Modelling the Covid19 epidemic across a health system in the UK using Systems Dynamics

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Modelling Covid-19 pandemic

- The question…
- The team
- Developing the model
- How many ventilators do we need???
- Data and information
- Long term scenarios
- Key reflections
- The danger of Castles

A couple of comments before I begin…

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- Any views and reflections are my own only, and are not that of the health and care system we have and continue to support
- Behind each number was a loved one
- Acknowledgment that this still is not over and there are continuing and new challenges for health systems as they develop new ways of working in trying to resume business as usual
- None of the team are epidemiologists. Personally, I'm a clinician, Paramedic, by background, and this presentation is not a technical piece. A colleague has written a technical paper that can be shared on request.
- An acknowledgement to ISEE Systems who in the spirit of sharing and doing things together kindly allowed us to use their Covid-19 model structure for our v.1. You can view their simulator at the link below 

https://exchange.iseesystems.com/public/isee/covid-19-simulator/index.html#page1

The question…

'…to help local systems to plan for the capacity across a range of services in response to COVID-19 and in the context of social distancing policies and the early progression of the disease within a specific population'

- Provide key insights and outputs that support the planning for key services in the Covid-19 pandemic across the Integrated Care System (ICS)
- Develop outputs at the Integrated Care Partnership (ICP) level, each with a separate seeding and, if required, different assumptions
- Provide outputs against a reasonable set of *'what if'* scenarios
- Create a learning process with rapid iterations and updates to the model as new information and data becomes available
- Develop the model using a combination of Systems Dynamics and Excel spreadsheet analysis
- The model should be able to support both now casting *(1-14 days forecast)* and medium long term planning *(1 -12 months)*
- To include the impacts of national policy on social distancing
- Initialise the model using national modelling assumptions

The team…

A local **NHS Covid 19 modelling lead** was assigned, and a local group established, that met 'virtually' on a regularly basis to support the work. This included **Consultants in Public Health**, **Chief Analysts, strategic analysts**, and latterly included **NHSE/I regional support**.

Discussions at these meetings from the off provided…

- Sense ***check and challenge*** to the modelling
- Transfer and forwarding of ***key and emerging public health insights***
- Developments of the modelling moving forward
- ***Milestones and deadlines***

The ***WSP team*** comprised of 4 full time members. All trained in SD with varying levels of proficiency.

Both the local team and WSP had the support of a group of Actuaries, that joined us part way through the project, each had volunteered some of their time in support of the Covid-19 response. They provided support in ***developing macros and graphs for the local teams bi- weekly report***, and are currently developing datasheets so the model can be ***calibrated to any local system across the UK***. *(note: their time was not to be used for commercial gain, and the work assigned from WSP was to support the development local system models free of charge to the NHS)*

Developing the model
Epidemiological sector and segmentation approach

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- The whole ICP population is segmented into ***three cohorts based on the nationally defined categories of risk***. This would allow us to apply ***different assumptions for each risk group throughout the model***, particularly when it came to the ***effectiveness of social distancing*** measures.

These risk cohorts were…

1. ***High risk*** being those in the 'shielded' category. (not to leave the house under any circumstance, all healthcare visitors wear protective PPE etc)

2. ***Moderate risk*** being those with long term conditions and/or being over 70 years of age, and not in the shielded group.

3. ***Low risk*** *all those not in moderate or high risk*

- For ***low and moderate risk groups we used data extracted from the local integrated dataset,*** and ***national age specific prevalence for high risk groups***.

- *Table 1* below illustrates the age specific prevalence for each risk group. The risk groups are adjusted for each ICP again the integrated and national datasets.

Age group	Low	Moderate	High
0-9	99.6	0.2	0.2
10-19	98.9	1.0	0.1
20-29	89.1	10.7	0.2
30-39	87.9	11.8	0.3
40-49	84.8	14.4	0.8
50-59	80.9	17.5	1.6
60-69	78.3	19.8	1.9
70-79	0.0	96.8	3.2
80+	0.0	96.9	3.1
All ages	74.6	24.3	1.1

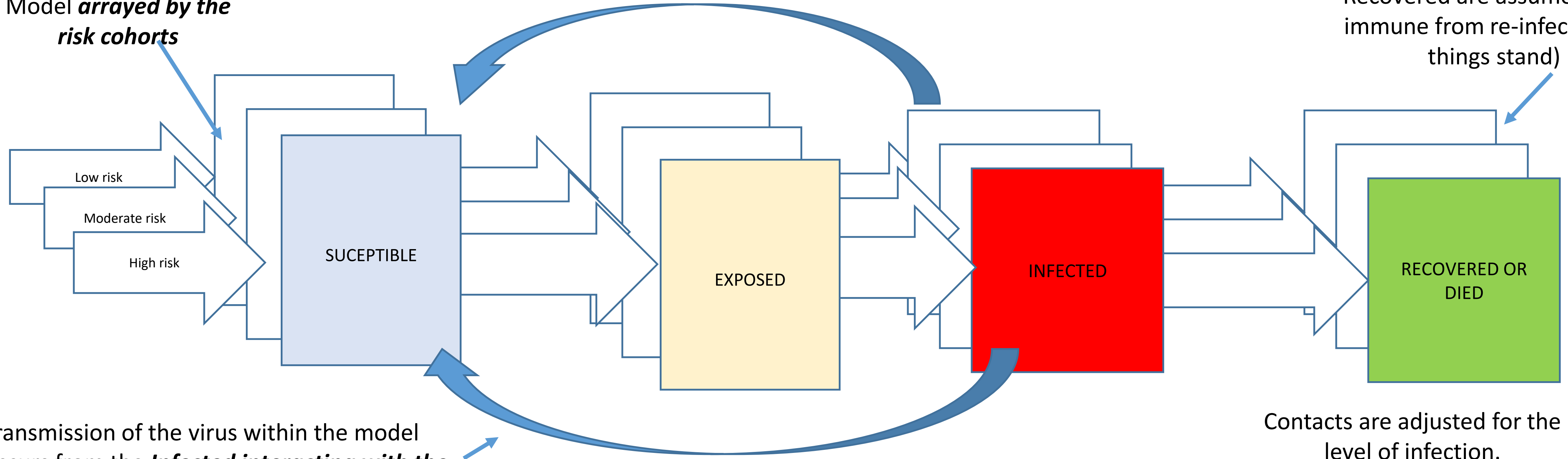
Table 1- Prevalence of Covid-19, risk and age groups

Developing the model cont…

Transmission and contacts

Model ***arrayed by the risk cohorts***

Recovered are assumed to be immune from re-infection (as things stand)



Transmission of the virus within the model occurs from the ***Infected interacting with the susceptible*** population via ***the average number of contacts***.

New infection = contacts x infected x susceptible/population

	Low	Moderate	High
Infectivity	0.015	0.015	0.015
Daily contacts	13	9	9
Days in each state:			
Asymptomatic (Incubation period)	5 (1-20)		
Days onset to recovery	13.5 (3-20)		
Days onset to hospital admission	6 (0-20)		

Table 2- model parameters

Contacts are adjusted for the level of infection. ***Mild/moderate symptoms contacts reduced by 50%. Severe symptoms contacts reduced by 95%.***

…though we know that people can ***pass on the disease before symptoms occur (if at all)***

Modelling impacts of social distancing measures…

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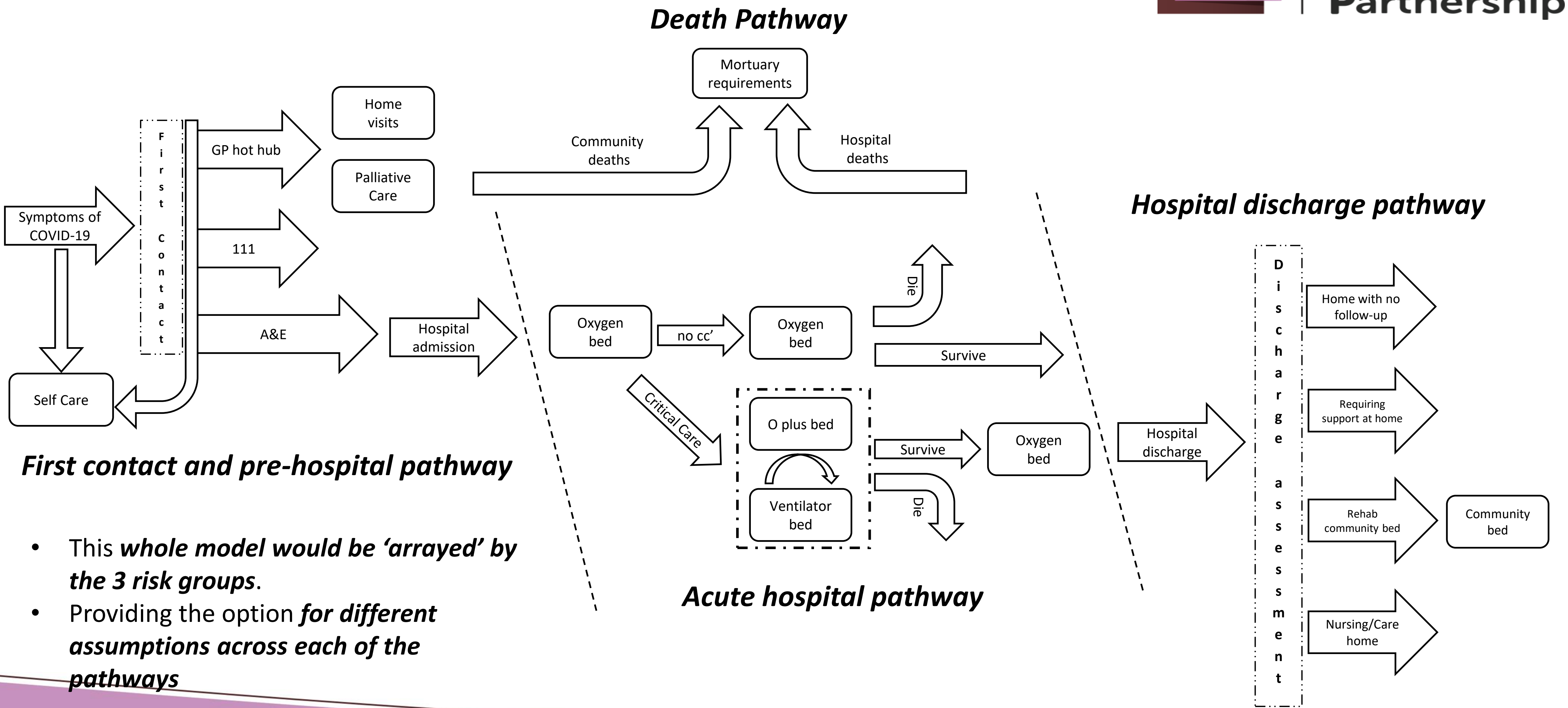
- The model ***run spec was in days*** over a 2 year period.
- Changes to national social distancing measures were matched within the model
- The effectiveness of the social distancing was then applied through a number of scenarios.
- 100% effectively meaning no daily contacts from the date of implementation.
- Different ***effectiveness levels were able to be applied for each of the risk profiles AND on the specific day of policy or likely effectiveness change***
- ***Approach is crude but useful…****future version to include more granular and less sensitive approach*

	Risk Profile	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Scenario 1	Low	80	80	65	65	55	65	65	65	65	65
	Medium	85	85	75	75	65	75	75	75	75	75
	High	90	90	80	80	75	85	85	85	85	85
Scenario 2	Low	80	80	60	60	60	60	60	60	60	60
	Medium	85	85	70	70	70	70	70	70	70	70
	High	90	90	75	75	75	75	75	75	75	75
Scenario 3	Low	80	80	50	50	60	50	50	60	60	60
	Medium	85	85	60	60	70	60	60	70	70	70
	High	90	90	75	75	80	75	75	75	75	75
Scenario 4	Low	80	80	65	65	70	70	70	70	70	70
	Medium	85	85	75	75	80	80	80	80	80	80
	High	90	90	80	80	80	80	80	80	80	80

Table 3- model scenarios for contact adjustments (adjusted to months)

Whole System conceptualisation…



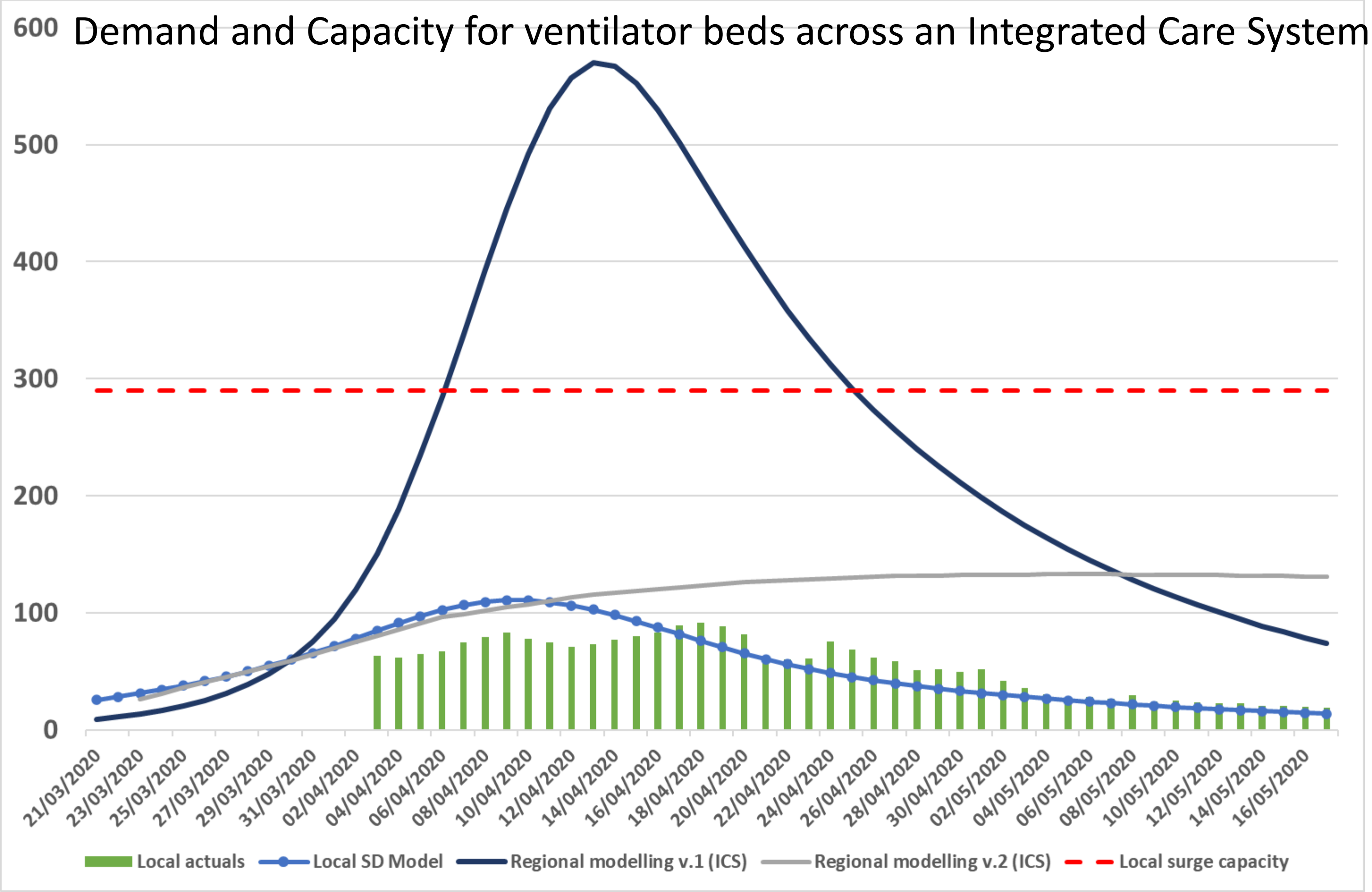
- This ***whole model would be 'arrayed' by the 3 risk groups***.
- Providing the option ***for different assumptions across each of the pathways***

First question…*how many ventilators do we need?*

- Given the nature of the disease and the very limited capacity of ICU beds the big question was always around ventilator beds numbers.
- The UK had significantly less ICU beds per 1000 when compared to other countries in the same economic bracket, ***for comparison UK had 6.6 per 100,000*** and ***Italy nearly double at 12.5***, before Covid-19.
- Given the lockdown occurred on 23rd March, there was with some certainty and general consensus that a ***peak would occur around the mid April***. Both early NHS National planning and our local SD model both suggested this.
- What local health/hospital systems needed in this early stage (late March/v.early April) was what ***'their' peak in ventilators will look like***.
- The hospitals across the system we supported surged their capacity 2 – 4 times their usual, but ***was this going to be enough?*** And given the different seeding, ***did capacity across their network need to shared?***

The ventilator demand trajectories…

- Local systems were provided **two versions** from central NHSE/I. One late March, the other early April.
- These figures were **provided at the regional level only,** of which a smaller ICS system would make up a fraction of. Local systems could then estimate their share of the demand.
- The local SD modelling was performed at the more granular **Integrated Care Partnership (ICP) level,** of which 4 made up a strategic ICS health system.
- This meant **4 differently seeded models were produced for a local health system,** allowing for more bespoke results when aggregated up to ICS system level.



Data and information…

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Throughout gathering appropriate data and information has been challenging…

- Admissions to hospital data was poor due to delay in test results.
- Two key triangulation points were used in the early stages – the number of **ventilator beds occupied** and the **number of hospital deaths.**
- We soon figured that we couldn't ameliorate the deaths with current assumptions, and made early conclusions that significantly more people must be dying outside of the ICU than going through.
- Initial assumptions derived from the Imperial College work suggested 30% of all hospitalised patients would require a ventilator. ***In reality this was only 15-20%, with very few over the age 80 being ventilated*** (and instead taking a palliative care pathway, either in hospital or out of hospital (pre). This key insight drastically changed the shape of ventilated bed demand.
- Those in the ***low risk group were extremely unlikely to have a severe symptoms that required an ICU stay***.
- We resisted early temptation to alter assumptions across the 4 ICPs to match what was happening, and only changed assumptions when we had good evidence to do so.
- Throughout we've been limited by data. We are only now (1 month past the [?first] peak) getting reasonable data.

Age-group (years)	% symptomatic cases requiring hospitalisation	% hospitalised cases requiring critical care	Infection Fatality Ratio
0 to 9	0.1%	5.0%	0.002%
10 to 19	0.3%	5.0%	0.006%
20 to 29	1.2%	5.0%	0.03%
30 to 39	3.2%	5.0%	0.08%
40 to 49	4.9%	6.3%	0.15%
50 to 59	10.2%	12.2%	0.60%
60 to 69	16.6%	27.4%	2.2%
70 to 79	24.3%	43.2%	5.1%
80+	27.3%	70.9%	9.3%

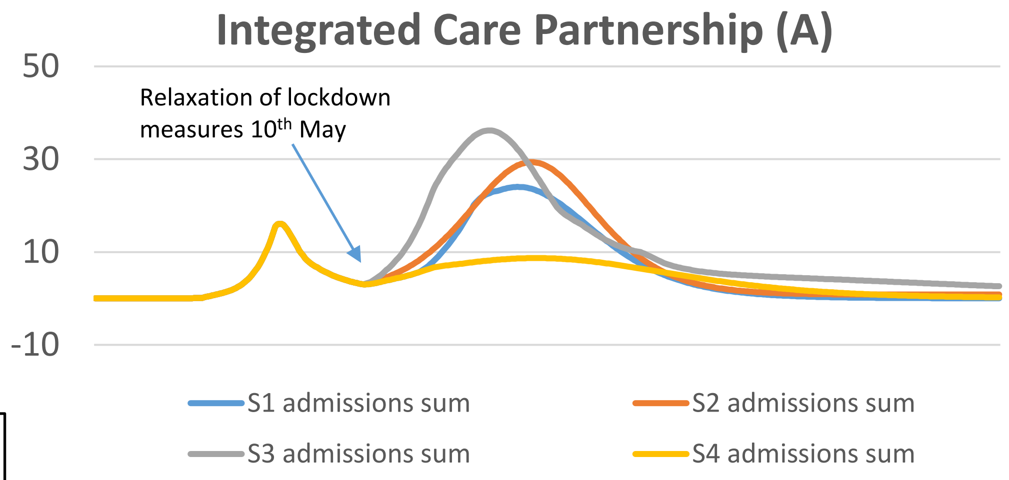
Specifically these assumptions from the original Imperial paper were critical to the inflated early national estimates of critical care demand.

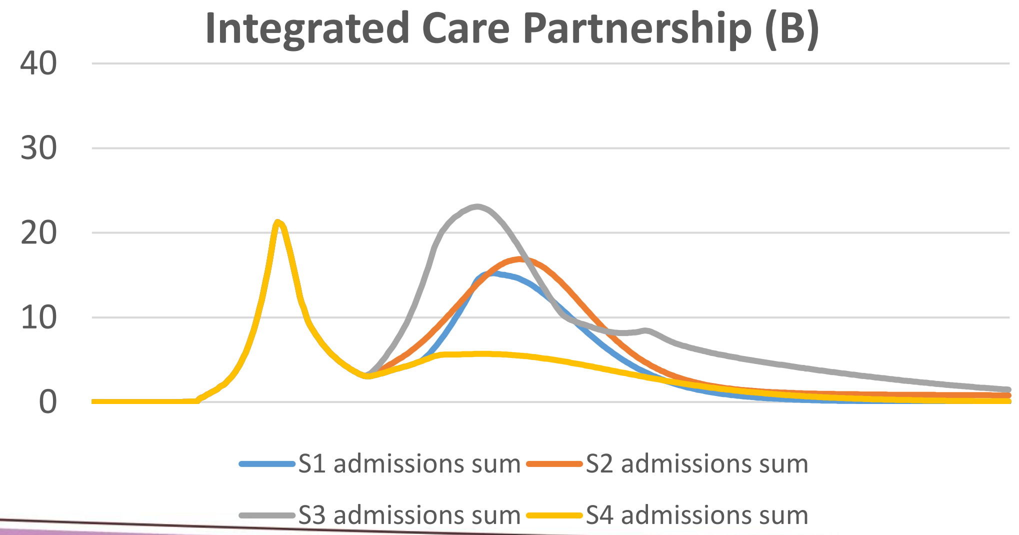
In reality these numbers (particularly for 80+) were sadly very small, and instead this cohort either died on a hospital ward or outside of hospital.

Developing long term scenarios…

- We developed ***4 reasonable case scenarios*** to provide some understanding of future health care demand.
- A description of these scenarios are presented *below*
- To the *right* are outputs out of ***daily admissions to hospital across two different ICPs***.
- ICP (A) had a significantly lower incidence of Covid-19 through their population in the first peak, and ***the scenarios demonstrate ICP (A) is at significantly more risk of a higher peak than their first***. Which is in contrast to their ICP neighbour who is just 27 miles away.

Scenario 1
Extended, but weakening of initial local down followed by increasing effectiveness of test, track and trace
Scenario 2
Gradual, medium to long term relaxation - May 10th relaxation with reduction in the effectiveness of social distancing by 10%
Scenario 3
Cyclical relax/restrain - May 10th relaxation with 15% reduction in the effectiveness of social distancing following by subsequent lock down and release
Scenario 4
Extended, but weakening of the initial lock down followed by effective implementation of track and trace





Key reflections…

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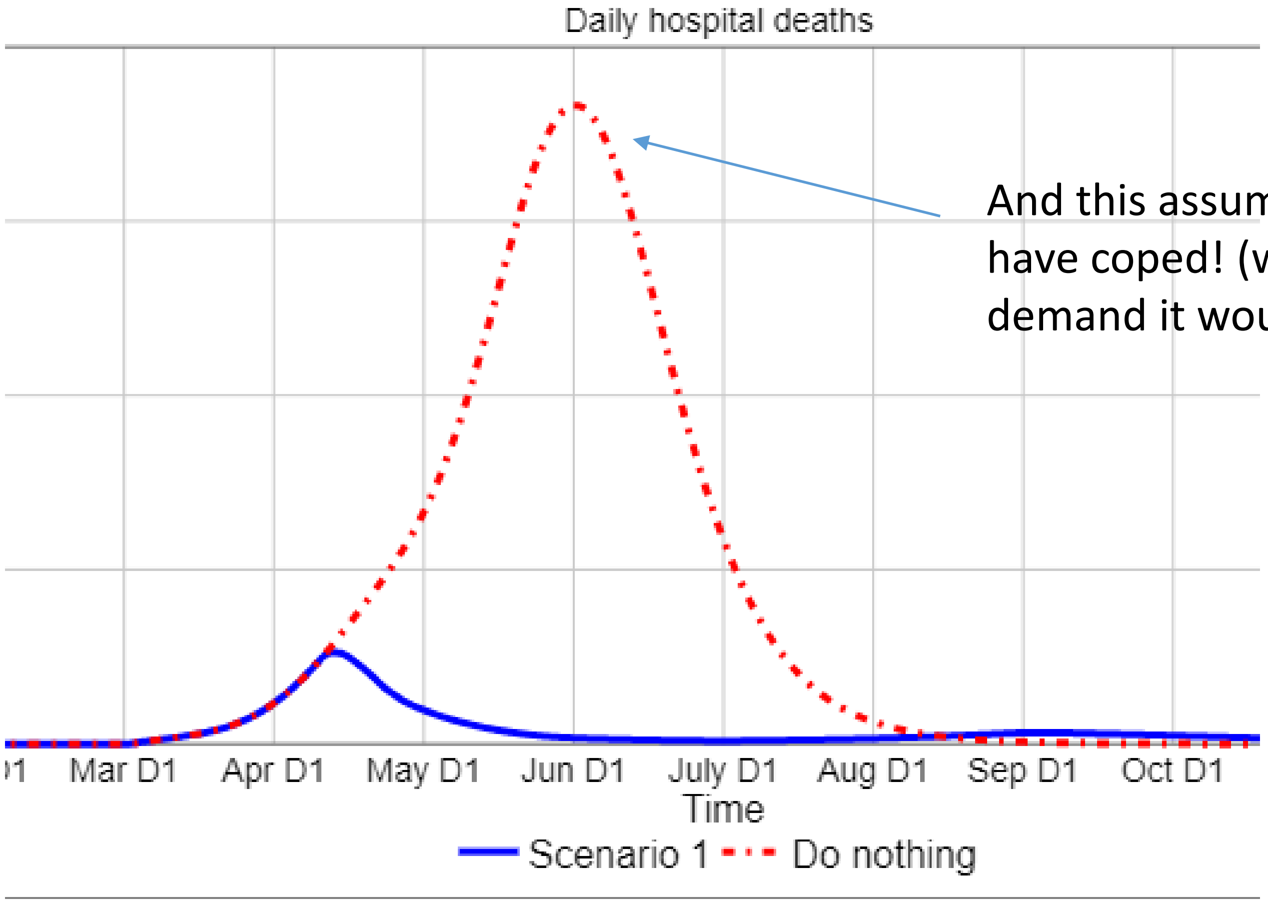
- Daily and accurate information driven locally, but be patient before changing assumptions.
- Create positive and trusting relationships across all stakeholders and system.
- Given the speed and importance of the work a focussed and moderately sized team is required. Get expertise in if required.
- Remain at the strategic level, but remain flexible for very local outbreaks.
- Further consideration to risk groups in regards to ‘setting’, and consider including a ‘setting’ context within the modelling. *(Despite what has been said care/nursing homes were not protected, and many were seeded by Covid+ patients being discharged from hospital into them)*
- Appropriate modelling is key to getting things right. The shift of resources has led to a backlog of healthcare demand we have yet to understand, though we already know that there have been excess deaths above and beyond those directly caused by Covid-19 (though some will have been brought forward)
- Central modelling can work – but would require key assumptions to be changed for local nuisances, e.g. seeding, rate of infection, population health and demographics etc
- SD allowed us to quickly develop a model with very limited data. It was also accessible allowing four modellers to build separate sections and bring together their individual parts seamlessly, normally a dangerous process but we made it work!

The danger of castles and the scenario of ‘doing nothing’…



And this assumes the NHS would have coped! (which with this demand it wouldn’t have)

The model…

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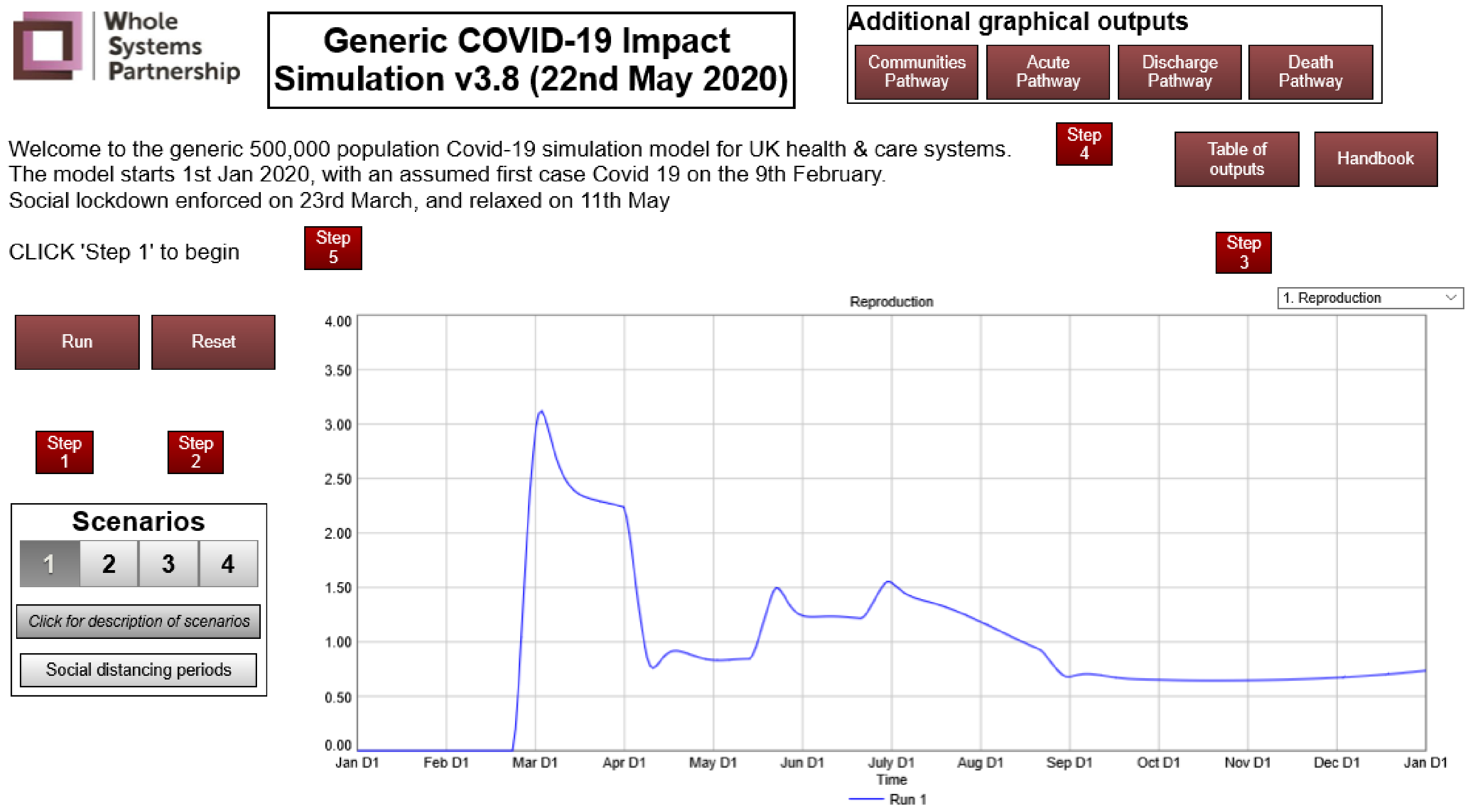
A generic 500,000 population model is created with first infection seeding at the 9th February.

The simulation can viewed and used at the link below…

https://www.thewholesystem.co.uk/covid-19-scenario-and-impact-model/



Thanks for listening…
…and keeping your distance ☺

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