

REAL Centre

Working paper

Nurse supply model: progress so far

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**The
Health
Foundation**

About the REAL Centre



The Health Foundation's REAL Centre (research and economic analysis for the long term) provides independent analysis and research to support better long-term decision making in health and social care.

Its aim is to help health and social care leaders and policymakers look beyond the short term to understand the implications of their funding and resourcing decisions over the next 10-15 years. The Centre will work in partnership with leading experts and academics to research and model the future demand for care, and the workforce and other resources needed to respond. The Centre supports the Health Foundation's aim to create a more sustainable health and care system that better meets people's needs now and in the future.

www.health.org.uk/REAL

About DAS



DAS is an independent management consultancy with offices in the UK and Australia. We are a leading supplier of Futures, Data Analytics, Systems Thinking and System Modelling consultancy to public and private sector organisations. Coupled with extensive programme management, regulatory, operations delivery and engineering experience, this expertise underpins our ability to look deeper into issues, to provide clearer insight and foresight, and to solve critical client challenges. DAS specialises in bridging the gap between strategy and operations, creating effective solutions to uniquely complex issues faced by our clients worldwide. DAS' clients cover the public, private and third sectors who look to us for strategic and operational support for their most critical issues.

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Executive summary

Even before the COVID-19 pandemic, workforce issues were identified as the [single biggest challenge](#) for health and social care in England. These issues have taken centre stage during the pandemic, with workforce shortages coming to the fore. Nursing has long been the [key NHS shortage area](#) and accounted for 45% of full-time equivalent vacancies in the NHS in England in June 2020.

Against this backdrop, the Health Foundation has established the REAL Centre (Research and Economic Analysis for the Long term) to provide new evidence and analysis that will help health and social care policymakers consider the long-term implications of their funding, design and delivery decisions. Modelling of future workforce requirements in health and social care will be a core activity of the REAL Centre.

As a first step towards this goal, the REAL Centre commissioned Decision Analysis Services Ltd (DAS) to develop a [nurse supply model](#). The model will provide projections of the future nursing workforce supply in England under alternative policy scenarios over a 10 to 20-year time frame. In the longer term, this will enable the REAL Centre to publish evidence-based estimates of the future supply of nurses, to identify where shortages are likely to be most pressing and to assess the implications of different policies to fill those gaps. This will be a vital contribution to the evidence base and the wider debate on this key workforce issue.

A comprehensive model of nurse supply that captures not only the stocks and flows in domestic and international nurse training, recruitment and retention but also the factors that drive individual nurse participation decisions, informed by academic expertise and the knowledge of system stakeholders, is needed now more than ever. This highlights the relevance of the ongoing development, led by DAS, of the REAL Centre's nurse supply model.

DAS is adopting a collaborative approach to developing a mixed-methodology model for long-term nursing supply projections. The model will enable a wide range of forward-looking scenarios and policy levers to be investigated. This will involve a quantitative simulation set within a conceptual framework that represents the nurse supply system. In parallel, DAS is developing a participative strategic policy assessment framework, comprising a documented analysis methodology, to set out how the model should be applied to develop robust projections.

Several activities have been undertaken to date. These include research into the current state of nurse supply modelling, scoping of the data relevant to the nurse supply system and a review of the economic theory that can be used to describe nurse supply. This work has been used to support the production of the model specification. At every stage, the REAL Centre and DAS are engaging the wider stakeholder community through workshops and interviews. This will ensure that the data and assumptions underpinning the model are appropriate and well founded.

This first phase of model development will conclude in August 2021, when the model will be transferred to the REAL Centre team for use in analysis and further development. In addition to setting out the context, this working paper summarises the activities undertaken so far and provides a brief description of the nurse supply model as it stands. In conclusion, it sets out

forthcoming tasks and plans for developing the model. In the [International Year of the Nurse and the Midwife](#), the REAL Centre and DAS are proud to be engaged in this endeavour.

1. Introduction

Decision Analysis Services Ltd (DAS) has been commissioned by the REAL Centre to produce a model that can be used to develop supply projections of the nursing workforce with a time horizon of 10 to 20 years. This working paper describes the progress to date.

1.1 Background

The [Health Foundation](#) is an independent charity committed to bringing about better health and health care for people in the UK. The aim of the Health Foundation is a healthier population, supported by high quality health care that can be equitably accessed.

The REAL Centre ([Research and Economic Analysis for the Long term](#)) is a specialist semi-autonomous centre within the Health Foundation. The REAL Centre focuses on economic research, model development and supporting analysis in health and social care. The Centre was formally launched in October 2020. A key objective of the Centre is to ensure that decisions about the funding, design and delivery of the health and social care system are informed by the best available analysis and evidence, and with consideration of the costs and benefits over the long term.

One of the REAL Centre's major outputs will be a series of projections of the long-term trends affecting the health service in England and the resources needed to provide a high quality service in the future. To support this, the REAL Centre requires models that can provide projections of the health and social care workforce under alternative policy scenarios over a 10 to 20-year time frame. A new model representing the whole of the nurse supply system would represent a significant improvement to the current models used by the Health Foundation and other organisations in the UK. To be useful to policymakers, such a model would provide estimates of the future nursing supply based on the labour participation decisions of nurses.

Decision Analysis Services Ltd (DAS) was commissioned to develop the model in September 2019. DAS is an independent management consultancy with offices in the UK and Australia. DAS has expertise in the use of simulation, systems thinking, programme management, investment modelling and data analytics in government and business domains. Coupled with extensive regulatory, operations delivery and engineering experience, this expertise underpins their ability to look deeper into issues, to provide clearer insight and foresight, and to solve critical client challenges. DAS specialises in bridging the gap between strategy and operations, creating effective solutions to uniquely complex issues faced by its clients worldwide. DAS' clients cover the public, private and third sectors who look to it for strategic and operational support for their most critical issues.

1.2 Nurse supply in England

Even before the COVID-19 pandemic, workforce issues were identified as the [single biggest challenge](#) for health and social care in England.¹ Workforce shortages are a major concern, with NHS full-time equivalent vacancies [exceeding 80,000](#) in June 2020.² Nursing is the key shortage area, accounting for close to 38,000 (45%) of these vacancies. While both figures have declined slightly relative to June 2019 (when

overall NHS full-time equivalent vacancies exceeded 100,000 and nursing vacancies numbered over 40,000), nursing vacancies accounted for a higher share of all vacancies in June 2020 relative to June 2019. Looking further back, while output in NHS trusts increased by over a quarter (26%) between 2010/11 and 2017/18, the number of full-time equivalent nurses increased by just 1%. * Workforce shortages are already having a direct impact on patient care and staff experience, with a recent RCN survey highlighting nurse perceptions of increases in stress and work hours.³

One of the main reasons for the shortages in nursing, and in the NHS as a whole, is a lack of long-term planning around staffing levels and a 'boom-and-bust' approach linked to funding.⁴ As the Health Foundation set out in 2016, 'The less costly, reactive and short-term solutions – being used by national and local leaders to tackle current problems – are quick fixes, and will only put a sticking plaster on deep-seated and systemic problems for the NHS.'⁵ The lack of high quality, robust, and transparent projections of workforce supply and demand is a major factor underlying the lack of a coordinated workforce strategy. This is partly due to a lack of capacity and capability at both national and local levels, exacerbated by reorganisations of the system architecture.⁶

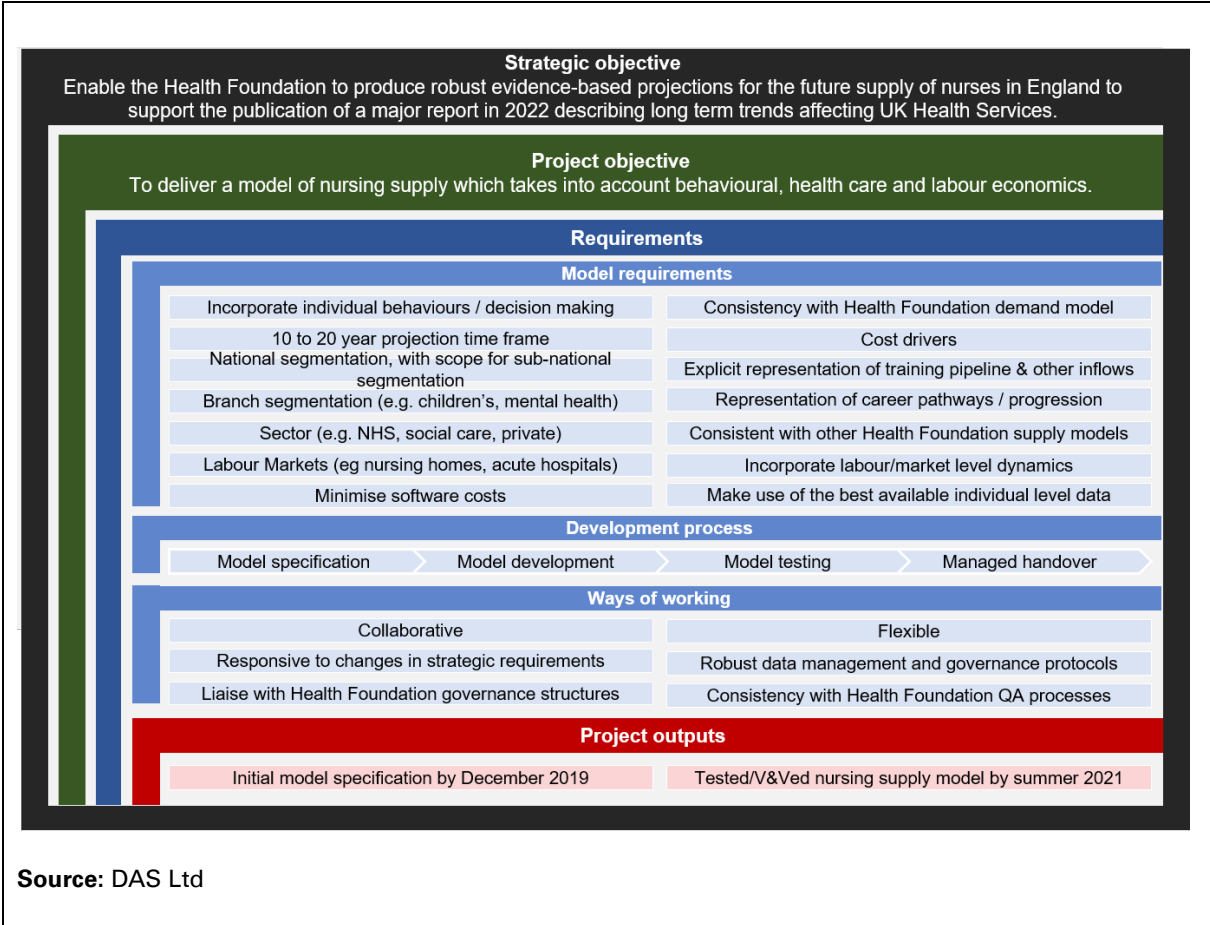
Most nurse supply models described in the literature take a 'stock and flow' approach to modelling the workforce: taking current workforce numbers then applying joiner and leaver rates in order to roll the model forwards by one year, and repeating this for a given number of years.^{7, 8, 9} The Centre for Workforce Intelligence previously produced and published [long-term projections of health care demand and supply](#), but it has now been dissolved. The remaining models in use in England tend to focus on specific clinical areas or training pathways, with none providing representation of the whole system, for example no models were identified that provided a cross-sector view (See section 3.2). This is despite the future supply of nurses being a core determinant of the future sustainability of the NHS.

A comprehensive model of nurse supply rooted in system dynamics that capture not only stock and flow numbers but also the factors that drive individual nurse participation decisions, underpinned by academic expertise, is needed now more than ever. It is in this context that the REAL Centre has commissioned DAS to lead the development of a nurse supply model.

* Source: NHS Digital, NHS Workforce Statistics; ONS, Public service productivity: healthcare, England. Note: output is cost and quality adjusted activity.

The initial set of requirements identified by the REAL Centre, which formed the initial basis of the model specification, are illustrated below:

Figure 1-1: Nurse supply model requirements as initially defined in the ITT (Health Foundation / REAL Centre, 2019)

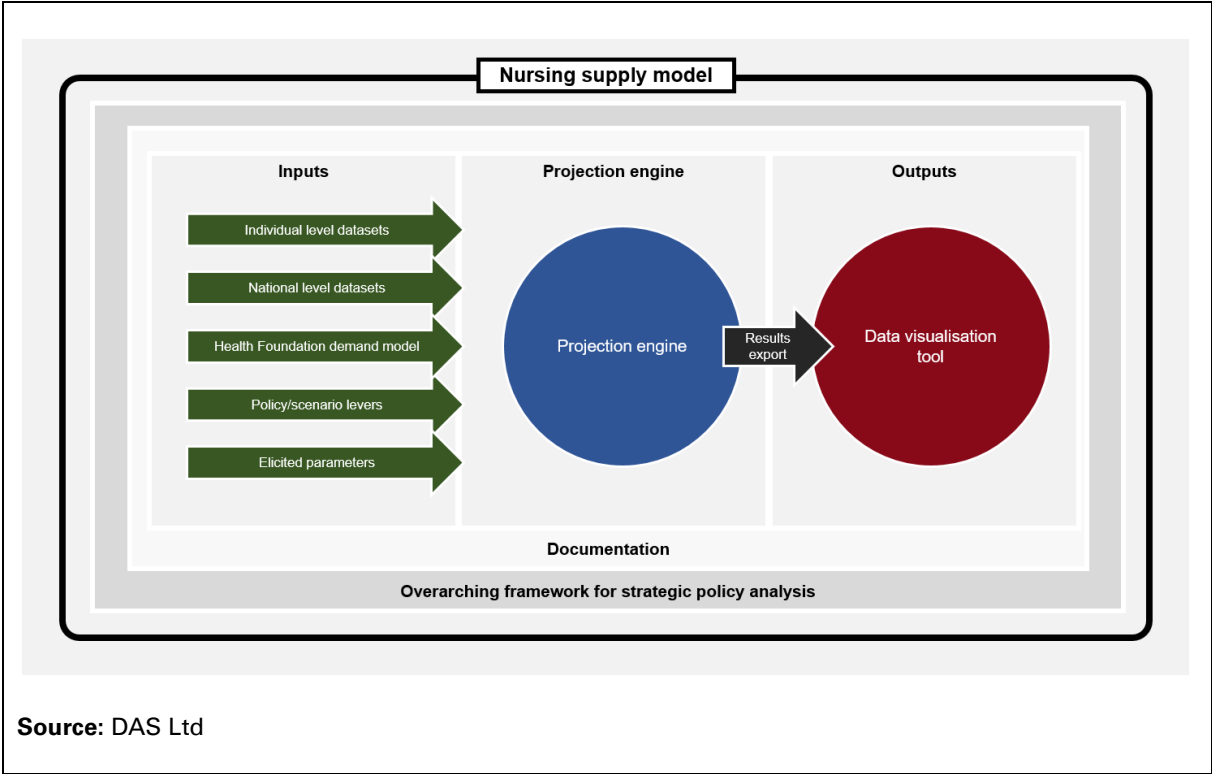


1.3 DAS’ approach to delivering the nurse supply model

More details about the nurse supply model are provided in a later section (Section 4) of this working paper. A high level overview is provided below.

DAS is adopting a collaborative approach to developing a mixed methodology model for long-term nursing supply projections that enables a wide range of forward-looking scenarios and policy levers to be investigated. A mixed methodology model integrates a number of qualitative and quantitative modelling techniques drawing on the advantages of each. For the purposes of this project, the ‘long term’ is a time period of 10 to 20 years. The model is being co-designed with the REAL Centre and stakeholders so that it is widely acknowledged as being valid and fit for purpose. DAS will use the best and most efficient analytical tools based on the available data to ensure a handover of capability to the model’s end users (principally the REAL Centre and other Health Foundation teams, policymakers and academic experts).

Figure 1-2: A high level overview of the proposed nurse supply model solution



The nurse supply model (hereafter, NSM) will involve a quantitative simulation set within a conceptual framework that represents the nursing supply system. The conceptual framework will take a broader view of the nursing supply system and will include variables that are not quantified within the simulation engine. This will be used as a tool to support scenario development and to set research agendas for quantifying relationships in the simulation engine.

The simulation model will be composed of two key components, a projection engine and a data visualisation tool. The purpose of the NSM projection engine is to produce projections of nurse supply for England with a time horizon of up to 10 to 20 years. The purpose of the data visualisation tool is to enable the analysis and visualisation of the supply projections produced using the NSM projection engine.

The projection engine will adopt the system dynamics approach. It will represent training and workforce pathways, with individual level modelling (where data is available) providing insight into various workforce members’ behavioural characteristics. The projection engine will incorporate actionable and meaningful segmentations, calibrated to provide a representation of individual behaviour based on historic data.

The data visualisation tool will enable libraries of projection scenarios to be analysed individually and comparatively using a variety of analysis tools. The projection engine will also produce data exports for use by other applications.

In parallel to the model development, a participative strategic policy assessment framework will be developed to describe how the model should be applied. This will take the form of a documented analysis methodology.

1.4 Structure of the document

The remainder of this working paper is organised as follows:

Section 2 gives an overview of the collaborative approach being adopted by DAS and the REAL Centre to delivering the nurse supply model. This includes a description of the development ethos being applied during the project, a high level description of the different stages of the project and the organisations involved to date.

Section 3 provides details about some of the key activities that have been undertaken since the project began.

Section 4 provides a detailed description of the model that is currently under development. This includes a description of the simulation engine, the data visualisation tool, and how it is anticipated that the model will be used.

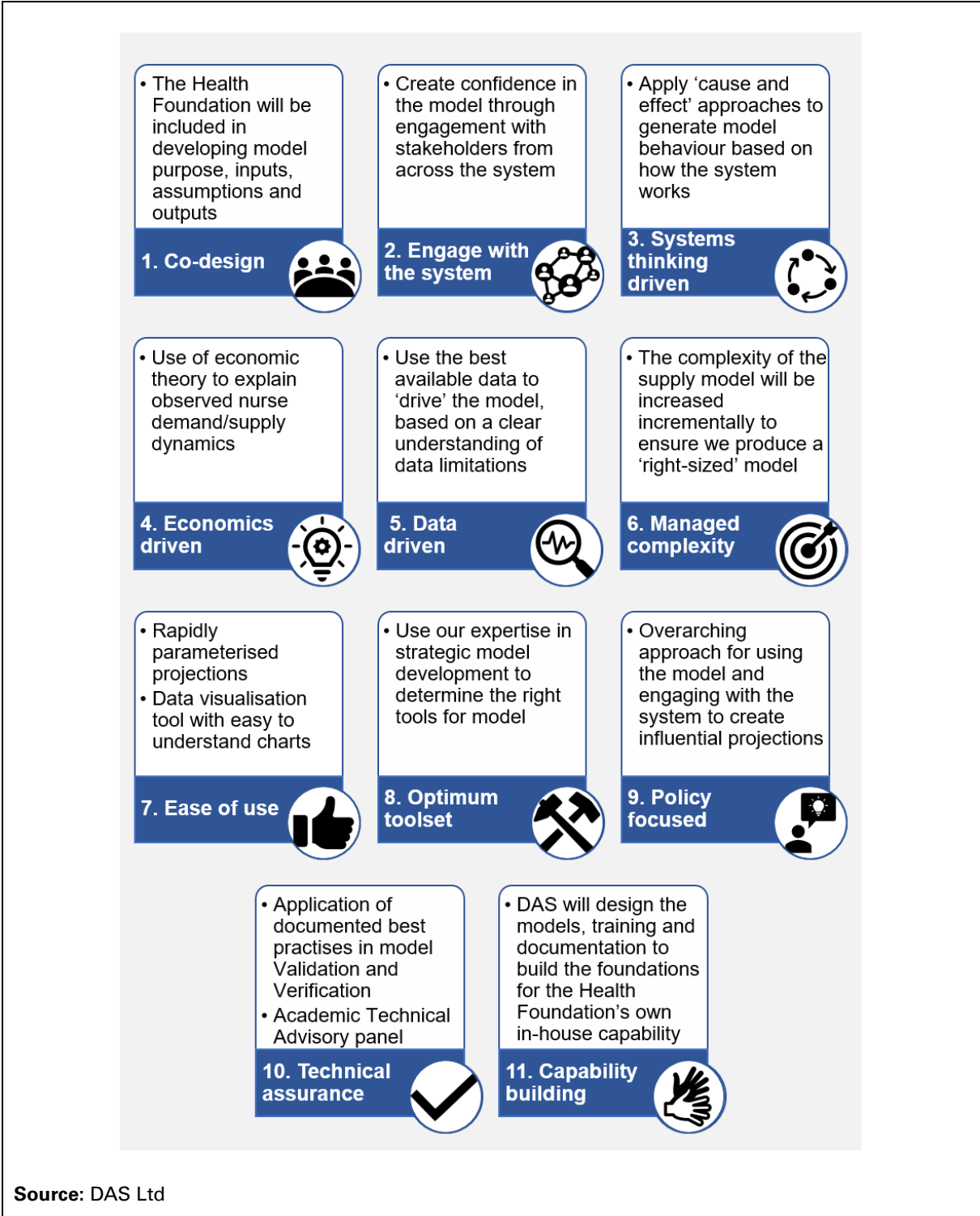
Section 5 describes the next steps in the development of the nurse supply model.

2 Delivering the model

A collaborative approach is being adopted by DAS and the REAL Centre to delivering the nurse supply model.

A number of best practice model development principals are being applied throughout the development of the NSM, as illustrated and described in the diagram below:

Figure 2-1: Nurse supply model development ethos



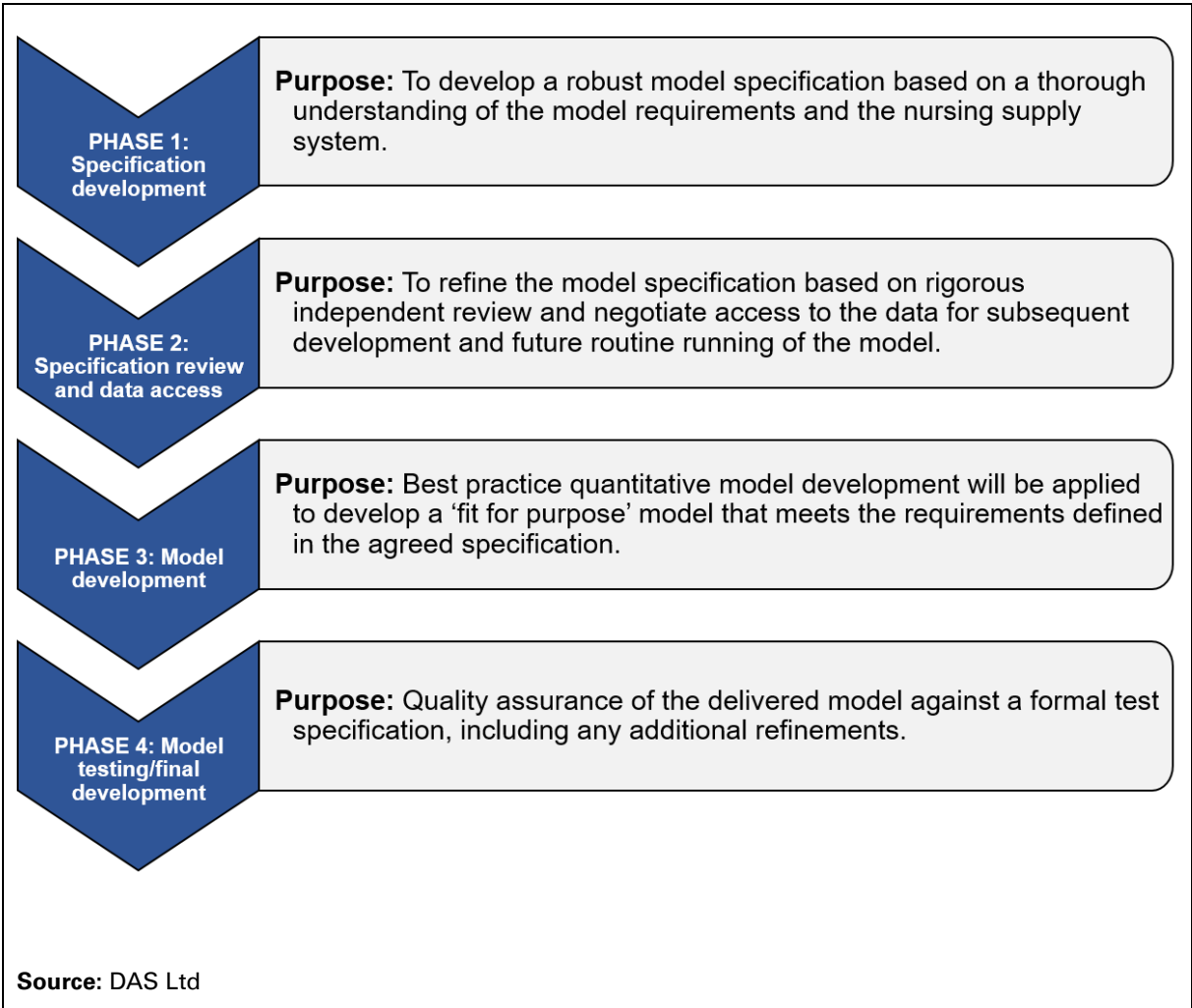
Source: DAS Ltd

2.1 Staged development approach

The project is designed to deliver a transfer of the nurse supply model to the REAL Centre in August 2021. The REAL Centre will continue to develop the model beyond this date as new data become available and to account for shifts in the policy landscape. DAS has developed a delivery plan to design, develop and test the model. An academic advisory panel from the University of Southampton is providing oversight and scrutiny throughout the process. The panel is composed of experts in health care modelling and simulation from the University of Southampton: Dr Steffen Bayer, Dr Stephan Onggo and Professor Martin Kunc.

The development plan is given below including the purpose of each of the stages of model production.

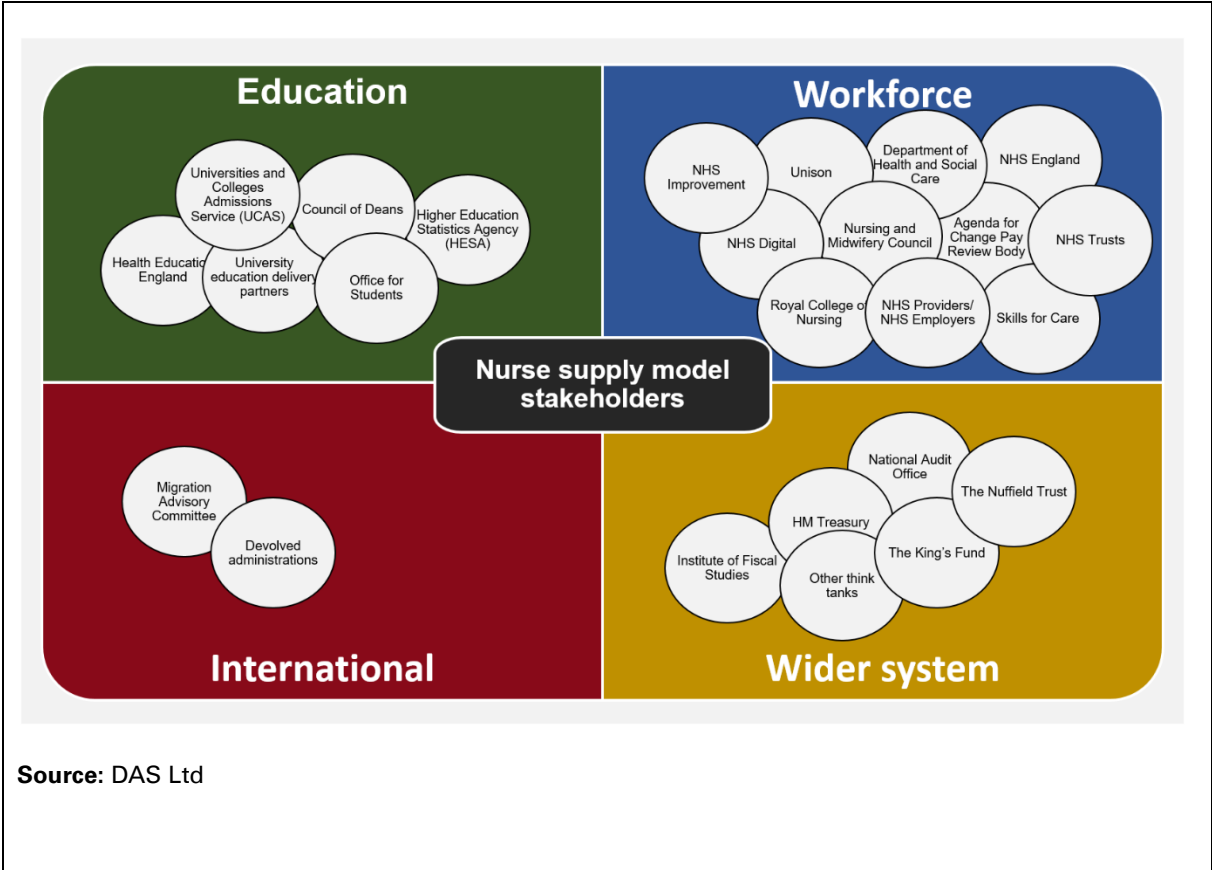
Figure 2-2: Project stages



2.2 Stakeholder involvement

It is critical to engage the wider system to ensure that appropriate assumptions and data are used and to build confidence in the model. This has been carried out thus far through interviews and workshops with a number of stakeholders, to build a coherent understanding of the supply system, including behavioural drivers and stakeholder requirements. The diagram below illustrates the key stakeholders in the system:

Figure 2-3: Stakeholder involvement

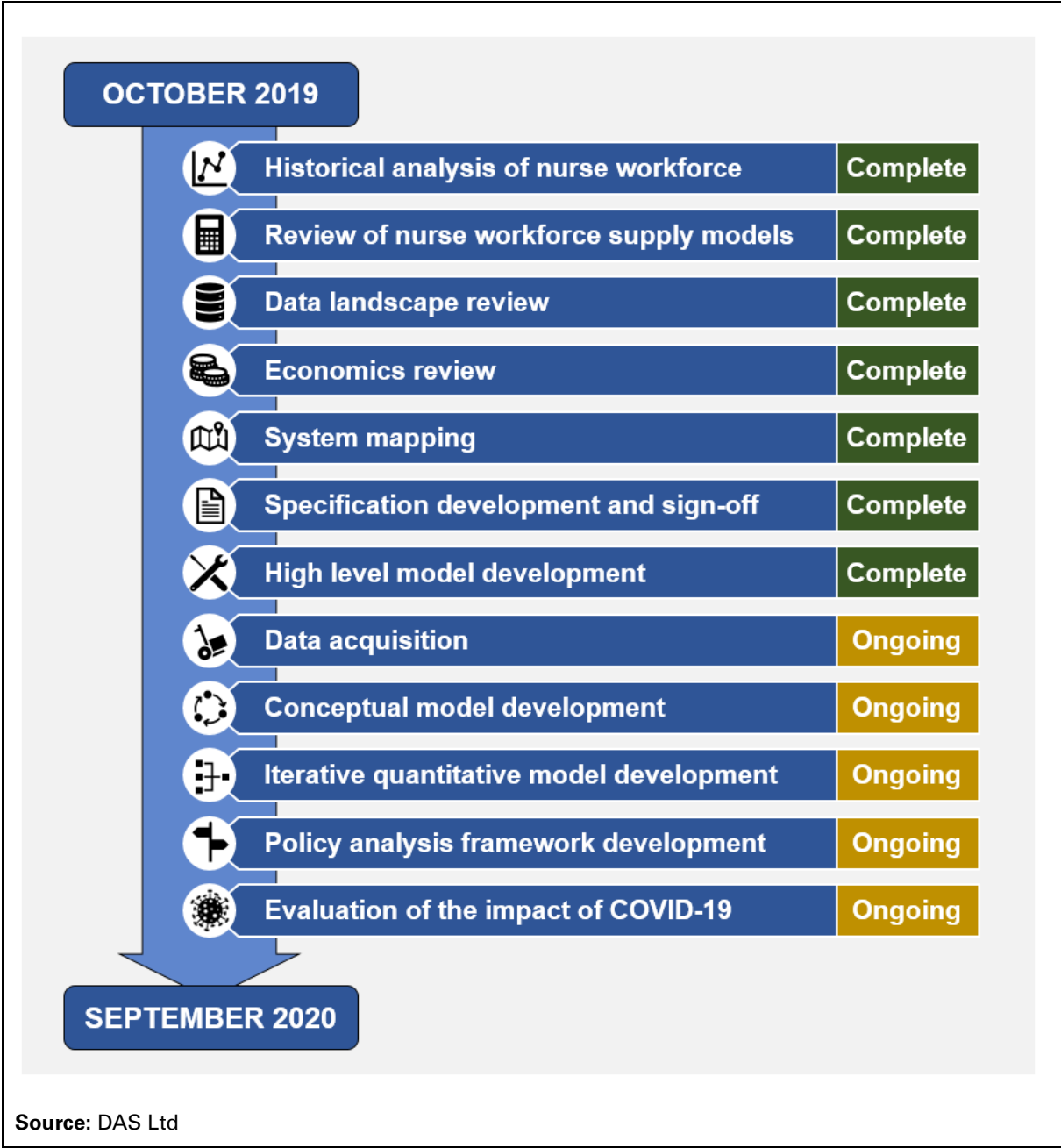


3 Review of activities undertaken so far

A large number of activities have been undertaken, each contributing significantly to the development of the model specification. This has included desk research, workshop delivery, extensive stakeholder engagement and the production of the model specification.

The diagram below lists the key activities that have been undertaken to date.

Figure 3-1: Overview of work to date



Each of the activities is described below. Certain activities will contribute to combined DAS and REAL Centre publications.

3.1 Historical analysis of nurse workforce

Purpose: To better understand the current state of the nurse supply and workforce planning system.

- To describe the evolution of the current nurse shortage from a position of equilibrium in 2010/11 with 3-month nurse vacancy rates in the Hospital and Community Health Service (HCHS) sector of 0.6% in 2010/11 to 12% in early 2020.
- To show that because the current nursing shortage is so visible and high cost, it should serve as an opportunity for wider system learning. Key lessons are:
 - Workforce planning has not been a priority area for the Department of Health and Social Care (DHSC), as evidenced by lack of consistent and robust workforce data, especially on vacancies*.
 - Different agents in the workforce planning system have different motivations and different perspectives, some regarding training as an overhead cost to be minimised and providers more focused on short-term efficiency targets than future workforce need.
 - A workforce planning system that is in a state of flux is less likely to diagnose the need for adjustments early enough and will lack the credibility to persuade decision takers to reallocate resources.

3.2 Review of nurse workforce supply models

Purpose: To understand the current status of nurse supply modelling in the UK and the approaches applied overseas to inform the development of the nurse supply model. What can we learn from them and other modelling work from the UK and overseas?

- Review of 40 workforce projection models from the UK and overseas. This included models used by Health Education England, the DHSC, NHS Wales and the Scottish Government.
- Determining how workforce models are applied to strategic planning.
- Identification of common approaches to workforce projection modelling and the pros and cons of available tools and methodology.
- Identification of common issues or constraints.
- Review of data typically required for a model projecting nurse supply.

3.3 Data landscape review

Purpose: To provide an initial overview of the available data describing the English nursing system. This ranges from nurse specific data sets such as the Electronic Staff Record (ESR) to national data sets covering regional indicators, regular surveys by the Royal College of Nursing (RCN) and any ad hoc research undertaken previously (eg satisfaction surveys, capability assessments etc).

* Agenda For Change Pay Review Body 2017 para 4.40 and Appendix G

- Review of public domain published resources.
- Engagement with stakeholders from the nurse supply system to identify data custodians and existing data sources. This included the RCN, the Nursing and Midwifery Council, NHS Digital, Skills for Care, University and Colleges Admissions Service, Higher Education Statistics Agency and Health Education England.
- List of data required for the nurse supply model.

3.4 Economics review

Purpose: To consider the economics theories that exist to explain labour and behavioural dynamics, for example the variations in bank and agency fill rates, and to consider how these hypotheses can be empirically tested.

- Conceptualisation of the nurse supply system as the nurse labour market plus three inflow/outflow 'feeder markets': nurse education, return to practice and the international nurse labour market.
- Economic theory was combined with review of the academic literature to identify the factors that determined participation of qualified nurses in the nurse labour market, including inflows from the nurse education market and the net inflows/outflows from return to practice and international nurse labour market.
- Although nurse pay (and job security) has a role in attracting students to the profession, the literature is consistent in finding a low pay elasticity of supply in the short run for qualified nurses. This is because nurses must continue to work as nurses to maintain their licence to practice. If a nurse has stopped working as a nurse for three years, they must complete a Return to Practice Course and re-register.*
- The literature also finds that non-pecuniary factors, in particular high workload and associated stress and 'being unable to deliver appropriate quality of care' are much bigger drivers of nurse dissatisfaction and of decisions to quit than dissatisfaction with pay.
- Unfortunately, there are few estimates of the relative elasticity of nurse labour supply to these non-pecuniary factors.

3.5 System mapping

Purpose: To use diagrammatic modelling approaches to capture the various training and career pathways associated with nurse supply in England and to better understand nurse participation decisions.

- Initial stock and flow (SFD) diagrams and causal loop diagrams (CLD) were created based on stakeholder interviews and the available literature.

* It will be interesting to see, in light of the COVID-19 response and temporary re-registration of nurses how much of a barrier to re-entry is the requirement for training.

- A workshop was held with stakeholders from across the nurse supply system attended by the groups identified in Figure 2-3 Stakeholder involvement. The workshop used group model building (GMB) structured around two sessions:
 - Nurse employment system – training and career pathways mapping
 - Nurse economics system – policy and behavioural mapping.
- During the workshop a series of diagrams was created that captured the core cause and effect relationships that drive system behaviour. Data that could be used to quantify the parameters and relationships were identified.
- Over 110 separate factors were identified as influential within the nurse supply system, and their degree of influence assessed.

3.6 Specification development and sign-off

Purpose: To develop a robust model specification based on a thorough understanding of the model requirements and the nursing supply system.

- The invitation to tender (ITT) was used to define the initial set of model requirements.
- The outputs from the nurse supply model review, data landscape review, economics review, data review and system mapping were used to refine the initial requirements.
- Each requirement was reviewed with the REAL Centre and categorised as ‘must do’, ‘should do’, ‘could do’ and ‘don’t do’.
- The specified requirements were used to create the model specification that includes a description of the projection engine, data visualisation tool and overarching development approach that are to be used.
- The specification was signed off by the REAL Centre in March 2020.
- Section 4 provides a summary of the key aspects of the nurse supply model described in the model specification.

3.7 High level model development

Purpose: The high level model was developed to demonstrate the suitability of the system dynamics (SD) approach for modelling the nurse workforce supply.

- Development of an SD model in Vensim (a commercial system dynamics tool) directly derived from a model developed by the REAL Centre.
- Demonstration of benefits of the SD approach.
- Description of model development approach and next steps.

3.8 Data acquisition

Purpose: To engage with a range of different organisations to identify and acquire relevant data required for the nurse supply model.

- Interviews with stakeholders to establish data available and the data acquisition process.

- Development of organisation-specific data requests.
- Agreement of commercial and data sharing arrangements.
- Review and analysis of obtained data.

3.9 Conceptual model development

Purpose: The conceptual model¹⁰ integrates the economics and stock and flow perspectives on the nurse supply system in order to provide a more comprehensive diagrammatic representation of the system.

- Review of system mapping workshop outputs, stakeholder interviews and literature to identify the most important factors that affect the flows in the system.
- Mapping the relationship between the factors and system stock and flows within a single coherent diagram which has been reviewed by the broader stakeholder community.
- Review of the economic and broader literature to create a set of structural equations that describe the potential relationships and how they could be quantified. This includes an approach to calculating the cost of under and over supply.
- The completed diagram was reviewed by a variety of stakeholders from around the nurse supply system.

3.10 Iterative quantitative model development

Purpose: Iterative development of the nurse supply model projection engine and data visualisation tool.

- The nurse supply model is currently being constructed based on the agile development process and best practices in model development. This covers the creation of the two components of the quantitative model, namely:
 - Development of the user-friendly simulation engine that will project the supply of nurses based on the available data and policy decisions. This is being developed using Vensim, a commercial system dynamics tool.
 - Development of a tool that can be easily shared with stakeholders and enables results from the simulation engine to be imported and compared. This is being developed using R/Shiny, an open source statistical programming language.
- Both activities follow our best practices in model development, for example full model documentation, internal data checking, formal model testing.
- Regular design sessions have been held with the REAL Centre, including review sessions with the wider stakeholder community.

3.11 Policy analysis framework development

Purpose: To develop a framework that provides guidance on how the nurse supply model can be used to support policy and strategy analysis through applying a replicable process.

- Requirement of the framework established with the REAL Centre to cover:
 - using the conceptual model to explore policy
 - using the simulation engine to create quantitative supply projections
 - using the data visualisation tool to share projection assumptions and results.
- The structure of the framework was agreed with the REAL Centre and summarised in a process flow chart which described the various processes associated with scoping the analysis, creating a baseline projection, policy exploration and quantification, and finally analysis reporting.
- The framework will be refined and tested during the subsequent development of the nurse supply model.

3.12 Evaluation of the impact of COVID-19 on nurse supply

Purpose: To understand the impact and implications of COVID-19 on the future supply of nurses and incorporate this insight and foresight into the development of the nurse supply model.

- Identification of COVID-19 induced changes to the nursing workforce through commentary, literature and stakeholder interviews.
- Review of commentary and experiences on the impact of COVID-19 on the nursing workforce through literature and stakeholder interviews.
- Following completion of the review a stakeholder workshop will be held to present and seek wider validation of the insights into the impact of COVID-19.
- These insights will be used to inform subsequent nurse supply model development.

4 Description of the proposed nurse supply model

The specification for the nurse supply model was accepted by the REAL Centre in March 2020. The model specification defines an agreed set of requirements that need to be met and how these requirements will be met. This section presents key elements of the model specification that describe the agreed architecture for the nurse supply model.

4.1 Overview

The purpose of the NSM is to enable supply projections for the nurse workforce to be specified, simulated and compared.

The NSM will:

- Help policy makers and planners make informed decisions and understand the range of uncertainty around outcomes, including costs.
- Enable testing of complex and multiple (phased and/or concurrent) policy options over time and in different economic environments and other factors, for example immigration policy or changing roles.
- Interface with the REAL Centre's demand model and be consistent with other REAL Centre supply models.
- 'Paint a picture' of the nursing workforce now and into the future.

For the purposes of this model nurse supply will be considered using two key measures:

- **Head count (HC)** – the number of nurses in terms of the number of people irrespective of their hours worked.
- **Full-time equivalents (FTE)** – A measure of the workforce size, taking into account the number of hours worked per person.

It is important to note that the model is intended to occupy the 'projection' space rather than 'prediction' space. Although the model will be calculating future supply in terms of head count and full-time equivalents, the relative difference between alternative scenarios is of more importance for policy analysis than absolute values. It is also important to note that as with any projection model uncertainty increases the longer the time horizon.

The quantitative model will be composed of two key components, a projection engine and a data visualisation tool. The purpose of the NSM projection engine is to produce projections of nurse supply for England with a time horizon of up to 20 years. The purpose of the NSM data visualisation tool is to enable the analysis and visualisation of supply projections produced using the NSM projection engine. The overall architecture is illustrated in Figure 4-1 below.

The projection engine will adopt the system dynamics approach. System dynamics enables complex systems to be better understood and their behaviour over time to be projected using computer simulation.

The projection engine will represent training and workforce pathways, with the highly segmented data providing insight into the varied workforce member behavioural characteristics. The projection engine will incorporate actionable and meaningful segmentations, calibrated to provide the representation of historic behaviour.

The projection engine will enable multiple scenarios to be defined and the impacts of future behaviour change calculated. Scenarios will be defined through specifying how 'policy levers' change over time, such as training intakes and the factors that affect nurse participation. For example, a potential policy could be increasing student intake by 50% against current values for 3 years followed by a 25% increase in student intake thereafter combined with reducing student attrition by 1% each year for the next 5 years.

The data visualisation tool will enable libraries of projection scenarios to be analysed, comparatively or using deep dive drill throughs. This will be realised through a variety of different data visualisations, such as time series plots, bar charts and tables. The data visualisation tool will enable data to be exported for use by other applications/models.

As the quantitative NSM is being developed, a conceptual model which takes a broader view of the nursing supply system will be created. This will include variables explored during the development approach but not quantified in the projection engine. The conceptual model will be used as a tool to support scenario development and to set research agendas for quantifying relationships in the simulation engine. The conceptual model will be created using causal loop diagram and stock and flow notation. Both forms of diagramming represent the cause and effect relationships that determine system behaviour. In both diagrams variables are named and linked together using arrows, indicating variables that influence other variables.

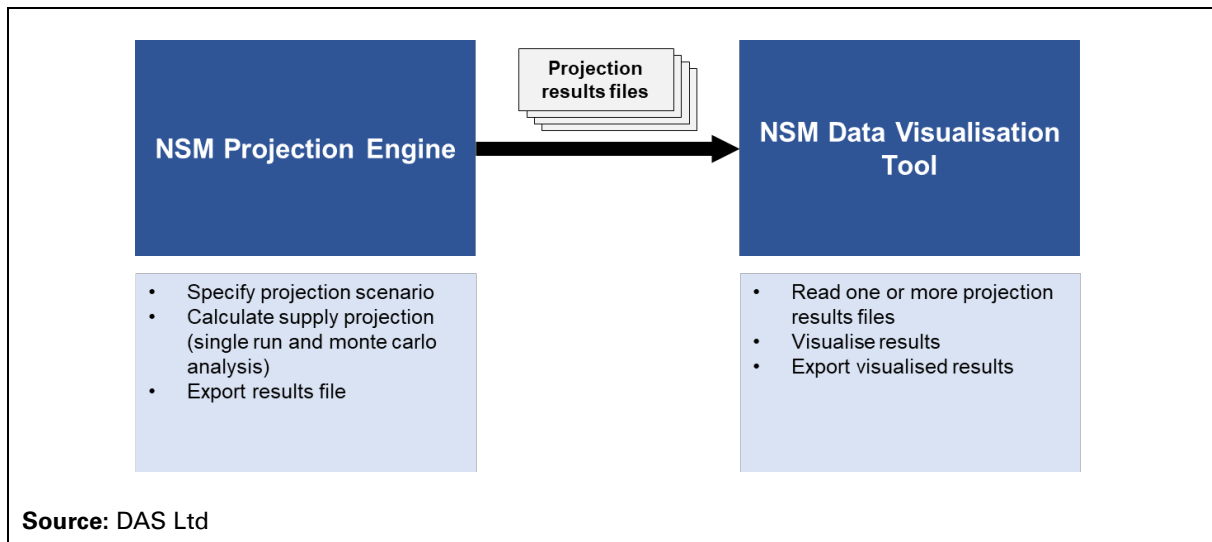
4.2 Model architecture

As previously described the NSM will comprise two components:

- NSM projection engine is to produce projections of nurse supply for England with a time horizon of up to 20 years.
- NSM data visualisation tool is to enable the analysis and visualisation of supply projections produced using the NSM projection engine.

The simulation engine and data visualisation tool will be separate 'applications', with the overall architecture illustrated below:

Figure 4-1: Model architecture



4.3 Development approach

A collaborative approach is being adopted to develop the NSM, being co-designed with the REAL Centre and stakeholders so that the model is fit for purpose, uses the best and most efficient analytical tools based on best available data and ensures handover of capability to model end users.

This is reflected by the approach used to define the model requirements. A subset of the requirements must be met for the model to be viewed as fit for purpose. Others should or could be met depending on the availability of data, valid quantitative approaches and time.

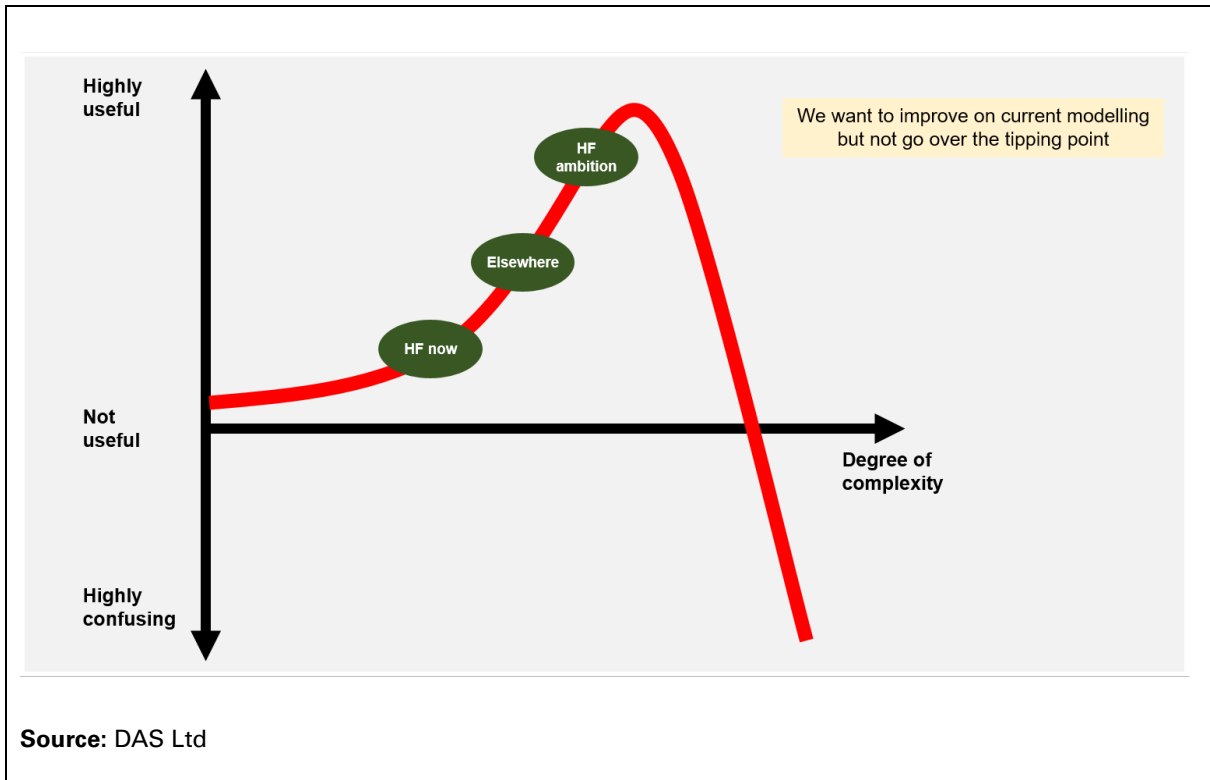
Further, there are some requirements associated with the model development approach itself:

- The model will be developed so that it can be readily used and handed over to REAL Centre economists.
- Where practical R* should be used, and development carried out consistently with REAL Centre's coding guidelines.
- The REAL Centre model custodian will be involved as far as possible during model design and development.
- The model will be developed to be as transparent as possible.
- The model will be supported by a technical description, user guide and training material.

An important skill for the development of the quantitative model is the management of complexity, as illustrated in the diagram below. This also applies to the strength of the assumptions that need to be made to account for increased complexity.

* R is a free software environment for statistical computing and graphics - <https://www.r-project.org/>

Figure 4-2: Managing complexity



Our approach to managing complexity is to incrementally add complexity as development progresses, bounded by regular review of model functionality trade-offs. Potential policy/questions and systemic understanding define the extent of the desired factors and segmentation. Analytics and data availability will determine the extent of feasible factors and segmentation in the quantitative model.

High level stock and flow simulations will initially be created, and simulation complexity increased as better data becomes available and hypotheses are confirmed. This will include developing ever more complex structural pathway models including the development of causal influences on each of the pathway flows representing the transitions in the states of the nursing population (reflecting skills, availability, roles and grades).

Simulation behaviour will be validated through stakeholder engagement, research and data analytics, and the 'best' and most insightful data visualisations explored with the REAL Centre. Stakeholder engagement could include policy dialogue meetings, scenario workshops, simulation behaviour review and focused interviews. Throughout the process the questions to be asked of the model will be reviewed to check that it is meeting the requirements for policy analysis.

As the quantitative model is developed a conceptual model will be developed in parallel which captures the key cause and effect relationships which impact on nurse supply. This will integrate economic and stock and flow representation of the nurse supply system (DAS, 2020). This model will be broader in scope as the quantitative model will only include those relationships that can be robustly quantified. For example, the conceptual model may include lower level drivers which may be represented at a higher level in the quantitative model. The conceptual model will be of use for scenario development.

During the development process the model calibration strategy will be created. This should include fitting the model to historic data and determining the impact of 'soft' variables on the system flows.

The model will be subject to robust technical assurance throughout the development process, including formal validation and verification using best practices in model testing. This includes internal testing (by DAS) and user acceptance testing (by the REAL Centre).

The process for internal testing is:

- Test specification development.
- Completion of the test specification by a DAS consultant independent of model development.
- Identified remedial actions undertaken by the developer and checked by the tester.
- All tests are logged in the test specification, along with corrective action, and provided as part of the model documentation.

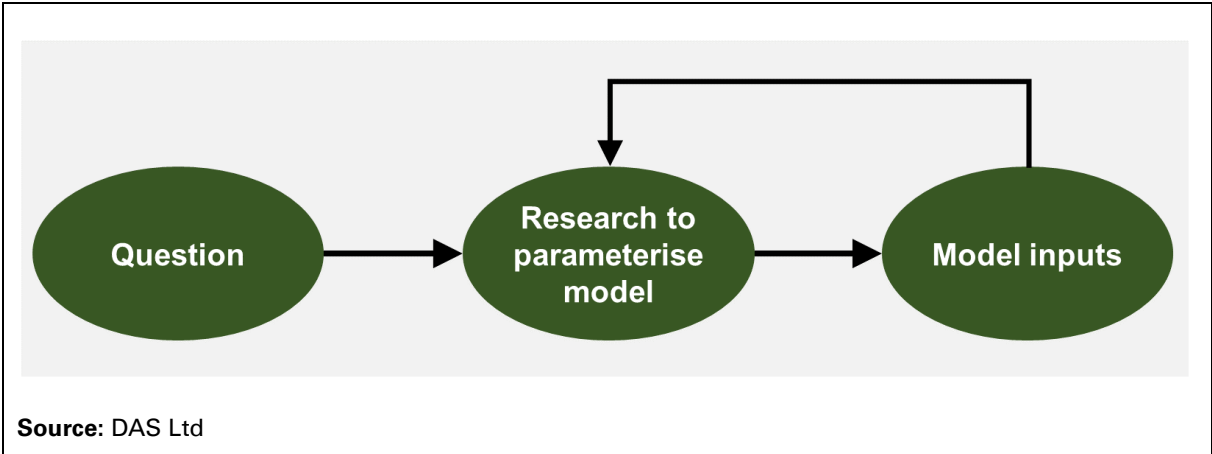
The process for user acceptance testing is:

- DAS provides the REAL Centre with a blank test specification.
- DAS will be informed of non-compliances to both the model and supporting documentation, will discuss whether remedial action is required, and will undertake any remedial action that is required.

4.4 How the nurse supply model will be used to support analysis

In summary terms, the nurse supply model will contain a series of time profiled model inputs that affect future supply, for example inflows, attrition rates, participation rates etc. When a complex or novel nurse supply question arises then research will be carried out by the REAL Centre to determine what values should be used for the model inputs. The research will be informed by the relationships described in the conceptual model. The model will be designed in such a way as to facilitate new research evidence and new initiatives to be factored into key model parameters.

Figure 4-3: Analysis approach









It is not intended for the scenarios to be developed and simulated with the decision maker, so there is not a necessity for rapid projection execution, but we do need to be able to explain the results afterwards and their sensitivity. This will be through insightful visualisations that explain the key dynamics.

The process for defining research questions in order to determine the appropriate parameter values will be included in the model documentation.

5 Next steps

The final version of the nurse supply model is due to be delivered to the REAL Centre in August 2021. The REAL Centre will be responsible for future development of the model.

The key stages of the ongoing development of the NSM are described below:

 <p>Data acquisition and processing</p>	<ul style="list-style-type: none"> • The acquisition of data from the key data custodians will continue. • Received data will be validated and analysed. • Data will be prepared for incorporation in the nurse supply model.
 <p>Publish outputs from research tasks</p>	<ul style="list-style-type: none"> • DAS and the REAL Centre will collaborate to produce summaries of the research undertaken to date for publication.
 <p>Model construction, documentation and testing</p>	<ul style="list-style-type: none"> • Agile development of the projection engine and data visualisation tool will continue. • The nurse supply model will be fully documented and will undergo robust testing. • Development progress will be shared and validated with the wider stakeholder community.
 <p>Policy analysis framework refinement</p>	<ul style="list-style-type: none"> • The policy analysis framework will be refined during model construction to ensure it is consistent with the final model.
 <p>Baseline projection development</p>	<ul style="list-style-type: none"> • A baseline model projection will be developed using the tested model, including the consideration of potential projection variants. • The projection assumptions and the resulting projections will be reviewed by stakeholders.
 <p>Final handover to REAL Centre</p>	<ul style="list-style-type: none"> • DAS will deliver the final model to the REAL Centre for user acceptance testing. • The REAL Centre will be responsible for future development of the model.

6 References

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About the Health Foundation

The Health Foundation is an independent charity committed to bringing about better health and health care for people in the UK.

Our aim is a healthier population, supported by high quality health care that can be equitably accessed. We learn what works to make people's lives healthier and improve the health care system. From giving grants to those working at the front line to carrying out research and policy analysis, we shine a light on how to make successful change happen.

We make links between the knowledge we gain from working with those delivering health and health care and our research and analysis. Our aspiration is to create a virtuous circle, using what we know works on the ground to inform effective policymaking and vice versa.

We believe good health and health care are key to a flourishing society. Through sharing what we learn, collaborating with others and building people's skills and knowledge, we aim to make a difference and contribute to a healthier population.

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