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Modelling COVID-19 response with local planners

Dr Jennifer Badham

COVID-19 Community Health and Social Care Modelling Team

Collaborators:

- Dr Pete Barbrook-Johnson (Oxford)
- Dr Camila Caiado (Durham)
- Prof Brian Castellani (Durham)

Overview

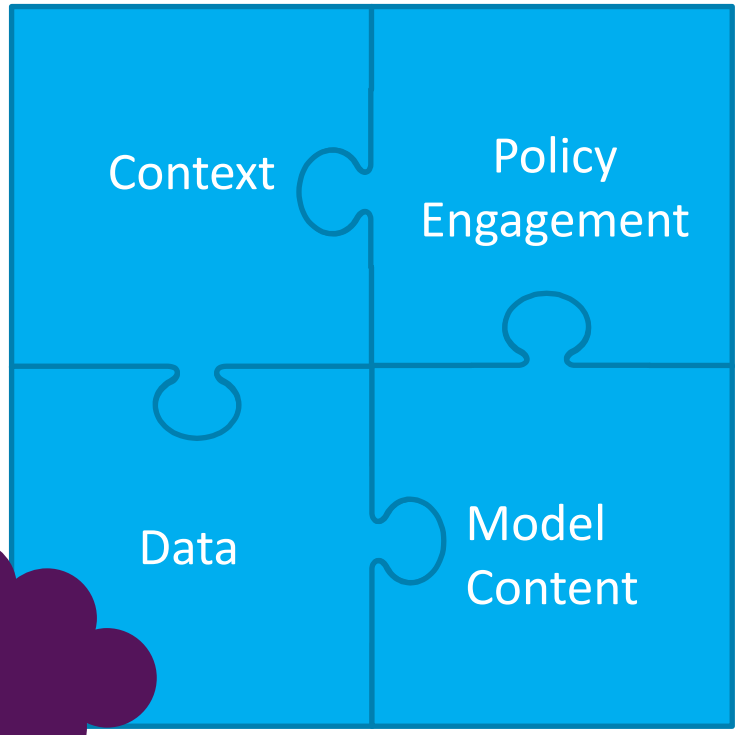
Four phases of the modelling process, and key topics for each point in the chronology

Building the Model
(March – May 2020)

Understanding options
(June 2020)

Regular scenarios
(October 2020)

New conditions
(January 2021)



End with some reflections, particularly about how the model is used for policy planning

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Key Players

Local Resilience Forum: Legal responsibility for coordinating emergency response

PREPARING FOR EMERGENCIES

IN COUNTY DURHAM & DARLINGTON

Partnership includes:

Principal contacts:

NHS County Durham and Darlington NHS Foundation Trust

Durham County Council

COVID-19 Community Health and Social Care Modelling Team

Led by:

Camila Caiado
mathematical sciences

Brian Castellani
sociology

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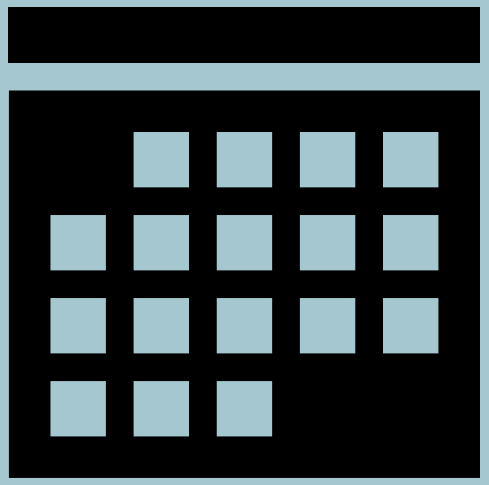
Chronology



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March to May 2020: Mobilise and build

Image source: The Guardian 24 Mar 2020

Computational Models That Matter During a Global Pandemic Outbreak: A Call to Action

Flaminio Squazzoni[a], J. Gareth Polhill[b], Bruce Edmonds[c], Petra Ahrweiler[d], Patrycja Antosz[e], Geeske Scholz[f], Émile Chappin[g], Melania Borit[h], Harko Verhagen[i], Francesca Giardini[j] and Nigel Gilbert[k]

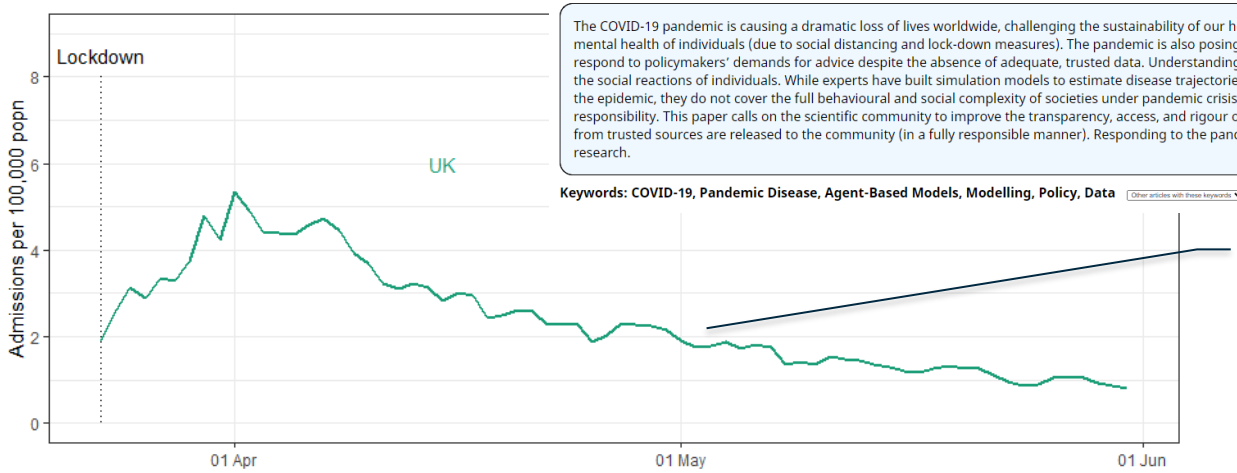
[a]University of Milan, Italy; [b]The James Hutton Institute, United Kingdom; [c]Manchester Metropolitan University, United Kingdom; [d]Johannes Gutenberg University Mainz, Germany; [e]University of Groningen, Netherlands; [f]Institute of Environmental Systems Research, University of Osnabrück, Germany; [g]TU Delft, Policy and Management, Netherlands; [h]UiT The Arctic University of Norway; [i]Stockholm University, Sweden; [j]University of Groningen, The Netherlands; [k]University of Surrey, United Kingdom

Journal of Artificial Societies and Social Simulation **23** (2) 10
<http://jasss.soc.surrey.ac.uk/23/2/10.html>
DOI: 10.18564/jasss.4298

Received: 31-Mar-2020 Accepted: 31-Mar-2020 Published: 31-Mar-2020

The COVID-19 pandemic is causing a dramatic loss of lives worldwide, challenging the sustainability of our health care systems, threatening economic meltdown, and putting pressure on the mental health of individuals (due to social distancing and lock-down measures). The pandemic is also posing severe challenges to the scientific community, with scholars under pressure to respond to policymakers' demands for advice despite the absence of adequate, trusted data. Understanding the pandemic requires fine-grained data representing specific local conditions and the social reactions of individuals. While experts have built simulation models to estimate disease trajectories that may be enough to guide decision-makers to formulate policy measures to limit the epidemic, they do not cover the full behavioural and social complexity of societies under pandemic crisis. Modelling that has such a large potential impact upon people's lives is a great responsibility. This paper calls on the scientific community to improve the transparency, access, and rigour of their models. It also calls on stakeholders to improve the rapidity with which data from trusted sources are released to the community (in a fully responsible manner). Responding to the pandemic is a stress test of our collaborative capacity and the social/economic value of research.

Keywords: COVID-19, Pandemic Disease, Agent-Based Models, Modelling, Policy, Data



Lockdown effective and declining admissions

Data source: coronavirus.data.gov.uk

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Broad COVID-19 modelling approaches

DATA ORIENTED

Roughly – statistical models

- Functional form influenced by theory, but not bound to it
- eg fit curve to admissions so far and extrapolating

Interaction expressed through mathematical relationships between variables

- Parameters calculated

Aggregated variables

- Subpopulation counts
- Homogenous, meaningful average

PROCESS ORIENTED

Roughly – mathematical models

- Parameters (some) from theory
- Interaction from process

Compartment models (differential equations, system dynamics)

- Aggregated variables

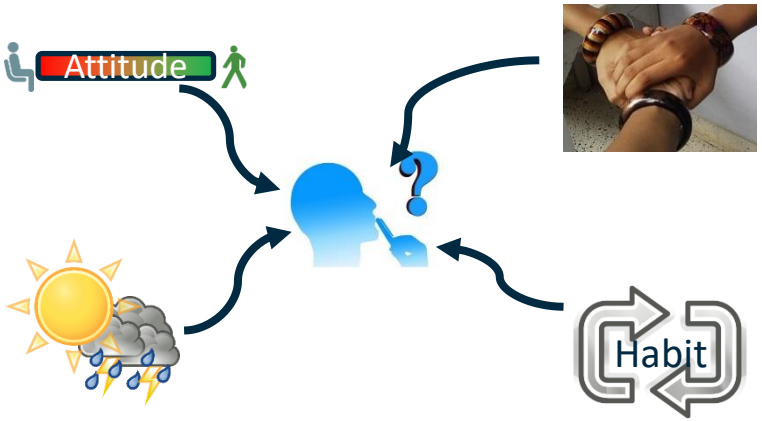
Agent-based models

- Heterogenous individuals
- Heterogenous situations

What is agent-based modelling?

[ABM] … is a computational method that enables a researcher to create, analyse, and experiment with models composed of agents that interact within an environment

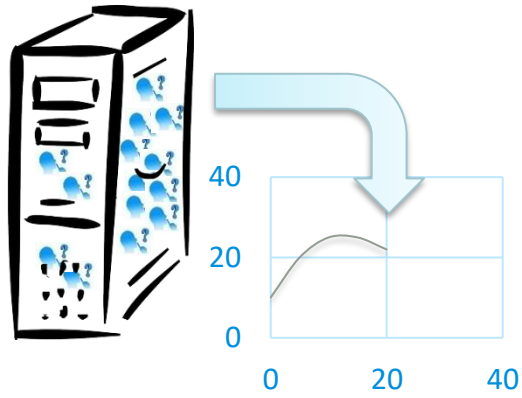
Gilbert N (2008). *Agent-Based Models*. Sage Publications



… agents that interact within an environment

what if…?

… to create, analyse, and experiment with models …



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Building the model (March to May 2020)

MARCH 2020

Durham University supporting LRF

- COMPLEX-IT projecting from Italian curves
- Several models proposed
- First ABM simply demonstrated difference arising from interaction approach
  - activity vs contact

Single point of contact with LRF (Camila)

MAY 2020

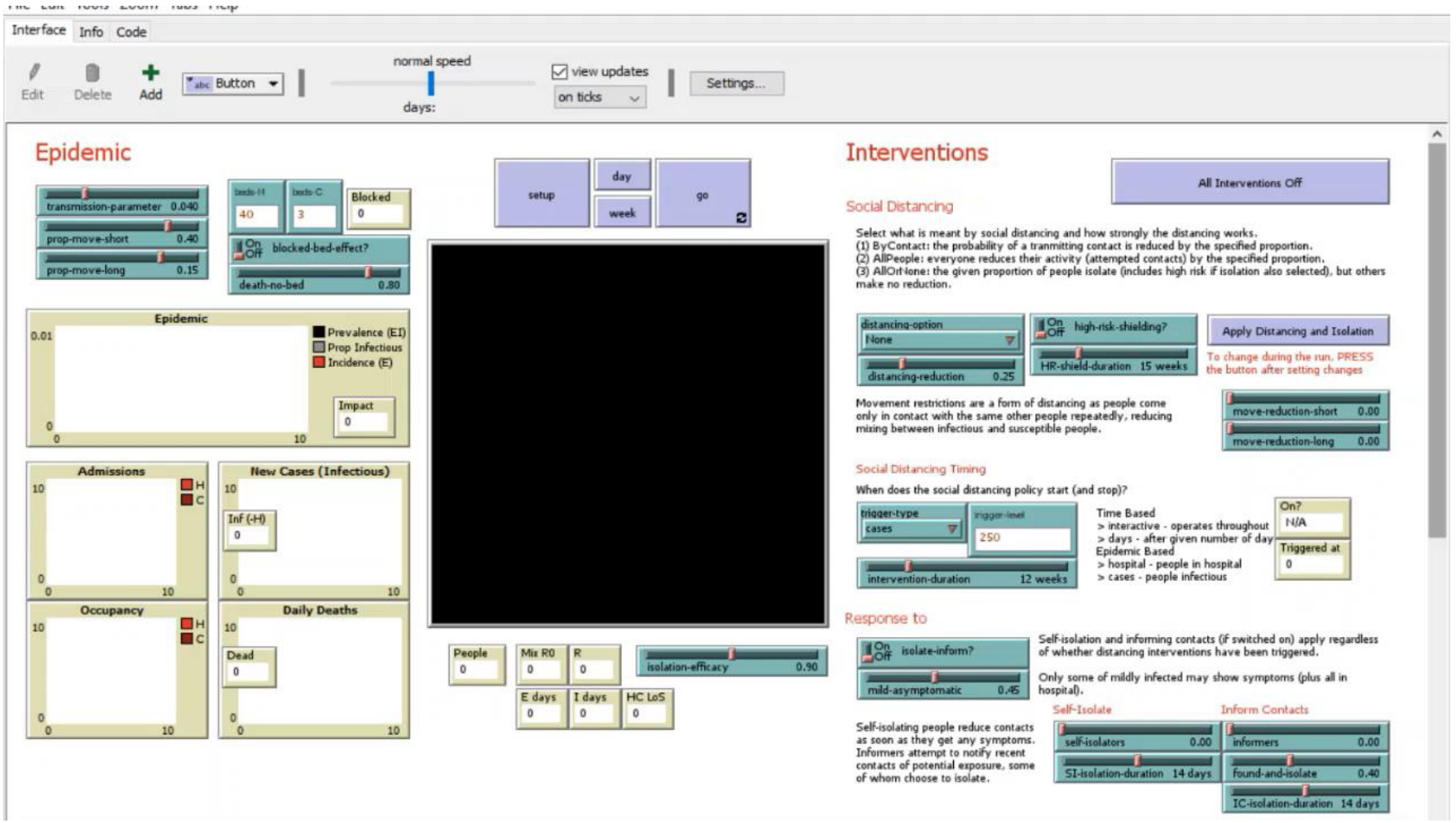
JuSt-Social v1.0 released

Three key elements:

- Transmission process
- Epidemic state transition for exposed (simulated) individuals
- Distancing measures

Example scenarios to demonstrate functionality

Demonstration



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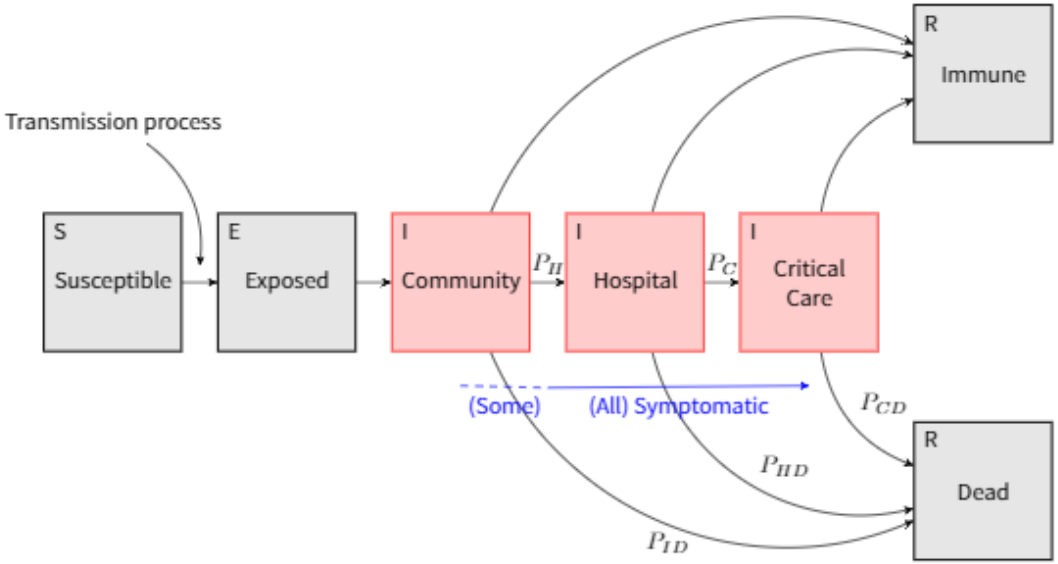
JuSt-Social: Epidemic state transition

- Extended SEIR
  - Simulated individuals progress through states after exposure
- Parameters
  - Transition probabilities
  - Durations in each state

- Sources
  - Imperial College reports
  - ICNARC (critical care)
  - ECDC (community durations)
  - ONS (prevalence, deaths)



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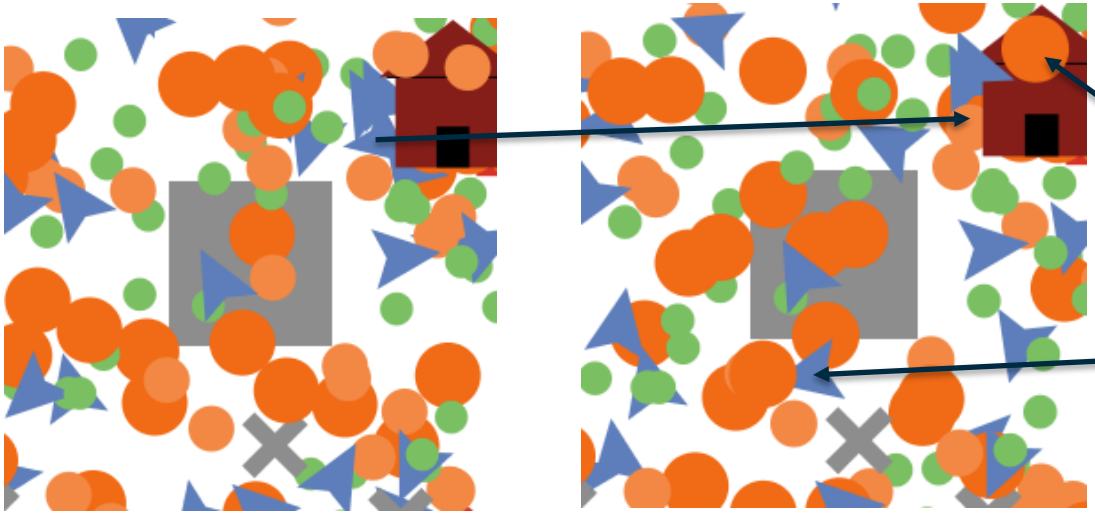
JuSt-Social: Transmission process

- Grid of 41x41 patches
- Infectious people can expose susceptible people on same patch
- Each day, some people move

- Each patch starts with 12 people
  - Literature, 11 contacts per day
- Transmission probability and movement to match UPenn SEIR curve without hospitalisation
  - Time, size of prevalence peak



3x3 patches magnified, sequential time

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JuSt-Social: Policy options and implementation

Higher probability of death if no hospital bed

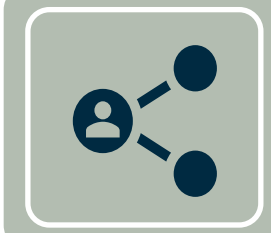
•As change state to hospital: if all beds occupied, draw for survival

Reduce activity – close public places (prob transmission)

Reduce transmission – hand hygiene (prob transmission)

Shield those at higher risk (treat as isolated)

Reduce movement



Symptomatic (not all infectious) inform their contacts

Symptomatic choose to isolate

- Combinations
  - Simultaneous
  - Sequential
- No calibration
  - Parameters set using user's judgement

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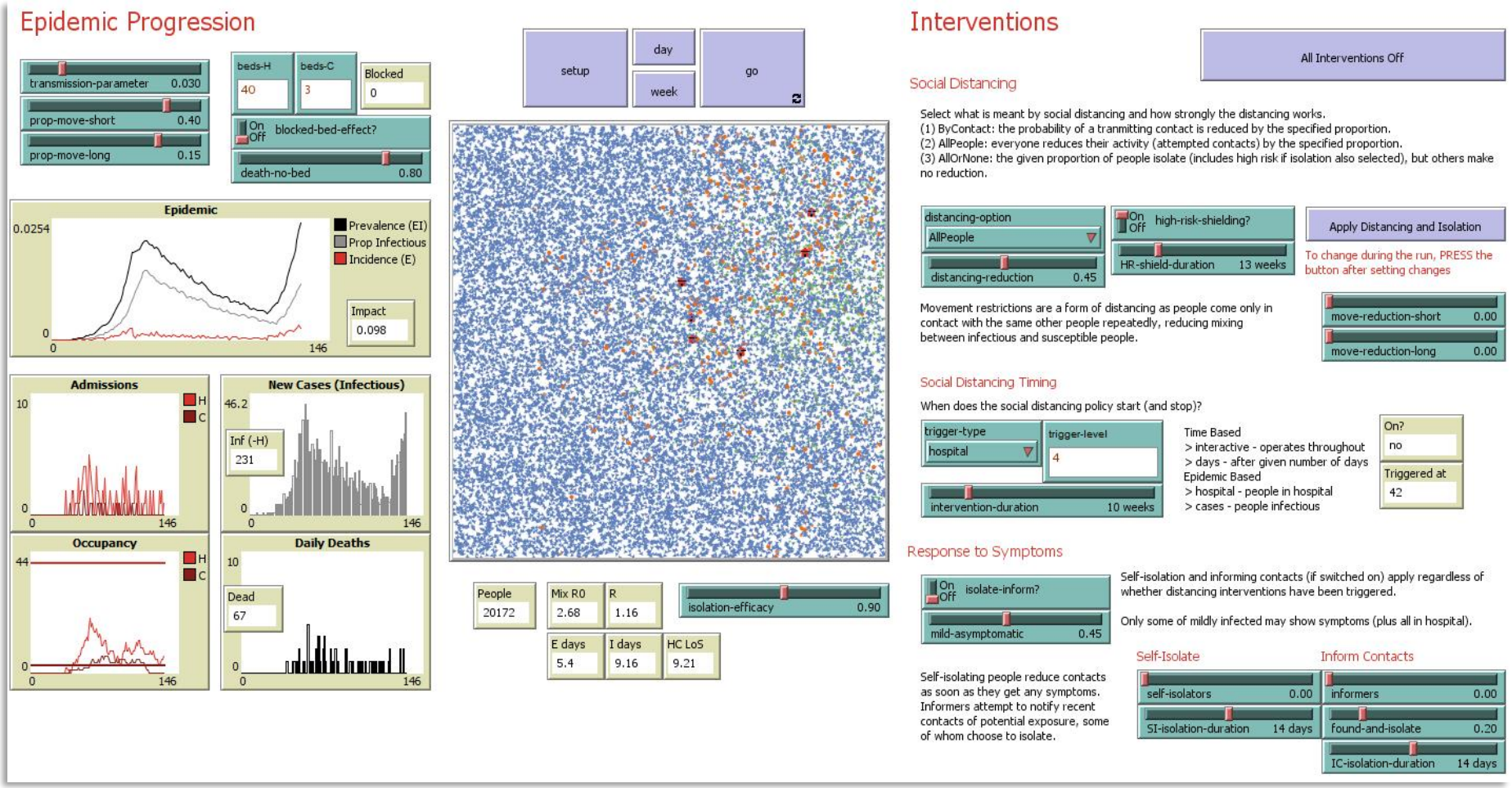
JuSt-Social main interface



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May 2020 report

Introduced the model

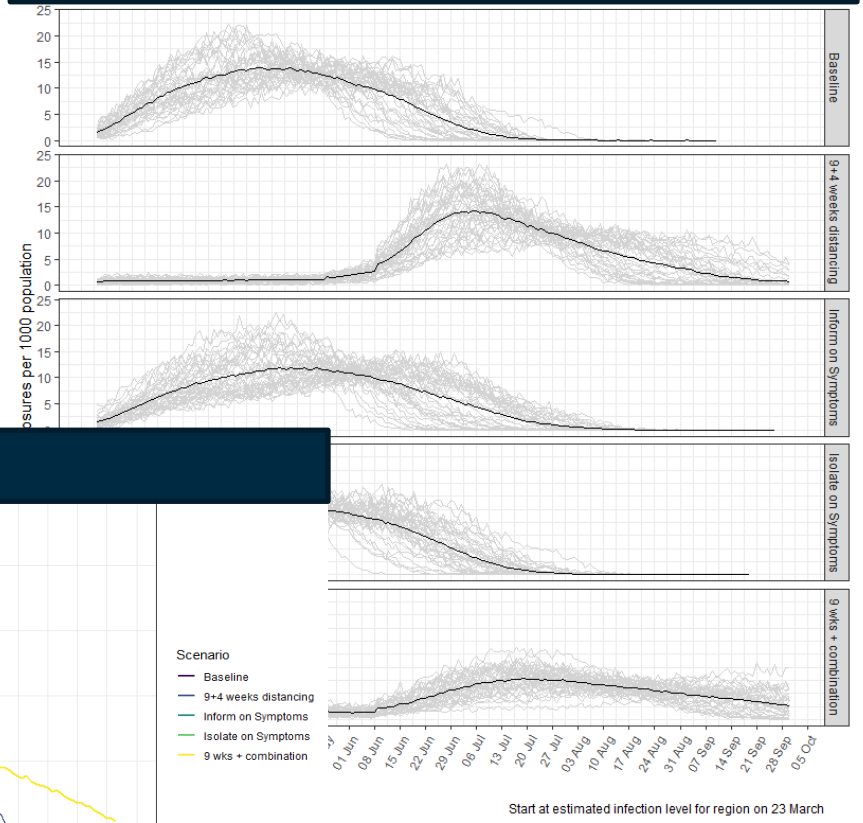
- Demonstration to DCC

Scenario discussion

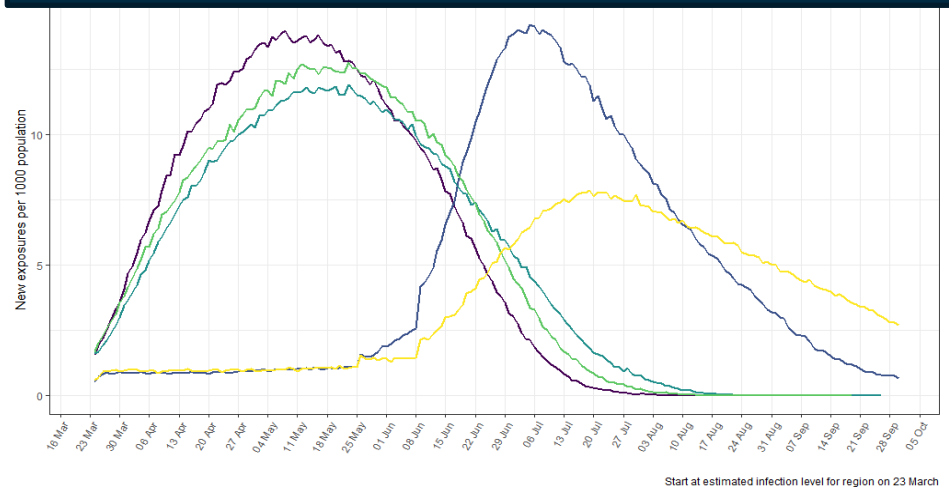
- Holding R at 1 just delays epidemic
- Tracing helps, but not enough
- Combining measures best

Emphasised uncertainty

Exposures over time: individual runs



Mean exposures over time: scenarios



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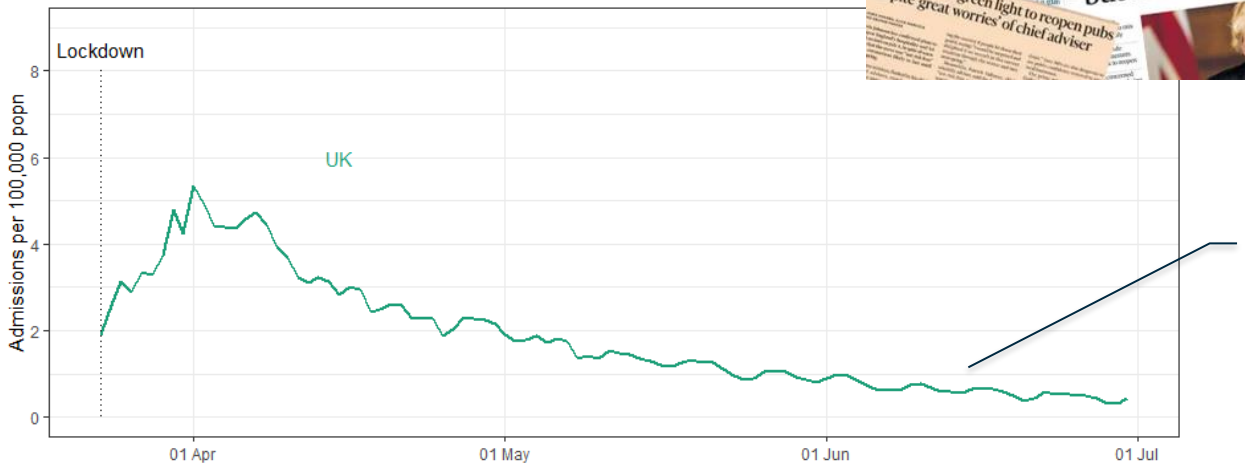
June 2020: Specific Questions

Image source: The Guardian 26 May 2020

Image source: The Guardian 24 June 2020



Continued decline in admissions

Data source: coronavirus.data.gov.uk

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Scenarios to examine specific questions

Some by us, some by DCC

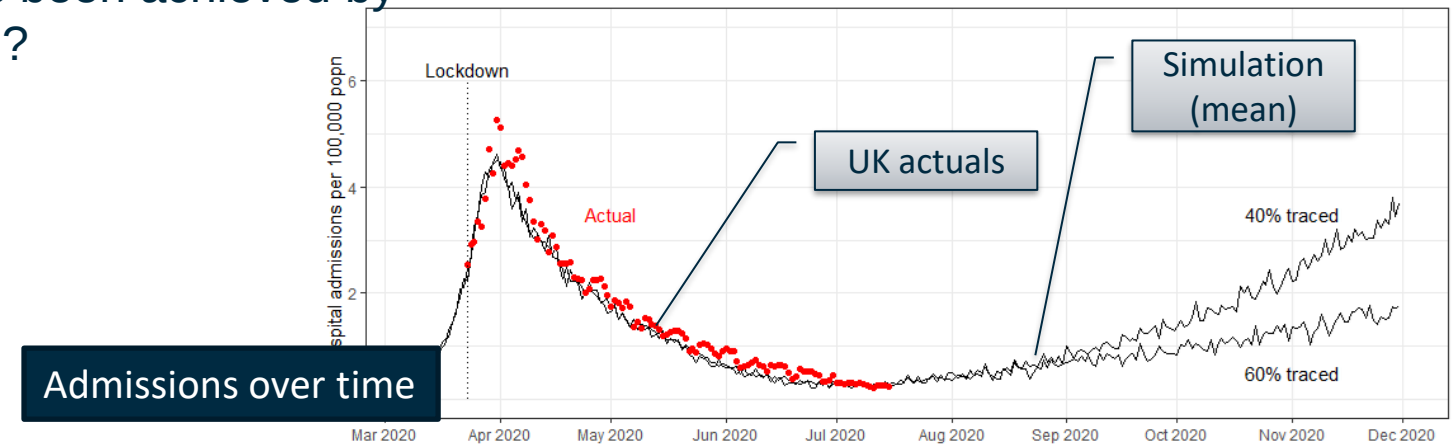
- From local prevalence, what is likely prevalence at end lockdown?
- Probability that lockdown would eliminate COVID-19
  - excluding import
- What has been achieved by lockdown?

Allows local planners to ask questions of interest to them:

- vs receiving centrally generated reports and estimates

And stimulate discussion

- What can be achieved with track and trace?



Admissions over time

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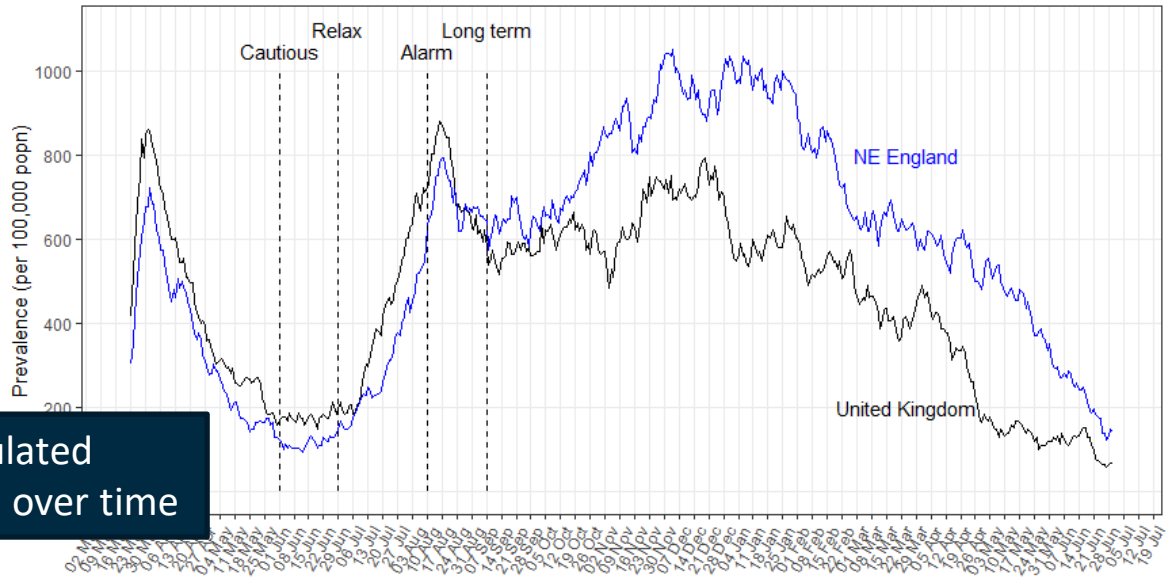
June 2020 report

Analysed a specific scenario proposed by the planners

- Assume policy applied based on UK trends
- Implications for local region

Implementation

- Varied distancing measures over time in response to prevalence levels
- Applied the same scenario assuming lower prevalence at initial lockdown



Mean simulated prevalence over time

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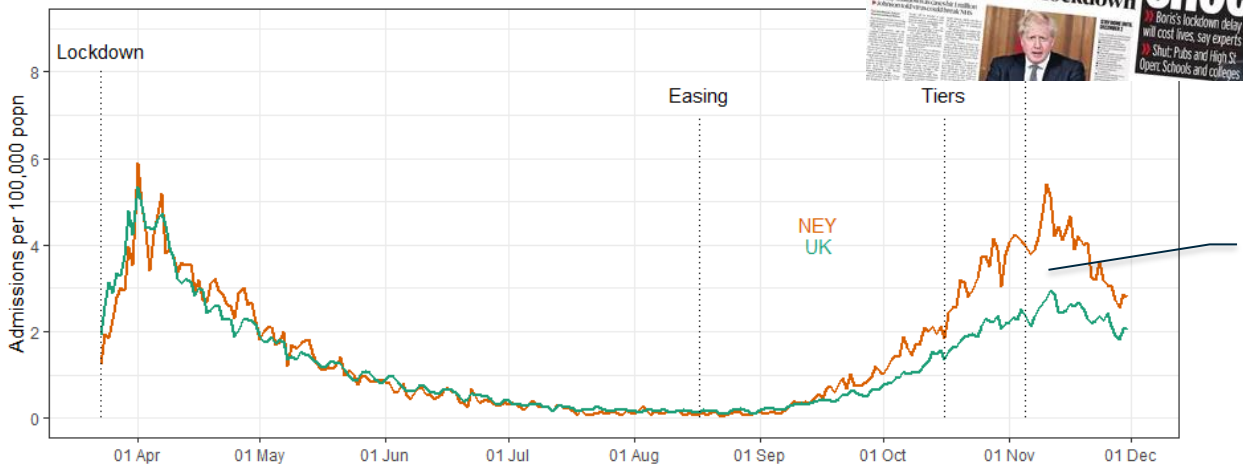
October 2020: Regular reports

Image source: The Guardian 13 October 2020

Image source: The Guardian 1 November 2020



New data: NEY

Data source: coronavirus.data.gov.uk

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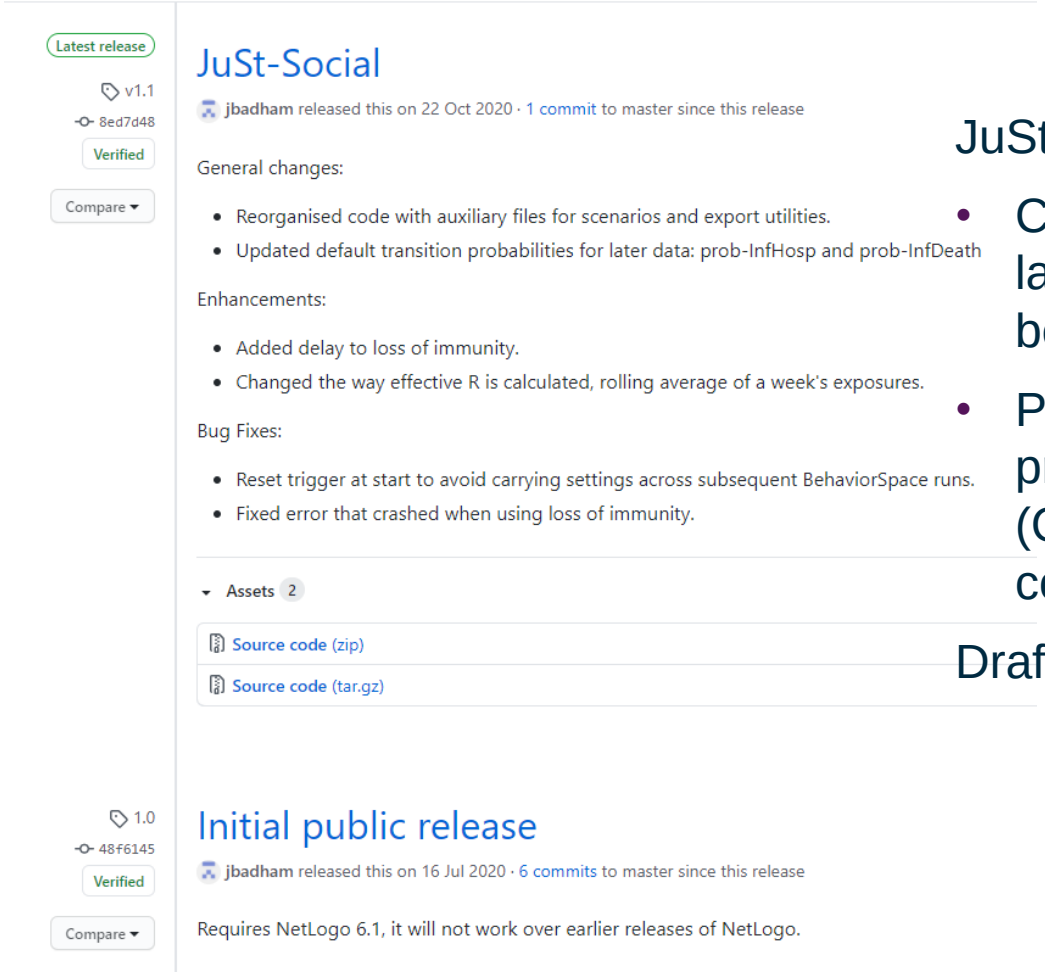
Minor model modifications



Latest release

v1.1

8ed7d48

Verified

Compare

JuSt-Social

jbadham released this on 22 Oct 2020 · 1 commit to master since this release

General changes:

- Reorganised code with auxiliary files for scenarios and export utilities.
- Updated default transition probabilities for later data: prob-InfHosp and prob-InfDeath

Enhancements:

- Added delay to loss of immunity.
- Changed the way effective R is calculated, rolling average of a week's exposures.

Bug Fixes:

- Reset trigger at start to avoid carrying settings across subsequent BehaviorSpace runs.
- Fixed error that crashed when using loss of immunity.

Assets 2

Source code (zip)

Source code (tar.gz)

1.0

48f6145

Verified

Compare

Initial public release

jbadham released this on 16 Jul 2020 · 6 commits to master since this release

Requires NetLogo 6.1, it will not work over earlier releases of NetLogo.

JuSt-Social v1.1 end October

- Code reorganisation to allow large number of scenarios to be stored and accessed easily
- Parameter updates as better prevalence data available (ONS infection surveys) to combine with admissions data

Draft journal article

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Scenario to match history and project forward

WHAT WE DID

Gov.UK dashboard now with regional data (defined by NHS boundaries)

- Occupied beds from ~ mid Nov

Historical scenario to provide a plausible epidemic in the simulated population

- Matched to admissions

Extrapolated with different assumptions of post-easing activity and self-isolation

HOW IT WAS USED

Regular reports (~ fortnightly)

Actuals tracked against projection

Gradually embedded in DCC and NHS trust planning dashboard

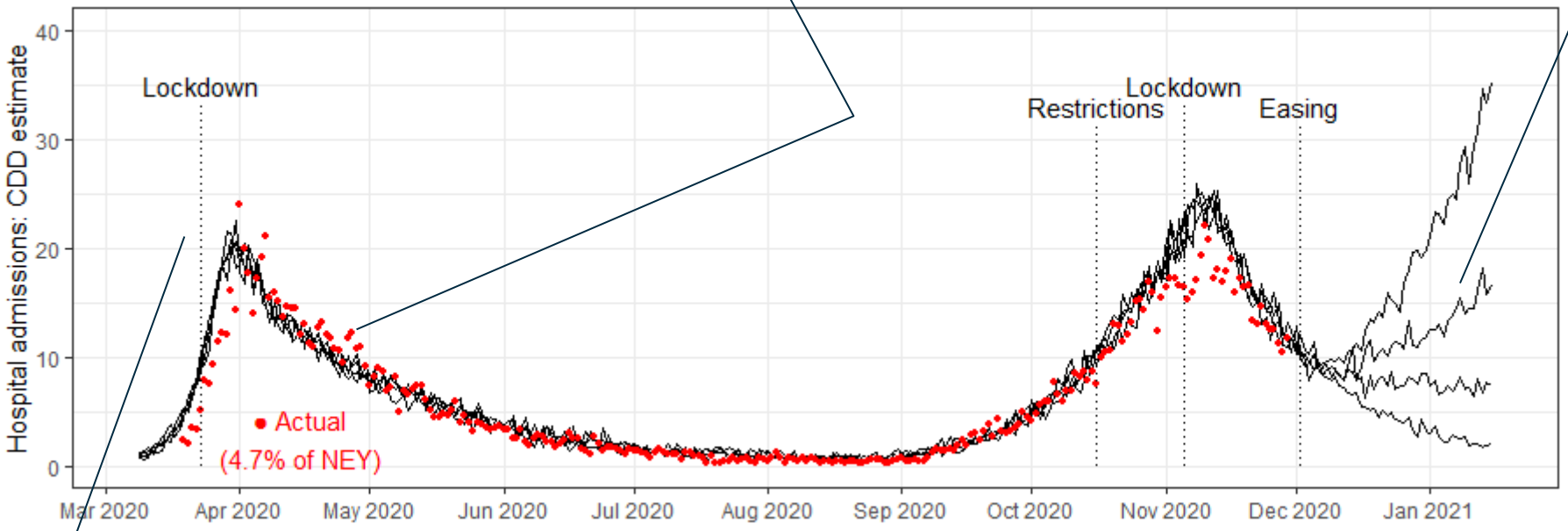
- Equal status with PHE projections

Presented to LRF leadership

Example report plot – Admissions per day

Red (and also blue) dots: actual measure from Gov.UK dashboard (coronavirus.data.gov.uk)

Black lines: average output from simulation runs for each scenario (also shaded areas for IQR)



Vertical dotted line: dates at which change in policy (actual and simulated) occur

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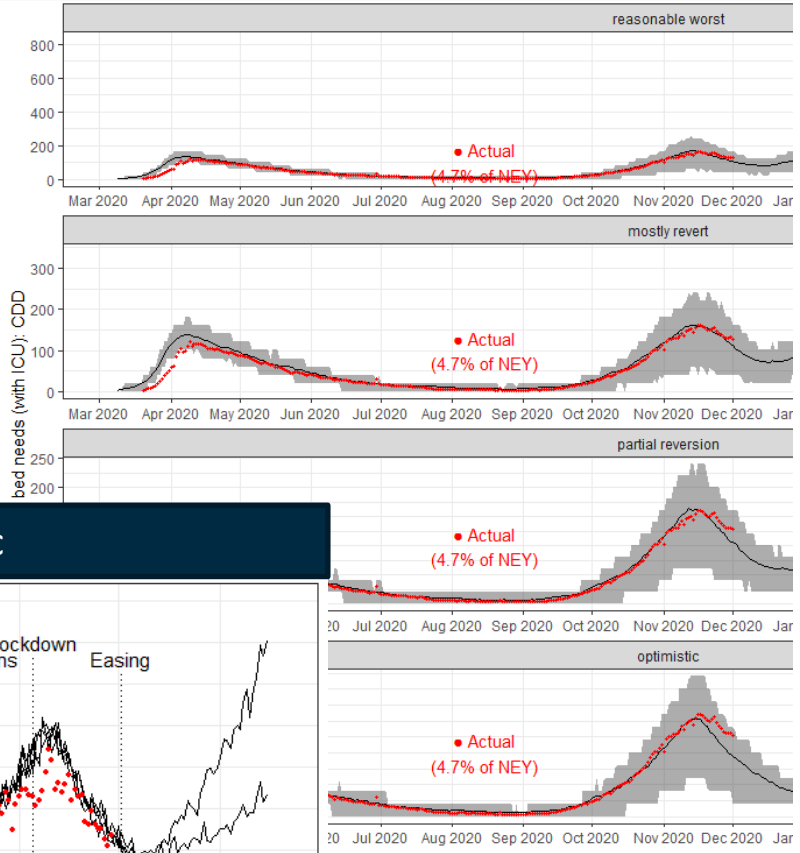
November (end) 2020 report

Assumptions developed with DCC

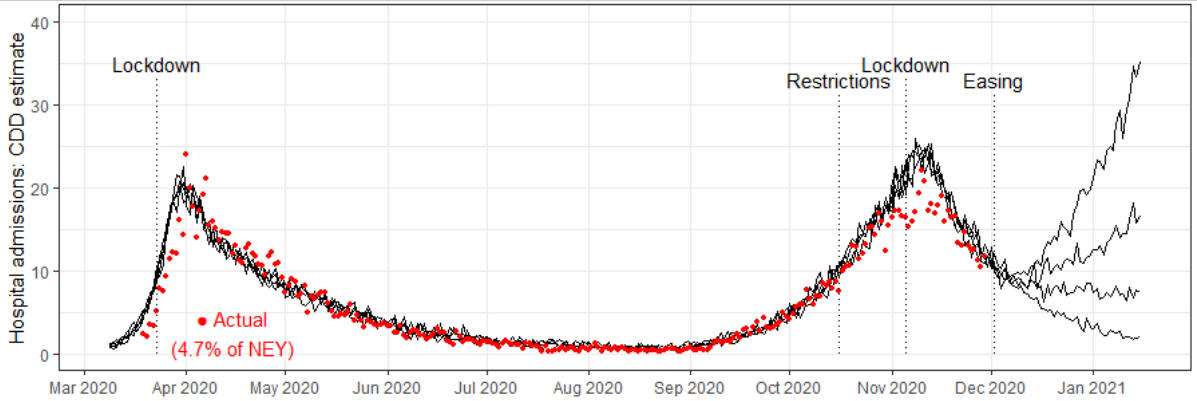
- Based on activity levels at various points in matched history

Appeared reasonable, but…

Mean and IQR beds required over time



Mean admissions over time: scenarios from 2 Dec



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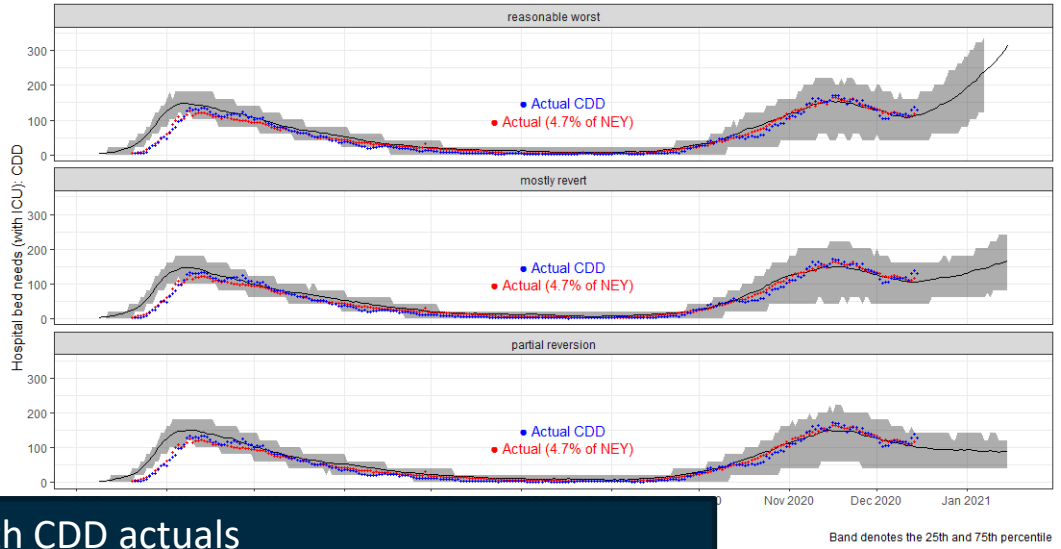
Scenarios revised from mid December

New data

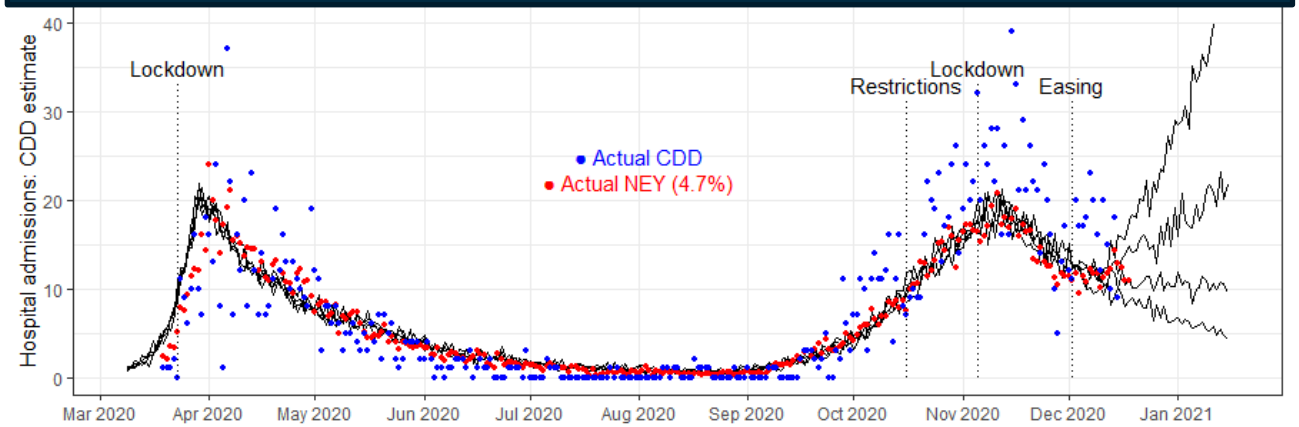
- Gov.UK dashboard at UTLA
- Beds tracked well
- Admissions peak mismatch

Mean and IQR beds over time: with CDD actuals



Band denotes the 25th and 75th percentile

Mean admissions over time: with CDD actuals



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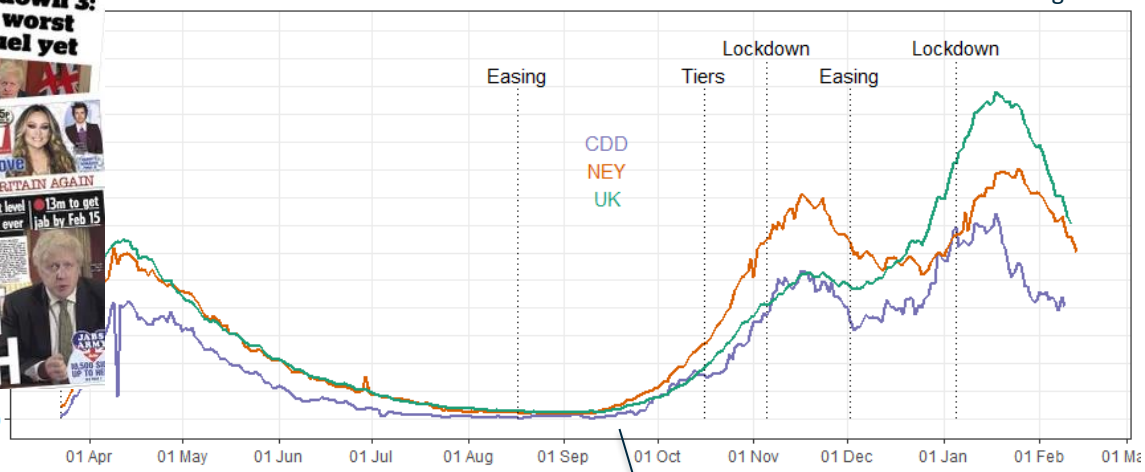
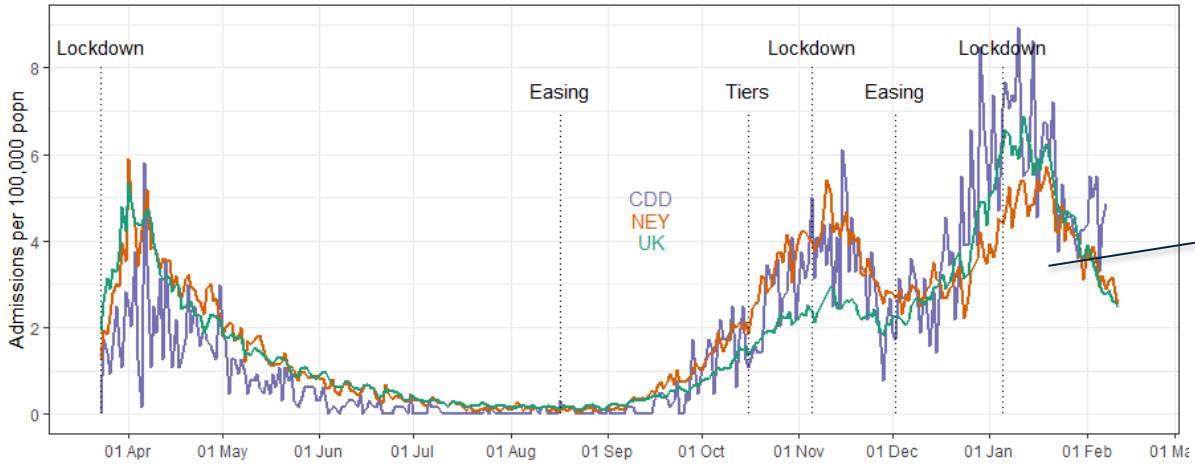
January 2021: New conditions

Image source: The Guardian 5 January 2021

Data source: coronavirus.data.gov.uk



New data: Beds



New data: CDD

Data source: coronavirus.data.gov.uk

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Three modifications required

New scenarios

- Three activity levels from 29 Dec (in advance of lockdown)

New variant: ABM allows each agent to be infected with, and transmit, a specific variant

- ~50% more transmissible
- Assign 35% in E&I on 17 Dec

Vaccination: targeted

- Reduce probabilities of community to hospital or death at 3 Feb

Introduced CDD specific hospital durations

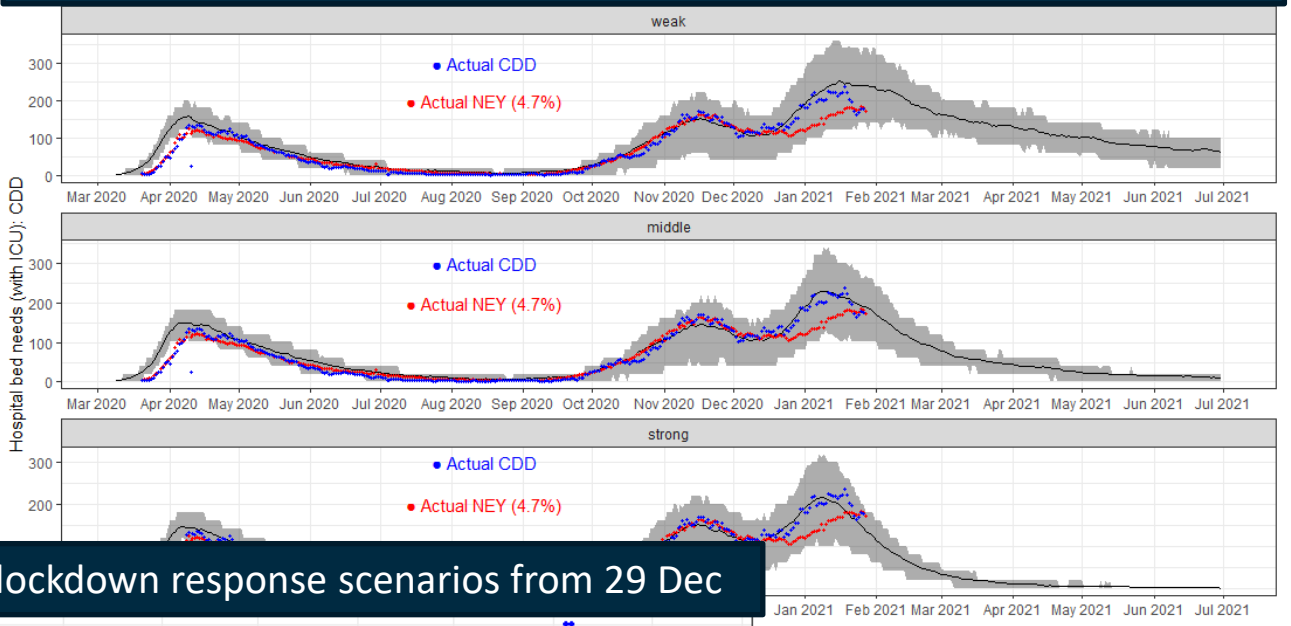
- Not in public version of model
- Attempted reconciliation of CDD with NEY

Policy engagement

- Activity levels selected by CDD
- Implementation of new variant and vaccination agreed with CDD
- Projections in planning dashboard
- Briefed LRF

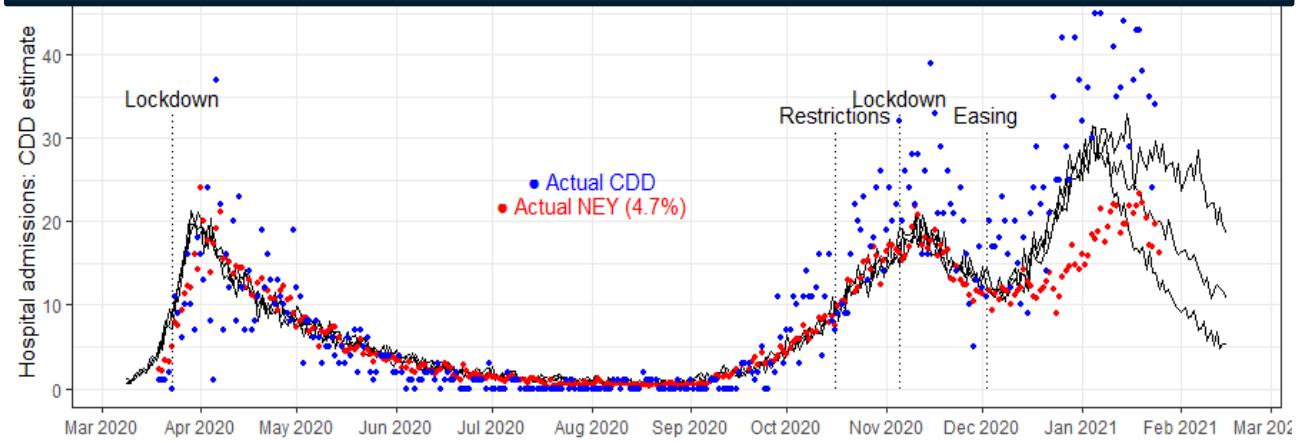
January (end) 2021 report

Mean and IQR beds required over time



Band denotes the 25th and 75th percentile

Mean admissions over time: lockdown response scenarios from 29 Dec



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Reflections

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ABM different – not better or worse

Process perspective

- Series of actions and consequences

Agent-centric thinking

- I, the agent, have certain characteristics and beliefs of my own as well as information about the world around me, and therefore will decide on some action

Potential model improvements

What is excluded but would include?

- Popn is 20172 for performance
- Age structure: Transmission risk gradient unknown when designed
- Contact network: would support different policies
- (maybe) prevalence in external population

What is excluded intentionally?

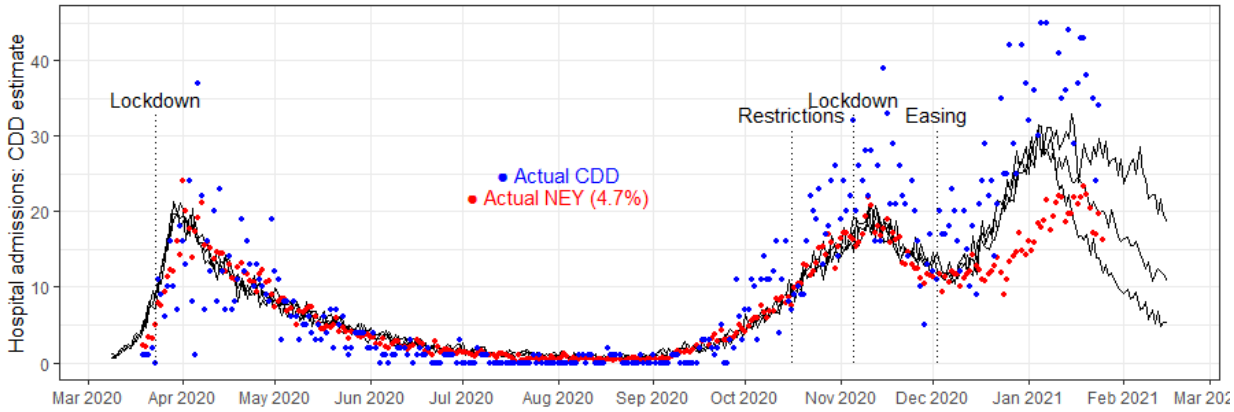
- High resolution transmission
  - Why include workplaces, transport etc if risk unknown?
  - Underdetermined for calibration
- Social effects of policies
  - Part of policy discussion, not hidden in model assumptions

Decision support: direct

Easy to think that the scenario forecasts are the important aspect of this modelling project

Compare scenarios

Assess adequacy of the scenarios



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Decision support: indirect

But indirect decision support is also important

Gain experience in complex systems thinking

- Counterintuitive outcomes
- Train intuition when decision required but limited information

Understand uncertainty: eg plausible prevalence

Explicit assumptions: eg track and trace compliance

Model insights not always the obvious ones

Tool for thinking: Summarise knowledge and extrapolate that knowledge

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Justified Stories: formalising “what if?”

MODEL PURPOSE

Proximate purpose: Description

- “not designed to explain or predict but to represent and formalise… some of the relationships and dynamics of the situation”

Edmonds et al (2019), 'Different Modelling Purposes’, *JASSS* 22 (3) 6. doi: 10.18564/jasss.3993

Ultimate purpose: Tool for thinking

- Model provides convenient access to organised knowledge

WHY IS “WHAT IF?” ANALYSIS USEFUL?

Stories

- Sequence of events (dynamic)
- Coherent
- Internally consistent

Justified

- Represents knowledge about the world
- Multiple sources: data, theory, expert opinion
- Externally consistent
  - plausible, given knowledge

Conclusion

JASSS

Justified Stories with Agent-Based Modelling for Local COVID-19 Planning

Jennifer Badham[1], Pete Barbrook-Johnson[2,4], Camila Caiado[3], Brian Castellani[1]

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Journal of Artificial Societies and Social Simulation 24(1) 8, 2021
Doi: 10.18564/jasss.4532 Url: http://jasss.soc.surrey.ac.uk/24/1/8.html
Received: 22-09-2020 Accepted: 22-01-2021 Published: 31-01-2021

Abstract: This paper presents *JuSt-Social*, an agent-based model of the COVID-19 epidemic with a range of potential social policy interventions. It was developed to support local authorities in North East England who are making decisions in a fast moving crisis with limited access to data. The proximate purpose of *JuSt-Social* is description, as the model represents knowledge about both COVID-19 transmission and intervention effects. Its ultimate purpose is to generate stories that respond to the questions and concerns of local planners and policy makers and are justified by the quality of the representation. These *justified stories* organise the knowledge in way that is accessible, timely and useful at the local level, assisting the decision makers to better understand both their current situation and the plausible outcomes of policy alternatives. *JuSt-Social* and the concept of *justified stories* apply to the modelling of infectious disease in general and, even more broadly, modelling in public health, particularly for policy interventions in complex systems.

Keywords: Agent-Based Modelling, Epidemic, COVID-19, Descriptive Model, Social Distancing, Justified Stories

Introduction

1.1 Computational models have been influential in the COVID-19 policy response of national governments (Adam 2020). Specifically, analysis of modelled scenarios indicated that mitigation strategies would not work once significant community transmission had occurred (Ferguson et al. 2020; Holmdahl & Buckee 2020). Instead, most models suggested that whole-of-population social distancing would be required to substantially reduce the number of cases to a manageable level, with periodic suppression to maintain control until effective treatment or vaccination is available. Governments around the world have accordingly implemented a wide range of more or less stringent social distancing measures (Flaxman et al. 2020; Hale et al. 2020).

1.2 Policy oriented models of COVID-19 can be organised by general approach (Holmdahl & Buckee 2020). Classic statistical models (including GIT 2020; IHME 2020; Jombart et al. 2020) normally provide short term forecasts with uncertainty based on data series such as cases or hospital admissions. In contrast, mathematical models represent the mechanisms of disease transmission in the model rules and generate simulated epidemics based on those rules. Methods such as differential equations and system dynamics implement rules at the aggregate level (including Hill 2020; Noll et al. 2020; Struben 2020). In the epidemic context, these are referred to as compartmental models as they calculate the number of people in different epidemic states or compartments. Such models are deterministic as the mechanisms represent flows from one compartment to another, or rates of change in the epidemic as a whole. Microsimulation and agent-based models (including Davies et al. 2020;

6.3 … COVID-19 decisions may need to be made quickly with incomplete information because delaying the decision is effectively a decision to take no action. …

6.4 The local planners have become more deeply engaged with the model over time. …With substantial time pressures on local planners, this high level of engagement demonstrates the value of the justified stories approach in their decision making.

Model and documentation from:
OpenABM - https://doi.org/10.25937/119s-yx54
Github - https://github.com/jbadham/covid-social

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