detailed all the tests to be carried out on the model, and included tests of the model structure, formulation and behaviour. The test specification ensured that the testing was carried out methodically, and that all areas of the model were tested.

The testing was carried out by a CfWI modeller who was independent of the simulation development process. The results of the testing were captured in a spreadsheet. The spreadsheet identified when and by whom the test was carried out. The outcome of each test was also logged in the spreadsheet. If the test resulted in a fail then the fault was corrected by the model developer. The test was then re-run by the model tester to ensure that it had been corrected, and also that the correction had had no wider implications on the model. The model tester also had the freedom to carry out additional tests on the simulation model, and these were also captured in the testing results spreadsheet.

In addition to the tests identified in the specification the following analysis was carried out:

- The results of the model were compared with previous simulation models that represented the medical workforce
- The projections produced by the model for each stage of the training and workforce pipeline, along with the associated assumptions, were reviewed with relevant stakeholders (for example the chief dental officer)
- The sensitivity of the model outputs to the input data was tested.

The sensitivity analysis was of particular importance. There were varying levels of confidence associated with the input data, and the sensitivity analysis was used to determine whether the model outputs were particularly sensitive to any low quality data. Figure 6 shows a sample sensitivity analysis output chart.

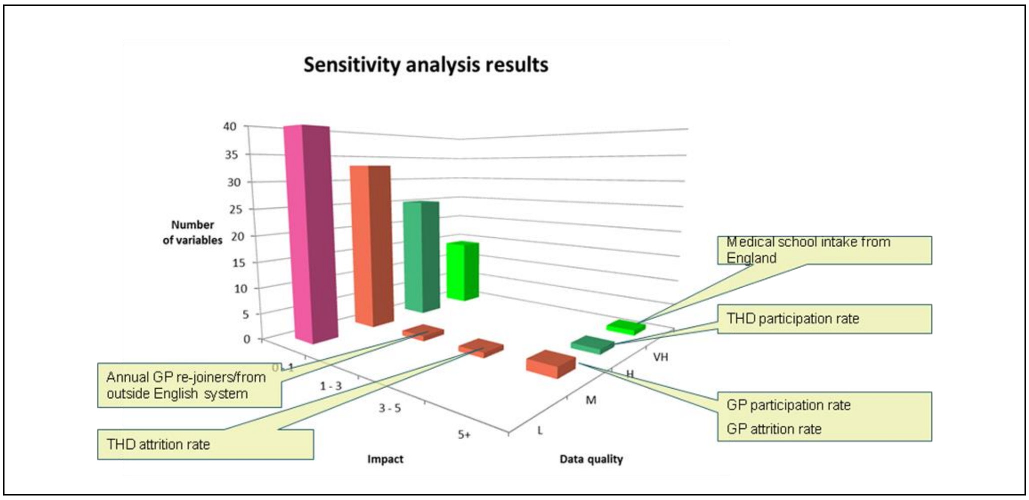

Figure 6 – Illustrative sensitivity analysis output

4.2.4 Policy analysis

Once each model had been tested it was considered to be implemented correctly and fit for purpose, and therefore suitable for policy analysis. Policy analysis required the consideration of the impact of different policies against the four different scenarios defined during the scenario generation phase of the workforce planning framework. Sample policies that were tested as part of the HENSE review included changes to:

- Productivity
- Skill Mix[4]
- Retirement Age
- Training preferences
- Training duration.

A more detailed review of the policy analysis is provided in the online report available at the DH website (Department of Health, 2012).

The Excel spreadsheet enables the simulation results to be presented in a number of different ways which allowed for very efficient exploration of the scenarios and policies. Sample simulation outputs are shown in Figure 7:

[4] Skill mix refers to the ratios of different staff types used to deliver a service.

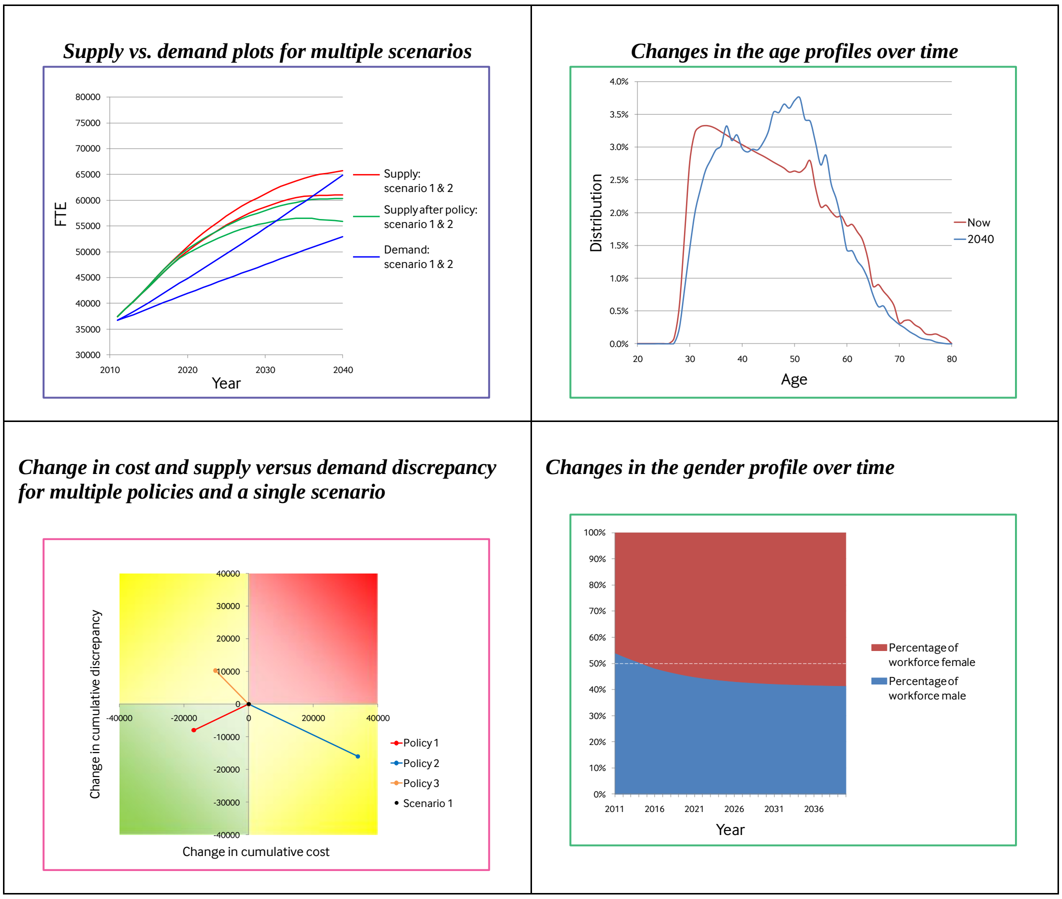

Figure 7 – Illustrative simulation outputs

Furthermore, it is best practice in modelling to quantify the uncertainty that is inherent in any forecast of the future, in this case: workforce demand and supply. Decision makers need to understand this to inform their analysis of findings and to make effective decisions. We considered the level of uncertainty through the use of Monte Carlo simulation. Figure 8 provides an example of this uncertainty as a fan chart, giving a probability distribution for supply under one specific scenario.

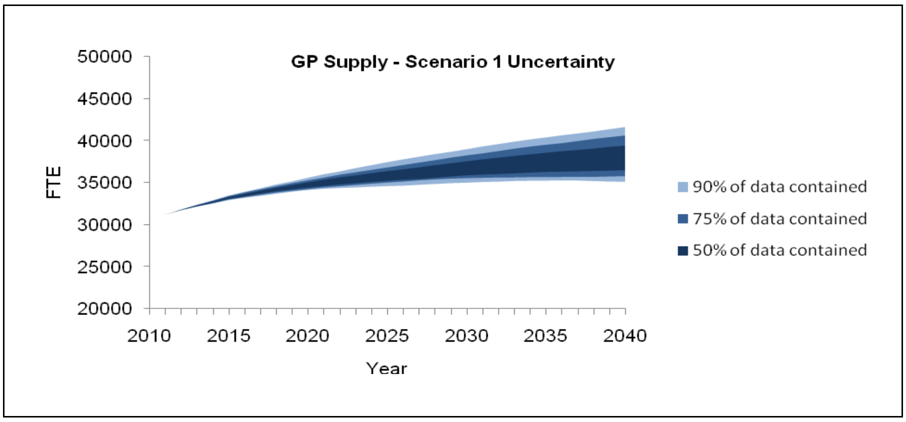

Figure 8 – Illustrative uncertainty analysis output

Finally, as each of the values for each of the input variables over time can be accessed from the user interface there is an infinite variety of different policies that can be tested using the model. Therefore the model has great utility outside of the HENSE review.

5 Conclusions

This paper describes the use of system dynamics in a major project for the Department of Health to inform a Health and Education National Strategic Exchange review of whether current levels of medical and dental school intakes were in line with predicted workforce requirements (Department of Health. 2012). It takes many years to train these professionals so an under or over-supply cannot be corrected quickly or easily. The cost of training and employing an individual are significant, estimated at over £2 million for a doctor, so the decisions to be made are highly important.

System dynamics workforce models were developed specifically for this project. The use of a system dynamics approach meant that robust, evidence-based supply and demand models could be created to test future potential policies and their impact. It also meant that the model was "transparent" and made it possible to synthesise the expertise of several hundred stakeholders from within the health care system.

The modelling also provided insight into what levers can be used to control and guide workforce numbers, identifying those that are most effective. A visualisation was produced to show the impact of potential policy decisions, and this was used to inform recommendations. Levers that are typically used to control workforce supply, such as intake to medical school, were shown to be slow acting because of the time delays, whereas changing productivity and reducing attrition by one percent year-on-year had a much faster impact. The modelling also identified what data the model outputs were most sensitive to, and where improvements would have a significant impact on accuracy – and thus on future workforce decisions.

A number of significant decisions were made as a result of this work, in particular:

- A 2% reduction in medical school intakes (120 people), to be introduced with the 2013 intake, with a further review in 2014
- No immediate change to dental school intakes because of issues over data quality highlighted by the modelling, with another review in 2013
- A rolling cycle of reviews of medical and dental student intakes should be established; to be undertaken every three years (not necessarily concurrently).

The model developed for this project has proven to be flexible and expandable, and will be used to monitor future changes in the workforce and to inform future reviews.

Furthermore, the system dynamics approach is being used to develop additional supply and demand models for other workforces across the UK health and social care systems, including nursing, midwifery, pharmacy and a range of medical specialties.

5.1 Next steps

A number of areas are under consideration for further work including:

1. Improving the linkage between the horizon scanning and scenario generation stages of the Robust Workforce Planning framework. In particular identifying

the most influential factors and driving forces, and investigating the stakeholder perspectives which have the most impact on the workforce problem under consideration, and greatest uncertainty of outcome.

2. Increasing the number of scenarios to explore a wider number of critical uncertainties. The scenario method generates four scenarios by selecting two clusters of driving forces with two outcomes of each. This might not give a sufficient spread of challenging futures under certain circumstances. Bringing in additional clusters of driving forces, possibly from several scenario exercises, may enable a portfolio of potentially reusable scenarios to be created. Work is also needed to understand which situations may require additional scenarios.

3. Measuring the effectiveness of a policy decision. In order to rank policies each scenario is given a ‘score’ which measures the deviation from the optimum. Policies that lead to the minimum deviation across the range of scenarios are considered most robust. Metrics for the optimum workforce might involve a number of factors, for example cost, the gap between supply and demand, and the workforce age profile. Further work is needed on the selection and proportion of these measures.

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