Financial modelling in government

Cross-government

National Audit Office

Key facts

9

years since the 2013
publication of HM Treasury's
*Review of quality assurance
of government models*

962

business-critical
models on departments'
central registers

45

of our sample of 75 business-
critical models have no
information available to
the public about them,
limiting the transparency
of these models

Six   different definitions of business-critical models across
government identified through our survey

Nine   out of 17 departments we surveyed have published registers
of business-critical models, only four of which were updated
since January 2017

Three   bodies have some responsibilities for the quality of
modelling across government, but no one body has
overarching responsibility

Summary

1   Analysis is at the heart of how the government runs its business. Government relies on financial models for its day-to-day activities including: estimating costs; distributing funding within organisations; and testing policy options. In recent years departments have used models to plan NHS test and trace services, set allocations for teacher training places, and estimate the cost of the financial settlement when leaving the EU.

2   Financial models use information or data to provide insight into a question or to better understand a problem. Using models helps government to select policy options, understand the impact of these options and improve the value for money of government spending. For example, UK TIMES, a bottom-up, cost optimisation model of the whole UK energy system, produces an estimate of all greenhouse gases, under different planning assumptions. Government uses this model to provide important evidence supporting its plans to tackle climate change, such as the net zero target decision. Models also underpin decisions which affect people's lives. In December 2020, we reported on the epidemiological modelling by NHS Test and Trace, which it used to help plan staff and testing capacity at a time of inherent uncertainty. We found that underestimating demand in September 2020 led to difficulties in meeting higher than expected demand for tests, increasing turnaround times and limiting tests available to the public.[1]

3   After the collapse of the West Coast Main Line franchise competition in 2012 – where errors in models played a role in the incorrect information given to bidders – HM Treasury (HMT) initiated a review of how the government produces and uses models, known as the Macpherson Review. This review was published in 2013 and made eight recommendations to extend the pockets of good practice it found across the whole of government. Following the review, HMT took action to improve the quality of models, such as setting up a working group to produce guidance. Separately, in 2013, the government introduced cross-government functions to provide professional support to departments. The two functions most related to financial modelling are the Analysis Function and the Finance Function.

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1   Comptroller and Auditor General, *The government's approach to test and trace in England – interim report*, Session 2019–2021, HC 1070, National Audit Office, December 2020.

4   Supported by the board, the accounting officer of each central government organisation is responsible for overseeing the use and quality assurance of models within that organisation. Models will vary in their importance to the organisation, and some will qualify as 'business-critical models'.[2]

Scope and purpose of this report

5   We have examined the roles that HMT, the Office for Budget Responsibility (OBR), the Analysis Function and the Finance Function have in improving modelling across government. We considered how well the principles set out in the Macpherson Review, *Managing Public Money* and other modelling guidance are embedded across government and applied to business-critical financial models. Our audit approach is based on the National Audit Office's (NAO's) *Framework to review models* (**Figure 1**) and the report examines:
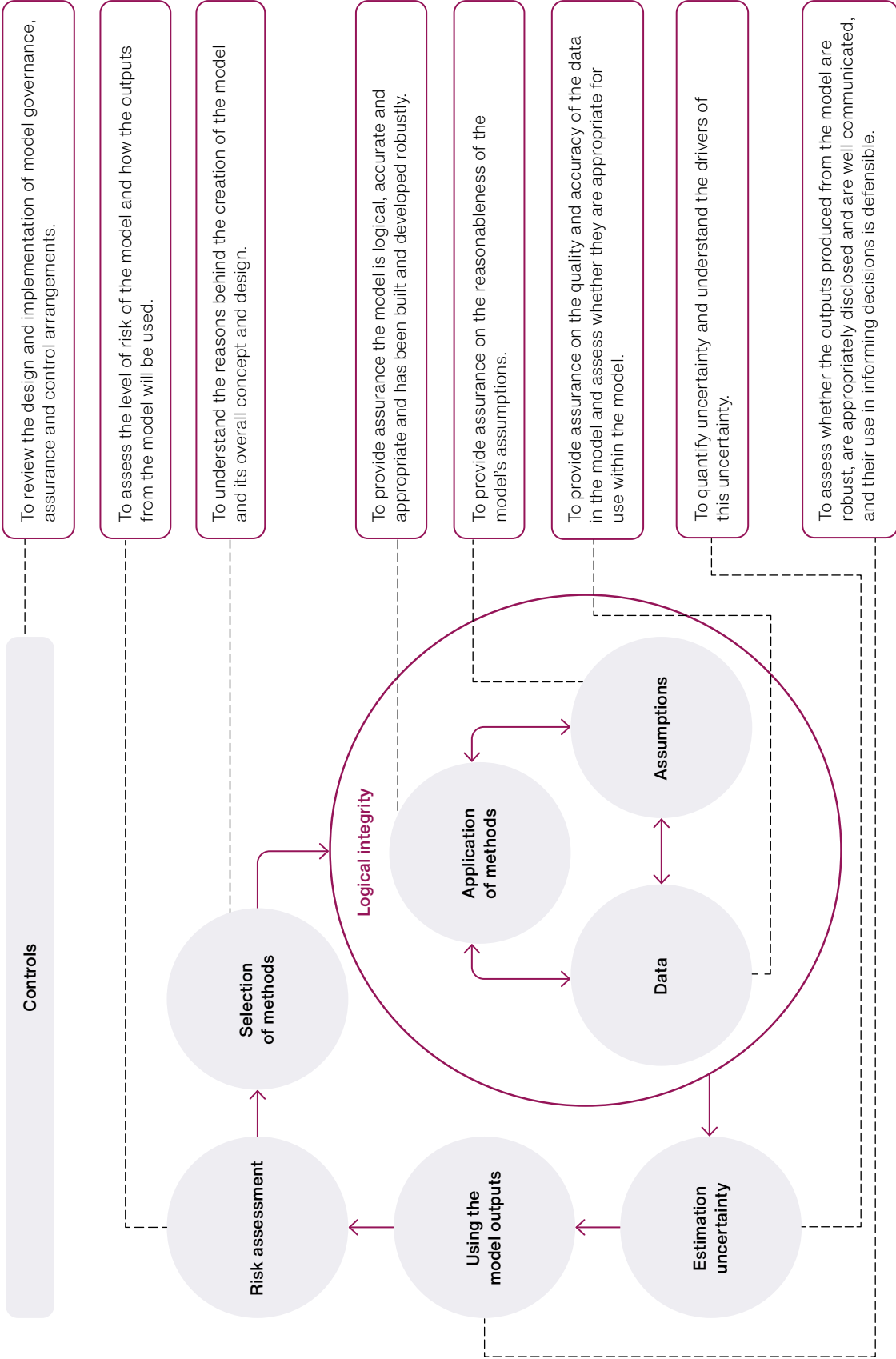
●   how the responsibility for modelling is organised across government (Part One);

●   the quality assurance processes across government and how organisations provide assurance that models are fit for use (Part Two); and

●   how uncertainty is assessed, communicated and taken into account when developing plans (Part Three).

6   This report reviews models used for financial planning, but many of the recommendations will be sensible principles to follow for all models across government. We use the term 'models' and 'modelling' to refer to financially focused business-critical models. This includes models used to inform debate on the costs of potential policies as well as models more directly tied to budget bids and financial reporting. We used 12 case studies across four departments to understand the processes these departments use for managing business-critical models. The report does not conclude on the reasonableness or robustness of any individual model reviewed as part of the study. Our methods and evidence base are described in Appendix Two.

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2   The Macpherson Review criteria for judging if a model is business-critical are based on the extent to which: the model drives essential financial and funding decisions; the model is essential to achievement of business plan actions and priorities; errors could engender serious financial, legal, or reputational damage or penalties.

Figure 1

The National Audit Office's framework to review models

We consider eight areas when reviewing government models

To review the design and implementation of model governance, assurance and control arrangements.

To assess the level of risk of the model and how the outputs from the model will be used.

To understand the reasons behind the creation of the model and its overall concept and design.

To provide assurance the model is logical, accurate and appropriate and has been built and developed robustly.

To provide assurance on the reasonableness of the model's assumptions.

To provide assurance on the quality and accuracy of the data in the model and assess whether they are appropriate for use within the model.

To quantify uncertainty and understand the drivers of this uncertainty.

To assess whether the outputs produced from the model are robust, are appropriately disclosed and are well communicated, and their use in informing decisions is defensible.

Controls

Selection of methods

Logical integrity

Application of methods

Assumptions

Data

Risk assessment

Using the model outputs

Estimation uncertainty

Source: National Audit Office, *Framework to review models*, January 2022

Key findings

Governance of business-critical models

7   It is unclear who is ultimately accountable for upholding modelling standards and for driving improvement across government. The Analysis Function, Finance Function and HMT all have an interest in how the 962 business-critical models across departments are managed and used. We have, however, been unable to identify any single body responsible and accountable for updating and maintaining guidance, monitoring and assuring whether the guidance has been implemented, or driving cross-government improvement by learning from others. We have reported before on the importance of clear aims, expectations, roles and responsibilities, especially where multiple government organisations are involved(paragraphs 1.7 and 1.8, Figure 2 and Figure 4).[3]

8   The centre of government and departments have worked together to improve understanding and oversight of models.[4] Following the Macpherson Review, HMT updated *Managing Public Money* to provide detail on accounting officers' responsibilities for the quality assurance of models and set up the Quality Assurance Working Group to promote good practice across government. The *Aqua Book* is one of the working group's core products. Published in 2015, it introduced guidance across government on how to produce high-quality analysis. The working group assessed actions since the Macpherson Review and found all departments had made progress in implementing governance and assurance processes and improving the robustness and resilience of models (paragraphs 1.4 to 1.6 and Figure 3).

9   The Analysis Function has yet to agree with HMT the funding it considers necessary to support efforts to improve modelling in government. In 2020-21 the Analysis Function received £1.3 million in funding from the Office for National Statistics. For the 2020 Spending Review, the Analysis Function prepared a bid for £4.9 million to cover its planned activities in 2021-22. However, because the scope of the Spending Review changed, HMT did not review the bid and the Function remained funded at the original rate for 2021-22. At the 2021 Spending Review, HMT did not allocate funding specifically for the Function, in part because the Function was in the process of working out its scope and governance arrangements. HMT agreed to consider the 2022-23 funding for the Analysis Function as part of the main estimate funding round in February 2022. This will determine the level of funding available to the Function and be a crucial step in enabling the Function to refine and then deliver its plans, including on modelling in government (paragraphs 1.5 and 1.6).

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3   National Audit Office, *Improving operational delivery in government: A good practice guide for senior leaders,* March 2021.

4   We use the term centre of government to refer to the Cabinet Office, HM Treasury and the senior leadership of the Analysis Function and the Finance Function.

10   **Departments take different approaches to managing their business-critical models.** A department's accounting officer is ultimately responsible for the use and quality assurance of models in his or her department. This responsibility is usually delegated to the department's director of analysis. Government guidance sets out high-level principles and it is left to departments and arm's-length bodies (ALBs) to interpret and apply this. This means that departments have developed at least six different definitions of business-critical models, customised their own guidance, and taken variable approaches to monitoring and improving the quality of models (paragraphs 1.12 to 1.16 and Figure 5).

11   **Departments take different approaches to overseeing and supporting ALBs.** We reported in 2021 that the risks in relation to ALBs are not well understood, and that there is no collective understanding of the oversight appropriate for different types of ALBs.[5] ALBs produce, quality assure, and provide outputs from their models for their department. There is no guidance for departments on the level of scrutiny on modelling they should apply to their ALBs. Our survey highlighted that the oversight of ALBs' models continues to be variable across government, with nine out of 15 departments sharing their resourcing and training with their ALBs and 14 departments giving responsibility for the quality of models to their ALBs. (Paragraphs 1.17 to 1.19 and Figure 7).

12   **It is difficult for Parliament and the public to access information about business-critical models.** Transparency supports scrutiny and quality assurance and *Managing Public Money* states that "transparency should be the norm in the development and use of all models". In practice, we found this is not usually the case. For a sample of 75 models, we found no information available for 45 of these models. For the remaining 30, we found a range of information, from basic details on the model through to extensive details of the model published. Only nine departments out of 17 have published their register of business-critical models since the Macpherson Review published the full list in 2013. Only four of these registers have been updated since January 2017 (paragraphs 1.20 to 1.22, Figure 8 and Figure 9).

5   Comptroller and Auditor General, *Central oversight of arm's-length bodies*, Session 2021-22, HC 297, National Audit Office, June 2021.

Assurance of data, assumptions, methods and calculations

13   Departments do not consistently use quality assurers who are independent of the modelling team, which leads to a risk of self-review. The *Aqua Book* and the Analysis Functional Standard both expect that models are independently reviewed. In our case studies, we saw examples of models being reviewed by a second analyst before use. However, the assuring analyst was usually located in the same team as the primary analyst, and the separation between duties was not always clear. In our audit work across government, we regularly find errors in departments' models. For example, our audit of a department's 2020-21 accounts identified errors of £800 million and £45 million in the calculations of two financial models. The department corrected these errors as part of the financial audit process and so they did not affect the published annual report and accounts. Before our audit, the models had not been independently verified, which could have identified the errors. Our case study departments told us that there are barriers to independent review, and they are taking various actions to address these (paragraphs 2.5 to 2.7).

14   Assurance of input data and assumptions is variable. We saw examples of good practice in departments: in some cases they tested their updated assumptions with stakeholders and in others they routinely compared forecast results to actual events. On the other hand, for some models, we found backlogs in the routine work of updating assumptions, and gaps in documentation and supporting evidence. This makes it more difficult to keep track of, assure and validate assumptions. Poor-quality inputs can have serious impacts: our 2021 report *Optimising the defence estate* found forecasts were initially based on assumptions which proved unachievable. This contributed to the potential net benefits being overstated. Expected savings have fallen by 73% since 2016. We reported it was uncertain whether the expected benefits would have still exceeded the costs if the department had considered all relevant costs and appropriate risk contingency.[6] Controls for the quality management and input of data also vary within and between departments. Our report *Challenges in using data across government* found that a lack of common data models and standards makes it difficult and costly to combine data, and data quality is often inadequate. In December 2020, government produced a framework to improve the quality of its data (paragraphs 2.8 to 2.13, Figure 10 and Figure 11).

6   Comptroller and Auditor General, *Optimising the defence estate*, Session 2021-22, HC 293, National Audit Office, June 2021.

15   There is room for improvement in model documentation. Effective quality assurance of business-critical models requires clear and proportionate documentation. In our 12 case studies, we found examples of good quality documentation but also some notable gaps: some models lacked technical guides, analytical assurance plans, assurance records or written succession plans. Gaps in model documentation make complex models difficult to interpret, revisit or review. As a result, senior responsible owners may lack the necessary information to make informed decisions on the risks of using their model's results (paragraphs 2.14 to 2.17).

Managing uncertainty

16   Model producers do not adequately assess or communicate the uncertainty in their models. Models cannot exactly represent what we observe or predict the future with perfect accuracy. Uncertainty is inherent in modelled information and should be considered as part of all analysis. This is emphasised by HM Government's *Orange Book*, which describes how analysis of risks provides the foundation to identify and manage risks and uncertainties. In our case studies we found limited evidence of detailed analysis of uncertainty and departments generally present outputs as best estimates. Where analysts do perform uncertainty analysis, this is often basic, for example, sensitivity testing of the main assumptions. We saw pockets of good practice in communicating uncertainty, such as including a confidence interval around a best estimate, but also found examples where uncertainty was often described only in qualitative terms or where it was not routinely presented to users (paragraphs 3.2 to 3.9 and Figure 12 and Figure 13).

17   Senior decision-makers need to use uncertainty analysis to manage risks to value for money. Models are used widely across government to support financial planning, risk management and decision-making for major projects and programmes. Decision-makers need information on the range of outcomes that may occur and their relative likelihoods to manage risks to value for money. In our case studies, we found departments often use best estimates as a basis for their financial and business plans. We found limited evidence of departments using uncertainty analysis or developing contingency plans to respond effectively to unintended but plausible events. Our report *Lessons learned from Major Programmes* found that many programmes we reviewed have not sufficiently recognised the inherent uncertainties and risks in early estimates.[7] For example, our report on *Completing Crossrail* found the decision-making in the latter stages of the project was dominated by achieving a fixed completion date.[8] Some of the decisions taken drove unnecessary cost into the programme. Furthermore, we found in our report *Learning for government from EU Exit preparations* that the civil service can improve how it deals with uncertainty.[9] This was also demonstrated in our report *Initial learning from the government's response to the COVID-19 pandemic*, which found that government lacked a script for many aspects of its response. This reduced the government's ability to respond to the emergency (paragraphs 3.1 to 3.3, 3.7 to 3.11).

18   There are opportunities for HMT and the OBR to improve their use of business-critical model outputs from departments and ALBs. Departments and ALBs present outputs from their models to HMT and the OBR as part of the spending review and budget process. HMT and the OBR use these outputs for forecasting, budget planning and to monitor emerging risks. Departments typically provide a best estimate and do not routinely provide a range of uncertainty around this best estimate in their initial submissions to HMT and OBR. HMT spending teams and the OBR told us they request further analysis from departments on uncertainty on a case-by-case basis. HMT and OBR would have greater insight from departments by routinely requesting the range of plausible outcomes. (Paragraphs 3.12 to 3.16).

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7   Comptroller and Auditor General, *Lessons learned from Major Programmes*, Session 2019–2021, HC 960, National Audit Office, November 2020.

8   Comptroller and Auditor General, *Completing Crossrail*, Session 2017–2019, HC 2106, National Audit Office, May 2019.

9   Comptroller and Auditor General, *Learning for government from EU Exit preparations*, Session 2019–2021, HC 578, National Audit Office, September 2020.

Conclusion

19   Financial modelling is at the heart of how the government understands its spending, performance and risks and makes business-critical decisions. Outputs from models underpin decisions made by departments and ALBs that often have very real impacts on people's lives. Errors in government models have directly caused significant losses of public money and delays to critical public programmes. Since the completion of the Macpherson Review of the quality assurance of models, the government has made progress through publishing cross-government guidance. Separately, the government introduced the Analysis Function and the Finance Function. Departments and ALBs have implemented new governance and assurance procedures.

20   Although progress has been made, there remain significant weaknesses in how government produces and uses models. There is scope for better leadership from the centre of government to drive further progress, uphold standards and support greater transparency around models that departments use to make decisions. Although we saw examples of good practice, the level of quality assurance that departments apply to business-critical models remains variable. The analysis of uncertainty is often a peripheral activity despite it being extensively recommended in government guidance and despite the risks to long-term value for money of not doing so. Taken as a whole, the government is overly reliant on best estimates from models which do not fully reflect the inherent uncertainty and risks. Without further progress, government plans will continue to be developed with weaknesses that place value for money at risk.

Recommendations

21 Accounting officers, supported by directors of analysis, are ultimately responsible for the quality of models in their organisations. Our recommendations are directed both to accounting officers and HMT, the OBR and the Functions. They are aimed at improving the clarity of requirements and the provision of oversight and incentives to support accounting officers in their role.

22 Accounting officers should:

a **Oversee the use of models within their organisation and ensure an appropriate quality assurance framework is in place and used for all business-critical models.**

23 HMT should:

b **re-emphasise accounting officer responsibilities for business-critical models as set out in *Managing Public Money*, and the importance of publishing lists of such models on gov.uk** by specifying this requirement in the guidance HMT issues on annual reports and accounts;

c **put in place processes to assure itself that outputs from departments' and ALBs' business-critical models, which HMT uses, have been quality-assured in line with modelling standards.** This should include clarifying in all relevant guidance that all models must comply with the *Aqua Book*;

d **build on its current approach to quantifying uncertainty and risk analysis by requiring departments to present HMT with a range of plausible outcomes from business-critical models as a matter of routine.** This range should be driven by key inputs and model parameters in each case to take account of where there might be material uncertainties around best estimates; and

e **agree with the Analysis Function on responsibilities for ownership and maintenance of the *Aqua Book*,** including appropriate sign-off arrangements between the Function and HMT for *Aqua Book* updates.

24 The Analysis Function should:

f **set out the appropriate governance structure for the ownership, maintenance, monitoring and assurance of analytical modelling standards and guidance, as presented in the Analysis Functional Standard.** As part of this, the Function should work with the Cabinet Office to develop an appropriate assessment framework to provide the necessary processes to monitor departments' and accounting officers' implementation of the Analysis Functional Standard;

g update its Functional Standard and relevant guidance to include clear principles for departments and ALBs to follow on independent review of business-critical models, and on publication of a model's inputs, methodology, assumptions, and outputs; and

h work with departments, ALBs and other stakeholders such as the Quality Assurance Working Group on guidance and training to facilitate system-wide learning and improvement. This should include sharing good practice on how business-critical models are managed and practical advice on how to analyse and communicate uncertainty.

25 HMT and the Analysis Function should:

i agree the funding and capacity implications of the proposed governance structure in relation to analytical modelling standards and guidance.

26 The Cabinet Office is working on common standards for departmental sponsorship of ALBs. As part of this work, it should:

j include guidance for departments on overseeing the production and assurance of models in ALBs, based on expert input from the Analysis Function.

27 The Finance Function should work with the Analysis Function to:

k strengthen the requirements in the Finance Functional Standard on departments to apply the Analysis Functional Standard and the *Aqua Book* to financial planning and reporting. This should include guidance on how accountants should analyse, manage and communicate uncertainty; and

l include appropriate elements relating to analysis and modelling from the Finance Functional Standard in the Finance Function's self-assessment tools to measure compliance of functional members with requirements on modelling.

28 The OBR should:

m require departments, as a matter of routine, to analyse and present the range of plausible outcomes driven by key inputs and model parameters in each case to take account of where there might be material uncertainties around best estimates.