A retrospective of System Dynamics based workforce modelling at the Centre for Workforce Intelligence

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Abstract

This paper presents a historical reflection on the application of System Dynamics for health and social care workforce modelling at the Centre for Workforce Intelligence. Between July 2010 and March 2016 the CfWI was a key contributor to the planning of future workforce requirements for health and care in England. The Department of Health, as well as Health Education England and Public Health England, engaged the CfWI to inform national and local workforce planning and policy decisions. Initially the CfWI used MS Excel to develop their workforce models. These models were based on standard System Dynamics concepts such as stocks, flows, delays and feedback. However, Excel was not ideal for developing complex models with large amounts of segmentation and complex training pipelines. It was also not easy to maintain or extend the models.

In 2012 CfWI transitioned to using System Dynamics software for much of its modelling work, and aligned its development approach with the System Dynamics method. This paper discusses the transition to System Dynamics based modelling, the impact that the System Dynamics based studies had, and lessons learn from building a System Dynamics capability. In addition to the transition to using System Dynamics, the CfWI has also made numerous advances to its workforce planning framework, for example to elicitation and scenario generation. These are discussed in other technical papers.

Key Words: System Dynamics, workforce planning, health, social care, public health

1 Introduction

This paper presents a historical reflection on the application of System Dynamics for health and social care workforce modelling at the Centre for Workforce Intelligence (CfWI). Between July 2010 and March 2016 the CfWI was a key contributor to the planning of future workforce requirements for health and care in England. The Department of Health (DH), as well as Health Education England (from 2012) and Public Health England (from 2013), engaged the CfWI to inform national and local workforce planning and policy decisions. Initially the CfWI used MS Excel to develop their workforce models. These models were based on standard System Dynamics concepts such as stocks, flows, delays and feedback. However, Excel was not ideal for developing complex models with large amounts of segmentation. It was also not easy to maintain and extend the models, and testing these large models was difficult.

In 2012 CfWI transitioned to using System Dynamics software for much of its modelling work, and aligned its development approach with System Dynamics methods. This paper discusses the transition to System Dynamics based modelling, the impact that the System Dynamics based studies had and lessons learnt from building a System Dynamics capability.

This paper is structured as follows. **Section 2** provides a background to health and workforce planning in England, including the role of the Centre for Workforce Intelligence (CfWI) in this process. **Section 3** describes how the approach to workforce modelling evolved over the lifetime of the CfWI, and in particular how System Dynamics became one of the key analytical tools for modelling. **Section 4** describes how the System Dynamics is integrated into the overall approach adopted by the CfWI for workforce planning, which is called the Robust Workforce Planning framework. **Section 5** provides examples where System Dynamics was used for workforce modelling at the CfWI. **Section 6** describes some of the lessons learnt from the adoption of System Dynamics at the CfWI. Finally, **Section 7** looks to the future for national workforce planning using System Dynamics.

2 Background to health and social care workforce planning in England

2.1 The health and social care system in England

The English health and social care system is large, complex and serves the needs of a population of 54 million people (Office for National Statistics, 2014). The total number of jobs within the health and care system in 2013 was 3.4 million (Office for National Statistics, 2013). Of this, the National Health Service (NHS) in England employs 1.4 million staff (Health and Social Care Information Centre, 2014). The health and social care system has an impact on the population of the England on a daily basis

Making improvements to a complex system is difficult. Changes can have unforeseen consequences, take time to manifest themselves and may occur at a place distant from the original intervention. It is inherently difficult to predict how a complex system will change over time and there may be resistance to change due to the way the system is

organised. A system will often involve many people, each with different perspectives on the system, and different ambitions and fears. The English health and care system exhibits all these properties, and we need innovative methods to continue to improve how it functions.

2.2 The complexity of workforce planning for the health and social care system

The risks of poor workforce planning are to put patient lives at risk, increase morbidity, and consume resources to correct for 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 (i.e. the stages required prior to entering the workforce).

Different issues need to be taken into account for different workforces. For example, it can take many years to train some of the health and social care workforce groups. Hospital consultants can require more than 15 of formal training, so an under or over-supply cannot be corrected quickly or easily, and the inherent delays need to be taken into account for the purposes of future planning. Another example is that of paid carers working in the social care system, which is a workforce which does not have a long training pipeline and which can change jobs between sectors with greater regularity.

Planning also needs to take into account the evolving shape of care with technological innovation, changing population demographics and changing morbidities and co-morbidities. Finally, the interplay between health and social care should be considered when looking to the future along with potential workforce migration across national borders.

2.3 The Centre for Workforce Intelligence (CfWI)

The use of models in workforce planning is an established method that was in use for many years before the CfWI was formed. The predecessor organisation, the NHS Workforce Review Team, was an arm's length body of the South central Strategic Health Authority and used models to support national and regional strategic decision-making. The work of the CfWI built on the existing methods and data developments of previous planners.

The CfWI was formed in July 2010, and through to March 2016 was a key contributor to the planning of future workforce requirements for health and care in England. The CfWI built on the work of the previous workforce planners. The Kier Group (formerly Mouchel) was contracted by the DH to set up and run the CfWI. The DH, as well as Health Education England (HEE) and Public Health England (PHE), commissioned the CfWI to inform national and local workforce planning and policy decisions. Over this period, the CfWI led more than 30 major studies on the future workforce needs of health and care workforces, which impact the millions of people working in health, public health and social care. As well as this, the published work of the CfWI has an international dimension, garnering interest from European member states and other international health

economies. In particular, the CfWI worked with the DH to share workforce planning capabilities with the EU Joint Action on Health Workforce Planning and Forecasting network.

In April 2016 the functions carried out by the CfWI were transitioned into the DH and HEE. The DH Director of Workforce stated that: "It is a key priority for the health and care system to ensure it has the right workforce in the right place at the right time. The decisions being made today about tomorrow's workforce are now being informed by a greatly improved bank of workforce intelligence and the skill and efforts of the CfWI team have played a major part in this. The decision to move the service back into the public sector reflects the increasing profile of this area of our work and also the changes in the health and care landscape since the Centre was set up in 2010."

3 The evolution of workforce modelling at the CfWI

The primary purpose of the workforce models used by the CfWI was to provide planners evidence based projections to consider when commissioning services or forming policy.

The models were required to project workforce demand and supply in order to indicate the trajectory of the system under different conditions. The models were also required to act as a "test bed" in order to assess the impact of different interventions. The models were required to make use of the available data, and take into account that historically the data sources used in workforce planning were often collected for a different primary purpose, such as registration of professionals or managing payroll. Consequently they often required considerable time to access, interpret, verify and standardise. Finally, the models were required to be fully documented and tested.

This section describes how the workforce modelling carried out at the CfWI evolved from using just spreadsheets to the use of System Dynamics, why this was done, how this was achieved and the greater analytical insights this provided. Section 4 provides more information about how System Dynamics has been integrated into the wider framework developed by the CfWI for workforce planning.

3.1 How workforce modelling was carried out prior to the use of SD

Initially the CfWI used MS Excel or R to develop their supply and demand workforce models. These models were based on standard System Dynamics concepts such as stocks, flows, delays and feedback.

As an example, the underlying concept of supply modelling can be summarised as:

Future workforce = current workforce + joiners - leavers

This approach was normally quantified for headcount and full time equivalent (FTE) in varying degrees of complexity depending on the requirements and scale of the investigation. Part of the complexity comes from the need of the model to age the existing workforce for each time step in the future, and apply assumptions regarding the degree of part time working.

MS Excel was used to develop simple time step models with basic feedback but with a limited number of variables and policy levers. For example, the last major medical workforce model created in Excel segmented doctors by specialty, stage of training, type of contract, gender and age. The complexity of introducing large amounts of segmentation to an Excel model limited the scope of further development without the use of VBA scripts and complex worksheet relationships. This tool became cumbersome to navigate and document, and making adjustments to the model became challenging for quality control due to the complexity. Furthermore, using Excel made it difficult to determine the uncertainty associated with the projection, and to manage multiple scenarios. It was also not easy to maintain and extend the models, and testing these large models was difficult.

A final challenge of using these models was a lack of a standardised graphical user interface, and the complexity introduced when the scope of the work changed to include new themes such as cost analysis.

As such it was recognised that a new modelling approach was needed.

3.2 The journey from Excel to SD

SD was initially used for the Medical and Dental School Intake (MDSI) project in 2012. The project was carried out by the CfWI for the DH and the Higher Education Funding Council for England (HEFCE). The purpose of the project was to determine the long term training requirements doctors and dentists in England. Two SD models were developed that enabled the future supply and demand of doctors and dentists to be projected out to 2040 (Department of Health, 2012). The CfWI were supported by Decision Analysis Services Ltd, a consultancy that specialises in System Dynamics and Systems Thinking. The System Dynamics model was developed using Vensim, and Excel was used to store all the input data and simulation results.

The project was a success. It influenced government policy of future training commissions and the SD model provided rapid policy analysis (Department of Health, 2012). Following the MDSI project the decision was taken that the CfWI would adopt SD modelling for subsequent workforce supply and demand models where appropriate.

Initially, workforce specific model were developed for the studies following MDSI, for example for the Pharmacy (CfWI, 2013a), Dentistry (CfWI, 2013b), Psychiatry (CfWI, 2014a,b) and General Practitioner (GP) (CfWI, 2014c) workforces. It was identified that different models were based on very similar model structures. For example, the training pipeline may appear different for different workforces, but in the majority of cases can be represented by a set of training courses with varying durations. As a result of this a generic workforce model was developed that could be parameterised to suit a large variety of different workforces. For example, the generic model was used for Speech and language therapists (SLT) (CfWI, 2014d), dental care professionals (DCP) (CfWI, 2014e) and variety of medical specialties. Having a generic model made the studies much more efficient, for example the level of model development, testing and documentation were much reduced.

An additional development in the SD modelling was carried out during the Horizon 2035 project. Horizon 2035 was a project commissioned by the DH to take a whole system view of how challenges across the health and care system may unfold out to 2035. This model was different to the previous models developed by the CfWI as its main 'currency' was skills and competencies rather than Full Time Equivalent (FTE) or Head Count (HC). (CfWI, 2014f; CfWI, 2015a)

Figure 5 in Section 5 provides an approximate timeline for selected SD based workforce studies carried out by the CfWI. The diagram also illustrates some of the workforces that were modelled using the generic workforce model rather than in models developed specifically for that workforce.

3.3 How the SD models were used for analysis

As described earlier, the SD models developed by the CfWI were used to project workforce supply and demand over time. More specifically, the key analytical outputs for workforce supply and/or demand, depending on the scope of the study, were projections for:

- A reference scenario to show the system trajectory if there are no major system shocks and historic trends continue as expected.
- A set of plausible and consistent but challenging scenarios.
- The impact that different policy interventions have under each of the scenarios.

The SD model architecture enabled the many simulations associated with the various scenarios and interventions required as part of a project to be managed.

In addition to the many simulations required, a key part of the analytical process was to have a clear representation of the impact of uncertainty on the model outputs. This was achieved in two ways:

- Key uncertain input variables were elicited from expert groups through workshops, as probability distributions. The simulations were then executed in "Monte Carlo" mode so the variation of the inputs on the model outputs could be determined.
- Making adjustments to each of the input data items separately to identify the variables that showed the strongest influence on the key outputs.

In both cases the software tool used to develop the System Dynamics models (Vensim) could automate these operations. As a result the simulations could be easily exported for subsequent analysis. For example, Figure 1 illustrates a typical fan chart created by exporting simulation results to Tableau, a specialist data visualisation tool.

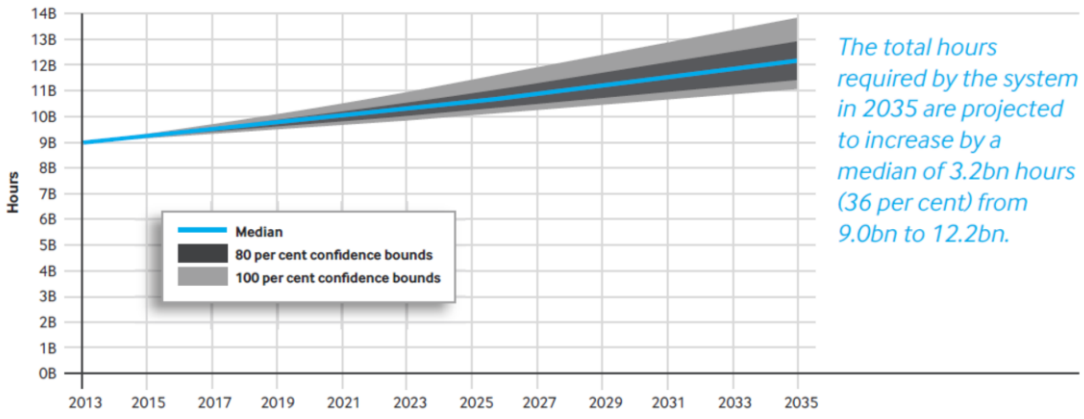

Figure 1: *Sample fan chart output from the Horizon 2035 project (CfWI, 2015a). The chart shows the projected change in demand for skill hours across the English health and social care system*

3.4 Building capability in System Dynamics

Following the successful application of SD in the Medical and Dental School Intake project (DH, 2012) the decision was taken to adopt SD for subsequent projects where appropriate. In order to deliver these projects it was necessary to build the CfWI's capability in SD model development. This capability was developed in the following ways:

- Analytical staff were provided with specialist training in SD.
- A mentoring system was implemented where people new to the SD method worked closely with more experienced practitioners.
- Initially analytical staff were tasked with testing elements of models in order to understand how they worked before moving on to model development.

This could be considered an "apprenticeship model" for capability development.

A range of documents was created in order to formalise and disseminate SD model development practice within the CfWI. The first was a detailed technical paper that provided a clear description of the stages of SD model development, best practice guidance for each stage and checklists that could be used to ensure the model was fit for purpose (CfWI, 2014g). This paper was available for download from the CfWI website, so that interested parties could better understand our modelling approach.

The second was an interactive model components library. The component library was a set of generic models (in a similar form to the Vensim Molecule Library (Hines, 2005)) that defined common structures that may be required for a workforce model. Each component was documented in an interactive PDF document (See Figure 2). The purpose of the component library was twofold. First, as a resource for people learning about typical System Dynamics models archetypes, and second as a way to speed up model development through copying and pasting the components into models.

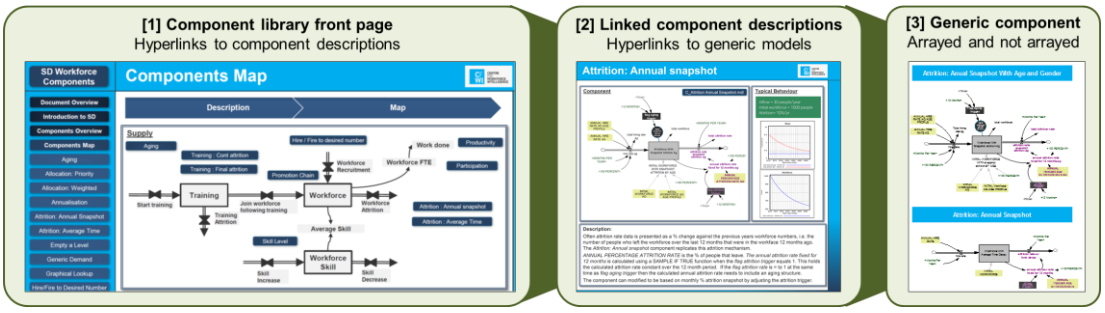

Figure 2: *Extract from the supply side model components library*

4 The position of System Dynamics within the overall CfWI workforce planning approach

The Robust Workforce Planning Framework (RWP) was developed by the CfWI as an approach for making robust workforce decisions in a complex world, taking uncertainty into account so that future workforce problems could be evaluated and robust well-informed choices made. The result was an advanced approach that allowed for the testing of policy interventions in a range of plausible and challenging futures. The SD model development approach adopted by the CfWI is fully integrated into the RWP.

The RWP was continuously updated and refined over the lifetime of the CfWI. The framework was applied to many health and care workforce reviews, from individual workforces to the whole health, public health and social care system. The framework, is described in CfWI Technical Paper No. 10 (CfWI 2014h) and is illustrated in the diagram below:

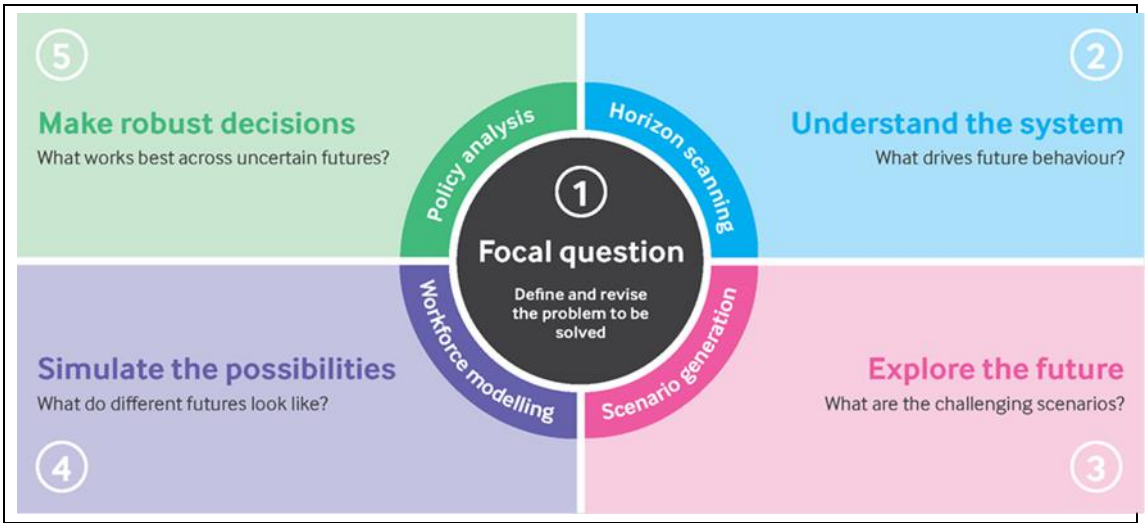

Figure 3: *CfWI's Robust Workforce Planning framework (CfWI 2014h)*

The framework has four stages:

- Horizon scanning to understand the system and what drives future behaviour.
- Scenario generation to explore the future and produce challenging scenarios.

- Workforce modelling to simulate these futures and quantify what they look like.
- Policy analysis to make robust decisions about which solutions are the least vulnerable to uncertainty.

The study is bounded by a focal question, which is a clear statement of the project purpose and scope.

Although the focus of this paper is on the adoption of System Dynamics by the CfWI, it should be noted that the CfWI has also made numerous advances to all areas of the RWP, for example to elicitation and scenario generation. These are discussed in other technical papers published by the CfWI.

The CfWI method for developing SD based workforce models has four stages: model scoping, model construction, model documentation, and model testing (CfWI, 2014g). A key initial document was the model specification created during the model scoping stage. This helped gain the confidence of stakeholders and raised concerns or questions from both sides before the build began. It would often open doors to previously unknown datasets or information

As with the stages of the RWP framework, the stages of the model development approach contain iteration and overlap. The approach is illustrated in Figure 4 with reference to the stages of the RWP.

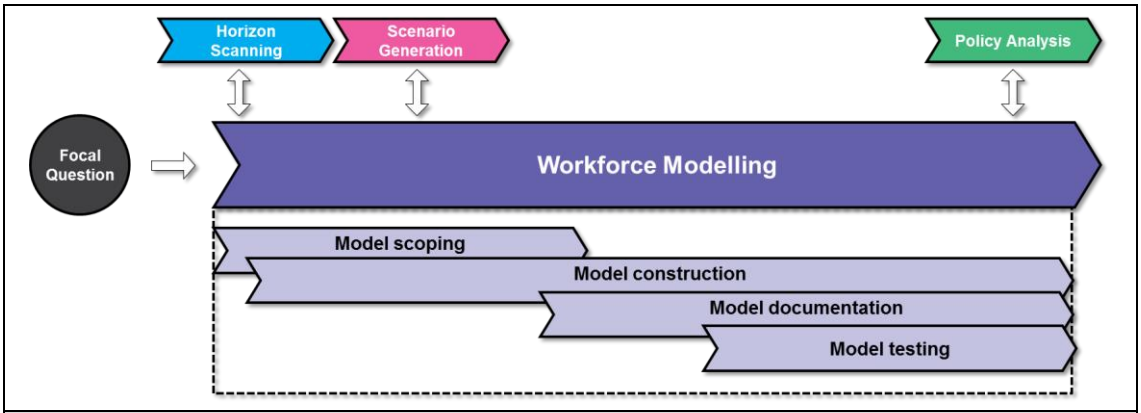

Figure 4: *Integration of SD model development within Robust Workforce Planning framework (adapted from CfWI 2014g)*

Figure 4 illustrates that the Workforce Modelling stage is influenced by, and influences all the stages of the RWP. For example, the focal question helps to bound the model, the Horizon Scanning stage helps to scope the detail of what needs to be represented, the Scenario Generation supports the development of the scenarios to be represented in the model, and the Policy Analysis Stage is where the model is used. The overall approach is consistent with guidance provided by the UK Government on producing quality analysis for government (HM Treasury, 2015).

It is worth noting the importance of model testing, and that Stakeholders were involved in this stage to determine whether model behavior was appropriate. This had the additional benefit of enabling the stakeholders understand things that were not always

intuitive due to the complexity of the models. For example, the circumstances under which length of training does or does not strongly influence the future supply of new workforce.

5 Studies that used SD for the workforce modelling

Figure 5 below shows an approximate timeline for selected SD based workforce studies carried out by the CfWI, along with references to project reports. It should be noted that this does not represent all the workforce studies performed by the CfWI, a number were not SD based. The timeline represents the duration for the complete project, i.e. all stages of the Robust Workforce Planning framework described in Section 4, rather than just the period where SD modelling took place.

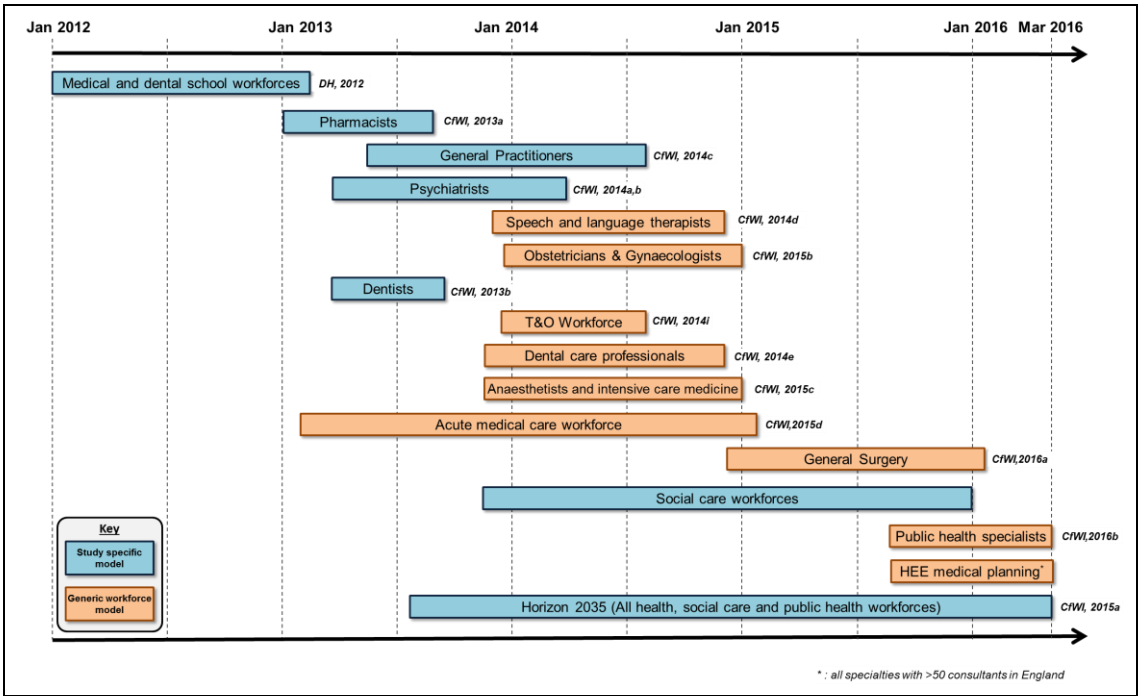

Figure 5: *Approximate timeline for selected SD based workforce modelling projects from Jan 2012 to March 2016*

5.1 The impact of the SD based studies

In each of these workforce studies, the commissioners were confident to use the results of the modelling to support their decision making process, in part due to the transparent process adopted in developing the models, and their involvement throughout the Robust Workforce Planning framework.

Other impacts of the SD modelling include:

- The number of commissions for many of the professions and specialties in the health and social care system have been influenced by CfWI modelling. The

CfWI's work has been cited by HEE in their commissioning and investment plans and empirical influence is present in many of the changes to trainee numbers (Health Education England 2014, 2015, 2016).

- Stakeholders such as Royal Colleges became more supportive and trusting of the CfWI's work[1]. The Royal Colleges are responsible for development of and training in one or more medical specialties. This greater level of trust was attributed to the more transparent approaches adopted by the CfWI, partly through the use of graphical SD models.

- The value of modelling has been highlighted by the CfWI embedding it in a framework that helps decision makers. The realisation that the models are only as good as the data they use has been understood. During the period of operation of CfWI there has been greater standardisation of workforce data (HEE are developing data and standards) and expansion in the scope of data collection, notably in the primary care workforce. This shows a confidence in evidence-based workforce planning.

- The profile of workforce planning and the standardisation of models allowed a greater proportion of project time to be given to addressing the core question, than before with the need to create custom MS Excel models.

- The published work of the CfWI has an international dimension, garnering interest from European member states and other international health economies. In particular, the CfWI worked with the DH to share workforce planning capabilities with the EU Joint Action on Health Workforce Planning and Forecasting network.

- A whole system approach was used to model the health, public health and social care system in the Horizon 2035 project (CfWI, 2014f).

Finally, feedback we have received from the many presentations we have given across Europe and the rest the world shows that in the field of health and care workforce modelling, our System Dynamics approach is class-leading. This was formally recognised when the CfWI and DAS were awarded the Steer Davies Gleave award for their contribution to significant policy questions affecting the UK.

6 Lessons learnt from use of SD

SD proved to be an excellent tool for developing the models used by the CfWI for carrying out strategic workforce analysis. The advantages of the approach included:

- The process of developing a model in collaboration with stakeholders from the workforce as well as planners, trainees, employers and decision makers helped all parties to understand the complex health and care system, and identify the key

[1] www.rcoa.ac.uk/news-and-bulletin/rcoa-news-and-statements/rcoa-response-cfwi-report

variables that influence it. The engagement with stakeholders raised the profile of our work and stimulated discussion of the focal question. This in turn led to better information to inform the models, and more informed use of the outputs. Engaging stakeholders during the modelling process considerably improved the confidence in the findings – which therefore had a greater impact.

- The visual representation of the model structure made it easier to share with the stakeholders. This was especially important during the scoping stage of model development (See Section 4) when the proposed model structure was 'signed off'. The underlying model stock and flow diagrams were widely used at large stakeholder events, with interested parties able to annotate and correct the diagrams so that they represented how they considered the system to be linked (Department of Health, 2012).
- The formalised approach to model development and the associated documentation, such as the model specification, built confidence in the modelling throughout the development of the model.
- The underlying "Stock and Flow" analogy made sense to the wider stakeholder group. Presenting the results of the model in linked stock and flow diagrams, together with behavior over time charts, made explaining model results straightforward. Figure 6 provides an illustrative example from the Pharmacist model.
- Validation of the SD model was made easier as the model links were explicit within the stock and flow diagrams. This is a clear advantage over Excel where the links between variables can often be opaque. It was much easier to interrogate the models at a variable level, which aided debugging and carrying out model behavior analysis.
- The models developed for workforce analysis were often highly segmented (for example, specialty training in the MDSI model (Department of Health, 2012) was segmented by age, gender, nationality and number of years remaining of training). It was much easier to handle and make changes to this level of segmentation in a SD model than an Excel model.
- Multiple scenarios could be represented by the model, and the inbuilt analysis tool made comparing multiple scenarios straightforward.
- The inbuilt Monte Carlo engine allowed the uncertainty of the projections to be made explicit.

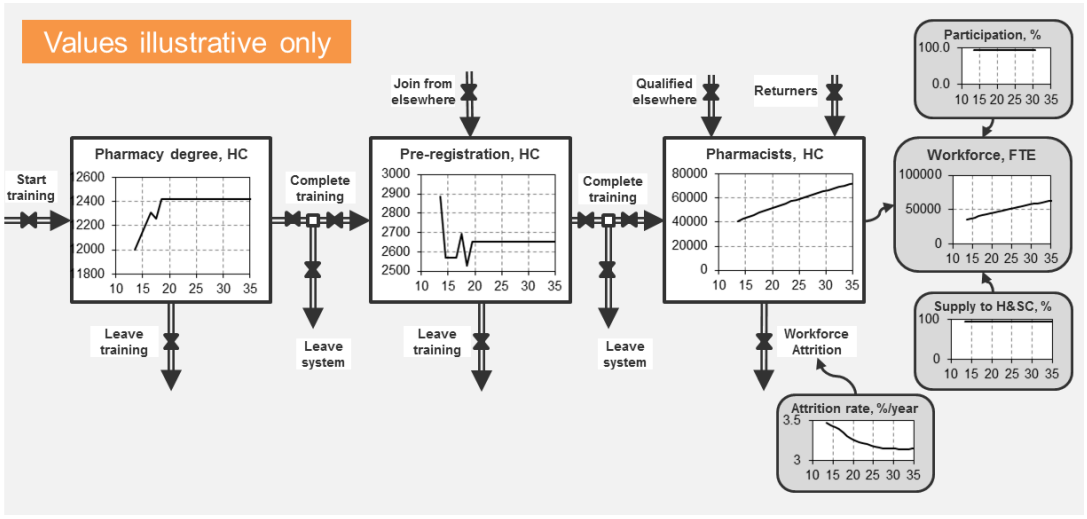

Figure 6: *Illustrative high level supply side Stock and Flow side diagram for the Pharmacist workforce*

However, some disadvantages were identified in the use of SD for the projection models.

- SD as a simulation method is not widely practiced when compared to developing models using MS Excel. As a result, analysts new to the CfWI required additional training in order to become familiar with SD and to become proficient using SD software. A mentoring style approach was adopted by the CfWI to make knowledge transfer as efficient as possible, which incorporated best practice guidance and exemplar models (See Section 3). In addition, the models were developed with an Excel model interface so that analysts as the CfWI who were not familiar with the bespoke SD software used could still carry out workforce analysis.
- SD models use specialist software, which require installation on a computer. This influenced the decision taken to create some of the simpler workforce models using Excel where it was known that the final model would be handed over to the client for them to use, rather than the CfWI carrying out the analysis.

Finally, the mentoring approach adopted by the CfWI was found to work, with experts sharing their knowledge on the SD approach in a supportive environment.

7 Looking into the future…

In April 2016 the functions carried out by the CfWI were transitioned into the DH and HEE. The DH Director of Workforce stated that: "It is a key priority for the health and care system to ensure it has the right workforce in the right place at the right time. The decisions being made today about tomorrow's workforce are now being informed by a greatly improved bank of workforce intelligence and the skill and efforts of the CfWI team have played a major part in this. The decision to move the service back into the public sector reflects the increasing profile of this area of our work and also the changes in the health and care landscape since the Centre was set up in 2010." It is anticipated that

the workforce modelling approached created by the CfWI will be adopted by the DH and HEE.

8 Abbreviations

CfWI	Centre for Workforce Intelligence
DAS	Decision Analysis Services Ltd
DCP	Dental Care Professionals
DH	Department of Health
FTE	Full Time Equivalents
GP	General practitioner
H2035	Horizon 2035 project
HC	Head Count
HEE	Health Education England
HEFCE	Higher Education Funding Council for England
MDSI	Medical and Dental School Intake project
NHS	National Health Service
RWP	Robust Workforce Planning framework
SD	System Dynamics
SLT	Speech and Language Therapist

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