Scottish COVID-19 Response Consortium Stakeholder Report

Authors: Yasmin Abdalla, Harriet Auty, Lisa Boden, Alys Brett, Min Chen, Ruth Dundas, Glenn Marion, Louise Matthews, Iain McKendrick, Dominic Mellor, Richard Reeve

Acknowledgements: The Scottish COVID-19 Response Consortium would like to thank RESAS for funding the time of employees from EPIC who contributed to this work.

Email: scrc@glasgow.ac.uk
Github: https://github.com/ScottishCovidResponse
Web: https://www.gla.ac.uk/scrc

Contents

Executive Summary

The Scottish COVID-19 Response Consortium has successfully developed a suite of epidemiological models and a sustainable framework for mobilising relevant modelling expertise to transform approaches to rapid real-time decision-making in disease outbreaks. The work undertaken by SCRC highlights the critical importance of an interdisciplinary Open Science, One Health approach to pandemic preparedness and response.

The Scottish COVID-19 Response Consortium (SCRC), formed in response to the COVID-19 pandemic in March 2020, is an interdisciplinary consortium comprising over 150 UK scientists from public and private sectors, including experts in animal and human epidemiology, social science, policy analysis, research software engineering, data visualisation and risk communication.

SCRC drew on this array of expertise to develop a virtual network with collaboration, open science and One Health at its core. In the last 6 months, the team has produced the following key outputs:

1. Six large scale COVID-19 disease models (adapted from pre-existing animal disease models) which can be used to evaluate future disease transmission and control strategies to support policy decision-making for COVID-19.
2. An automated data pipeline to ensure traceability, transparency and quality standards of data inputs and model outputs.
3. A model evaluation tool (a model "Open Epidemiology scorecard") to assess whether model outputs are fit-for-purpose (appropriate, relevant, ethical, robust) for decision-makers.
4. A visualisation platform that integrates visualisation at every stage of model development and output.

Taken together these provide the basis for definition of much-needed Open Epidemiology standards. Built on foundational principles of transparency, interdisciplinary and open science, and One Health we believe these standards represents a step change for policy relevant modelling of both human and animal diseases. SCRC has shown how Open Epidemiology approaches enable effective response by providing decision makers the tools they need to transform model outputs into policy, transparently and in the most efficient and accurate ways possible. They also provide tools to ensure that lessons learned will improve preparedness for future epidemics and pandemics.

The importance of SCRC's work in both the COVID-19 pandemic and in future-proofing pandemic preparedness, means that it is vital that this work continues to be funded. Grant applications to support continuing work have been submitted and are pending approval.

SCRC strategic aims

The Scottish COVID-19 Response Consortium (SCRC) formed in response to the Royal Society's Rapid Assistance in Modelling the Pandemic (RAMP) call to provide support to the core UK COVID-19 modelling team and develop a sustainable source of disease modelling capability in the event of demand by the UK or Scottish governments.

SCRC was established by scientists from three Scottish organisations: The Boyd Orr Centre for Population and Ecosystem Health at University of Glasgow, the Scottish Government's Centre of Expertise on Animal Disease Outbreaks (EPIC) and Biomathematics and Statistics Scotland (BioSS). Further volunteers were recruited from a variety of public and private institutions across the UK (https://gla.ac.uk/research/az/scrc/ourpeople), including experts in epidemiology, research software engineering, statistical analysis, visualisation, mathematics, and data processing and curation.

SCRC developed a series of aims that in line with the RAMP call to "enhance modelling capacity in time to create a clearer understanding of different exit strategies from the current lockdown", as well as to develop modelling and analysis to understand the evolving COVID-19 epidemic in the UK to inform emerging policy challenges.

The aims of the SCRC are to:

1. Produce a suite of robust COVID-19 models to respond to UK and Scottish Government needs;
2. Identify criteria to assess policy focussed epidemiological model-based analysis and create processes to both assess and improve models against such standards; and
3. Build SCRC work into a framework that allows future pandemic preparedness including by informing development of emerging Open Epidemiology standards.

SCRC strategy

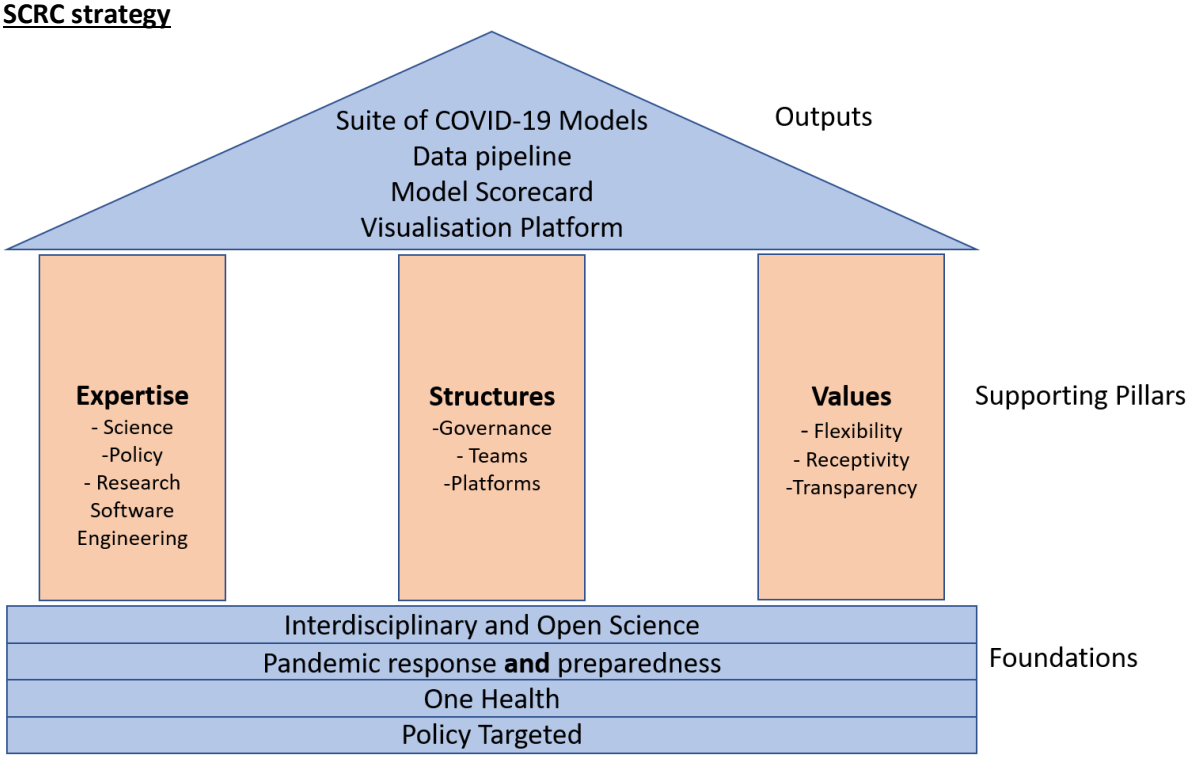

Fig. 1: Building on a foundation of principles of excellence to create a supporting structure for SCRC outputs

Governance

To deliver on SCRC's strategic aims, a consortium governance structure was created that maximised opportunities for collaboration, creativity, responsiveness, and delivery of useful outputs. This structure is summarised in the image below:

SCRC governance and communications structure

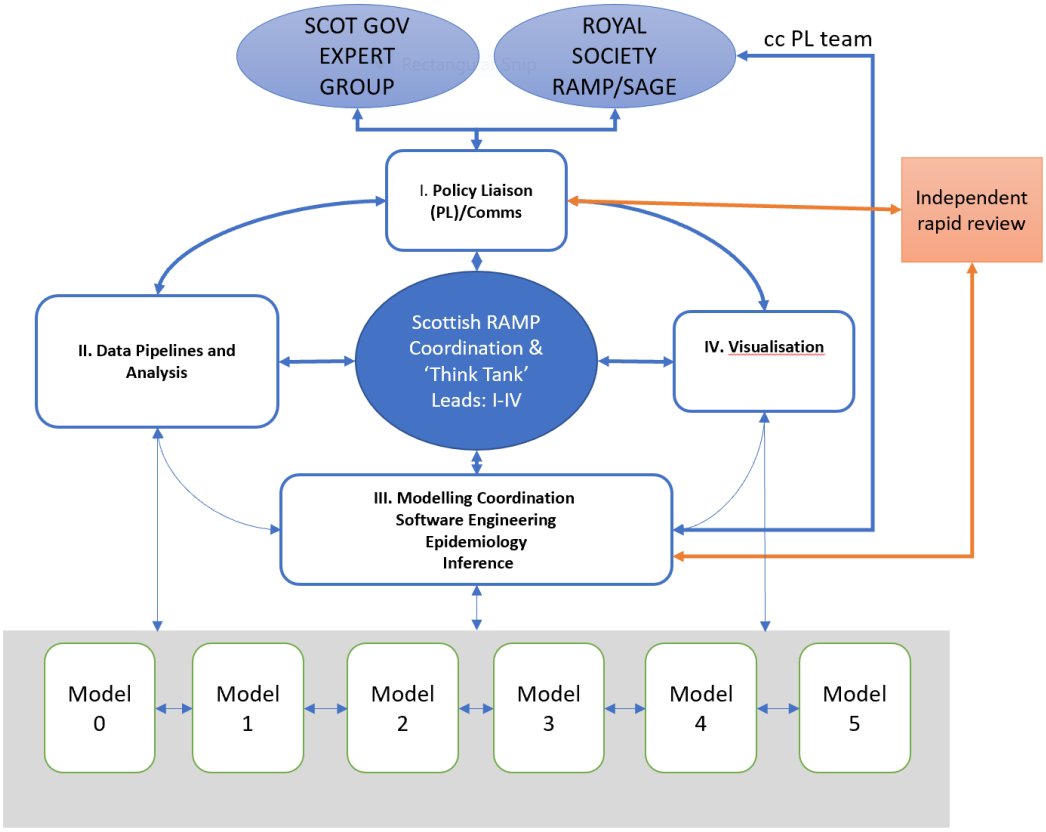

Fig. 2: Different governance, expertise and model teams in SCRC, and how these teams interact with one another.

Each of the Teams I-IV in the above diagram had specific roles and responsibilities summarised below:

I. **Policy**: To ensure timely and appropriate communication and translation of any policy requests and responses between model developers and end-users.
II. **Data Pipelines and Analysis**: developing the data pipeline, and sourcing and facilitating access to various health, demographic and human behavioural data available in public datasets, eg ONS, NRS, PHS, eDRIS, COVID-19 literature, and various data institutions (including the Centre for Urban Analytics, National Audit Office, Society of Actuaries). Developing protocols for extracting relevant quantitative information from the published and grey literature, and quality assessment of datasets, defining sets of relevant metadata for incorporation and use in the data pipeline.

III. **Model coordination**: Streamlined communications between the various teams supporting output development:
    a. **Research Software Engineering:** Working with COVID-19 model code owners to establish collaborative development processes and to improve the quality, efficiency and functionality of the software. Developing and implementing a software checklist that could be applied to any epidemiological model (within or outwith SCRC) to assess and communicate the level of confidence in the correctness and transparency of the software and the reproducibility of the results.
    b. **Epidemiology**: To provide consistent, up-to-date evidence on the epidemiology of COVID-19 to adapt the different models from animal to human epidemiology.
    c. **Inference**: Honest parameter estimates including assessment of uncertainty are essential if models are to reliably inform policy. Therefore, a range of tools were developed to infer key parameters from the observed epidemic. However, given current data, inference is not possible for all model parameters with some informed only by epidemiological knowledge and expert judgement.
    d. **Model validation**: Assess ability of models to match historical trends and (future) outcomes based on real and simulated data. Furthermore, robustness to variation in model structure and uncertainty in parameterisation.
    e. **Policy readiness**: Assess suitability of model to inform policy questions and likely ethical implications. Guide end-user interpretation and assess suitability of presentation/visualisation in terms of supporting good decision making.
IV. **Visualisation:** To provide general and model specific visualisation approaches not only to model outputs at the end of the modelling development process, but also to every stage of model development to improve risk communication and decision-making.

Outputs

Suite of COVID-19 Models

The six COVID 19 models developed by SCRC and their relevance to specific policy needs is summarised in the table below:

University of Glasgow | Boyd Orr Centre for Population and Ecosystem Health

Different SCRC Covid 19 models and their policy relevance

Models	Model description	Covid-19 response policy strategies								
		Schools reopening	Age Segmentation	Sector Segmentation	Geographic segmenting	Mass Testing	Contact - tracing strategy	Masks	Shielding	Other
Simple Network simulation	Network-based simulation model at population level.									
Contact Tracing model	Individual-based stochastic network model									
Spatial Simulation	Explicitly spatial compartmental model									
Individual based simulation	Individual level simulation model. Appropriate for smaller scale populations									
ABC-smc	Age structured stochastic epidemiological model.									Vaccination strategies
BEEPmbp	Individual stochastic model at regional and fine scales.									

Fig. 3: Models and their preparedness for various policy questions. **Dark blue**: Model relevant to these strategies. **Light Blue**: model easily adapted to be relevant to these strategies. **Orange**: Model could be adapted, but more complicated.

Data Pipeline

The SCRC data pipeline is an automated system for storing and using data in an entirely traceable, transparent and quality aware way. It consists of a data repository and data registry which store and organise data products and the metadata about them, respectively; a standard interface for pulling data from these repositories into models; and a mechanism for uploading model outputs back into the repositories.

As part of registering a new data product with the pipeline, it is given a quality rating based on from where it is sourced, which follows that data product as it moves through the pipeline and is associated with any model outputs to which that data product contributes. This can also be done retrospectively if issues are raised with data sources after they have been used in models, and the models outputs will be automatically tagged appropriately.

The data pipeline is a step change in the management of data in modelling. It fully automates these processes, so that, without creating massive inefficiencies, it is possible to trace any and all data products or other model results that went into a specific model output. This has huge ramifications for model accuracy as any model is only as good as the data it incorporates.

An initial implementation of the data pipeline software has been developed, and the pipeline has been integrated with all six of the new SCRC models as well as the existing Imperial and LSHTM models. Templates have been created to upload data products into the repository and, so far, over 40,000 papers (from the LitCovid database, bioRxiv and medRxiv) and 93 data products have been added to the repository.

As well as completing development of tools to allow data to be uploaded to the registry and models to pull data from the registry, SCRC has also completed specifications of how to assess data quality, representativeness and fitness for purpose.

Open Epidemiology Scorecard

SCRC has developed a prototype scorecard to assess models against five Open Epidemiology standards: (S1) policy readiness: fitness for purpose for intended application and warnings against potential misuse; (S2) data and model traceability: including appropriate use of the data pipeline; (S3) data and science quality: including model formulation, limitations, and data suitability; (S4) open and reproducible software:- correctness, quality and transparency of software implementation; and (S5) inference and model validation: including uncertainty quantification, parameter estimation, predictive accuracy tested against other models and observational data. Within each of these standards the scorecard provides a checklist against which models can be scored.

Iterative assessment against these standards enables model improvement. The six SCRC models have been assessed against S2 and S4 and are either classed as ready or with well-defined work remaining. Assessment and refinement against the three other Open Epidemiology standards is ongoing.

Visualisation Platform

Typically, visualisation has been used at the end of the modelling process to present modelling outputs. However, visualisation can also be extremely helpful in model development and data analysis, by allowing model developers and analysts to spot patterns in their work more quickly and efficiently.

The Visualisation team in SCRC has developed an online visualisation platform that integrates with every stage of model development. The platform has tools to allow visualisation of data products, model outputs, uncertainty quantification within data and model outputs, impacts of interventions and any public facing outputs.

Integration of data visualisation processes in every step of the process continues the commitment to transparency and traceability seen in the data pipeline, as well as improving efficiency.

Visualisation dashboards have been developed that are specific to each model. This allows model developers to visualise trends and changes in data that are specific to their models. Visualisations have also been created for model outputs so far to test different methods of presenting data output.

Lessons Learned

Beyond the specific outputs listed above, in many ways SCRC's greatest output is the model by which it has operated. Drawing on the risk management and science-policy focus of EPIC, and the exceptional technical capabilities of the Boyd Orr Centre, BioSS and UKAEA, SCRC has demonstrated a framework that ties together all the aspects needed to create meaningful pandemic preparedness.

SCRC has been able to bring together a large group of individuals from a variety of backgrounds and rapidly align them to a set of common, tangible goals. This group was then able not only to tackle the immediate COVID 19 work that was part of the initial RAMP call, but also to look forward to what lessons from this pandemic can be applied to future public health challenges.

This was possible because of a commitment to openness and transparency in science, that gave all relevant expertise a seat at the table. This collaborative approach has enabled an effective response to the current pandemic and a model for future pandemic preparedness and emergency response.

Next Steps

SCRC has achieved the fundamental aims as set out in the RAMP call. However, further work is necessary to refine model functionality and develop the data pipeline, visualisation platforms and Open Epidemiology Standards and scorecard system. As the next step in achieving these goals, SCRC has submitted the following three UKRI Grant applications to further develop the data pipeline, the visualisation platform and the Open Epidemiology framework as a whole, respectively:

1. Open Epidemiology for pandemic modelling: a transparent, traceable, reusable, open source data pipeline for reproducible science;
2. RAMP VIS: Making Visual Analytics an Integral Part of the Technological Infrastructure for Combating COVID-19; and
3. Open Epidemiology: implementing a scorecard system for robust and validated epidemiological modelling for policy support in the COVID-19 pandemic.

All of these applications are under review at the time of publication of this report.