Wales - Reasonable Worst Case (RWC) during Winter 2020/2021

Contents

Summary

As part of SPI-M and the TAC modelling sub-cell, we have agreed the following steering points:

- We anticipate that the age-profile of cases will be younger in future, as a result of differential behavioural patterns. Younger people are more likely to be asymptomatic or mildly symptomatic and therefore less likely to be tested. This will subsequently inevitably lead to increased incidence in higher risk groups.
- As is currently the case, a higher proportion of infections may be in harder to reach groups, such as South Asian communities.
- The nature of exponential growth means that, at first, there will be only a slow accumulation of new cases, but the prevalence of infection will increase more rapidly as time progresses.
- As we move into winter, infected people may be more likely to assume their symptoms are caused by another seasonal virus. They may be less likely to report symptoms if incidence is low in their local area, so that they consider it unlikely that they have COVID-19.
- SPI-M-O do not expect growth rates to reach those seen before the lockdown in March 2020, thanks to the implementation of COVID security, natural caution amongst the population, and increased testing. Doubling times of less than 14 days, however, are possible and have been observed elsewhere in other countries, such as in Japan, Romania, and Spain.
- Monitoring data from the TTP programme should be expanded further. Notably, we should monitor the proportion of confirmed cases that can and cannot be linked to known clusters. This is the best indication of uncontrolled transmission that we have, but this is not yet available to TAC to assess.

Ongoing Work:

We have developed Welsh specific seeded models with Swansea University (adapting the London School of Hygiene and Tropical Medicine) and Armakuni (adapting the Oxford University model). Both have completed multiple runs of the data to identify an appropriate scenario.

In parallel, SAGE has developed a reasonable worst case, based on a scenario identified by the UK Government Cabinet Office. We received the data[1] broken down by week from 1 July 2020 through to 31 March 2021 for the UK on 30 July 2020. Following a request from the CSO of Wales, we received the data[1] broken down by week for Wales covering the same period. This model is presented and discussed throughout this report.

Additionally, other models were considered by the Academy of Medical Science and one scenario from their "Preparing for a Challenging Winter 2020-21" report is also discussed in detail throughout this report.

[1] This refers to the number of infections, deaths, hospital admissions and (total and ICU) maximum bed occupancy due to COVID-19.

Background

A number of RWC scenarios for winter 2020/2021 were considered at the SAGE meeting of 23rd July 2020. However, only one model (Warwick) initially went down to a Wales level. On 30th July, the consensus SAGE RWC was agreed which also went down to a Wales level. The Academy of Medical Sciences (AMS) and UK Government Cabinet Office (UKG CO) also proposed various RWC scenarios.

We have considered numerous scenarios for Wales. However, four main models are chosen and covered in the main body of this report. Model 1 is the consensus SAGE RWC which could be used as the official RWC scenario. Model 2 is one of the AMS scenarios which could be considered a best case scenario. Model 3 is the RWC model developed by Swansea University, and can be considered the most realistic scenario.

The remaining scenarios which were analysed but not chosen are detailed in the annex. Please note these are scenarios of what may happen. They are not predictions of what will happen and should therefore not be planned to.

This report does not change the planning scenarios that NHS and other organisations have been asked to plan for – these scenarios are presented for information only.

Headline Figures [2]

The following table shows the number of infections, hospital admissions, max total (and ICU) bed occupancy, and deaths estimated to occur for the 2 chosen RWC scenarios[3] for Wales between 1st July 2020 and 31st March 2021.

	Infections	Hospital admissions[4]	Deaths[5]	Max total bed occupancy[6]	Max ICU bed occupancy[6]
Model 1: SAGE RWC	410,000	18,000	4,200	1,560	360
Model 2: AMS2 RWC (R rises to 1.1 from 1 September 2020)	n/a (15,300 confirmed cases)	1,600	1,200	570	40
Model 3: Swansea University RWC	809,000	12,100	1,500	1,200	400
Model 4: Armakuni 40/40/70 RWC	1,918,000 (37,300 cases)	32,400	10,400	3,850	750

Commented [AL(1]: Incidence or prevalence here? 60,400 cases.

[2] Figures in this table (and where reported throughout the paper) are rounded to the nearest 1,000 for infections, nearest 100 for cases, hospital admissions and deaths, and to the nearest 10 for total and ICU bed occupancy.
[3] Each of the models are described below the table in this report.
[4] Hospital admissions refers to confirmed COVID-19 patients admitted to hospital for COVID-19.
[5] PHW deaths are used for the SAGE RWC and AMS2 RWC. The Armakuni 40/40/70 RWC refers to hospital deaths only.
[6] Bed occupancy (including ICU bed occupancy) refers to beds occupied by confirmed COVID-19 patients.

Model 1: UK Cabinet Office RWC

On 30th July 2020, SAGE agreed the following RWC Scenario: It involves increasing incidence, based on agreed doubling times, from the end of July to the end of November 2020, reflecting a difficult autumn followed by a large winter peak. After this point, measures are implemented that reduce non-household contacts to 50% of normal, pre-lockdown levels (though all school contacts are maintained) and kept in place until March 2021. This will be modelled for the UK, the four nations, and regions of England.

The commission for this RWCS was designed to consider the whole UK. As policy responses to the epidemic are likely to differ between the devolved nations, it would be expected that each of Scotland, Wales, and Northern Ireland would have different trajectories over time; devolved administrations will want to take this into account. There is potentially significant variability in the devolved nations due to very low case numbers currently, and so these scenarios for Scotland, Wales, and Northern Ireland are likely highly uncertain.

In Wales, under this RWC scenario, between 1 July 2020 and 31 March 2021, there are an estimated 4,200 deaths, 18,000 hospital admissions, and a peak ICU bed occupancy of 400, greatly exceeding Wales' NHS capacity. These figures are higher than the estimates for Scotland (see figure 1 below). This is due to the higher initial incidence in Wales at the start of July compared to Scotland.

The SAGE RWC predicts a similar peak number of deaths to the first peak that happened in April 2020 but with a high number of weekly deaths sustained over a longer time period than in the first peak. It predicts a higher peak of hospital and ICU bed occupancy than the first peak which may be related to the central estimates for length of stay increasing from the previous RWC.

Further detail on this official SAGE-agreed RWC can be found in Annex 1.

Model 2: Academy of Medical Sciences RWC

In July 2020, the Academy of Medical Sciences (AMS) published a paper titled: "Preparing for a Challenging Winter 2020-21". Throughout this report, four different scenarios were stated. One of the scenarios (AMS2) where R rises to 1.1 from September 2020 until July 2021 is included in here as a potential scenario of the best case scenario. The remaining three scenarios are detailed in Annex 4.

Figure 1 provided by the AMS report shows that a second peak did not occur under this scenario. This could be due to assuming a lack of susceptibility[7] is attained at around 9%. However, we have not made this assumption of a 9% lack of susceptibility and so our figures (for admissions, deaths and bed occupancy) continue to grow for longer causing them to rise but not to the levels seen previously in April. Charts showing this can be seen in the Analysis section of this report below.

For AMS2, the number of confirmed cases uses real data (from PHW) until July 1st 2020. From this point, we have assumed R remains at the current level of around R=0.9 until September where R will increase to 1.1. From 1st July onwards, we have

[7] This is the new term adopted, previously referred to as 'herd immunity'.

applied ratios to the projected confirmed cases to determine the admissions, deaths and bed occupancy.

Model 3: Swansea University Model[8]

A COVID-19 epidemic policy model for Wales has been produced by colleagues at Swansea University. They have prepared a stochastic age-structured SEIR epidemic model exploring policy scenarios in Wales, with a focus on the impact of changes in contact structures at schools, work, home, community and shielded environments. The model uses the explicit demographics for Wales, and is calibrated at the local authority level.

The initial exposure in Wales was based on an R_0 of 2.5. Three lockdown parameters are estimated. Each parameter is a % scaling of the normal contact behaviour: pre-lockdown (in the week prior to 23rd March), lockdown (the maximum reduction in contacts) and post-lockdown (a small increase in contacts to reflect increased mobility). Further details on this model can be found in Annex 2.

The following assumed events are considered for the rest of 2020:

- During August, there is a general increase in mobility leading to small increase in contact rates above the post-lockdown level, R_t is close to (but exceeds) 1
- During September there is a further increase in transmission, due to additional mobility and the opening of schools (Rt approximately 1.3).
- During October, the trends in cases are detected, and a reduction in transmission is achieved.
- On 1st November there is a significant increase in winter transmission (Rt approximately 1.5) which is maintained for 30 days.
- Following detection of significant community transmission, and a small rise in deaths, mobility is reduced to similar to lockdown levels. Schools remain open, but with significantly reduced contacts.

Model 4 - Armakuni 40/40/70 RWC Model

Armakuni have carried out modelling work which involves testing changes in social contact levels from the start of September 2020. This experiment simulates different levels of relaxation in social contact in the work, school, and random contact networks of individuals in Wales.

This is an 'agent based model', which is a useful way of simulating the possible spread of a disease given the ways people mix in different networks such as home, work, and in the community. However, this like any model makes significant simplifications versus the complexity of real humans and healthcare systems, as well

[8] Prepared by: Dr Mark Dawson, Dr Ed Bennett, Ms Malorie Perry, Dr Gareth John, Dr Tom Connor, Dr Brendan Collins, Professor Biagio Lucini· Professor Mike Gravenor, Members of Technical Advisory Group (Supercomputing Wales and Swansea University, Public Health Wales, NHS Wales Informatics Service, Health Economics, Welsh Government, Department of Mathematics, Swansea University, School of Biosciences, Cardiff University, School of Medicine, Swansea University).

as there being significant underlying uncertainties about elements such as how many people are asymptomatic spreaders. Therefore the model's projections are a useful guide to how different behaviours and policies might affect outcomes for Wales, but are also subject to uncertainty that comes from all these unknowns.

Various scenarios are modelled ranging from the worst case (i.e. the highest number of infections) where society returns to normal with no social distancing or restrictions to the strictest scenario where the social contacts in schools, workplaces and random social contacts are all set to 20% of their normal level. We have considered each of the scenarios to come up with the most realistic scenario.

We envisage Primary schools will operate as normal (almost 100% of normal level of social contacts but not quite 100% due to handwashing and additional cleaning, etc. However, secondary school staff and pupils will be expected to socially distance. Therefore we have chosen 70% as the closest to the average level of normal contacts across all sectors of schooling.

With the Furlough Scheme coming to an end in August 2020, we estimate that more employees will return to their workplace. However, many will still be working from home and unemployment is expected to increase. Therefore, we consider 40% of the normal social contacts in the workplace to be a reasonable level to set for the most realistic scenario.

It is difficult to determine the most likely percentage for the random social contacts compared to normal times. This should be carefully selected as it has the most impact on the number of infections of COVID-19. We have chosen 40% to be the most likely to occur in reality.

We will refer to this model as the Armakuni 40/40/70 RWC to represent the percentages attributed to random/workplace/school social contacts as a percentage of their normal (pre-lockdown) level.

Further details on this (and the other) Armakuni models can be found in Annex 3.

Analysis

Confirmed Cases/Infections

We were provided with the total number of new infections for the SAGE RWC. For Wales, 410,000 new infections are estimated to occur between 1st July 2020 and 31st March 2021. The total number during this period for the Armakuni 40/40/70 RWC is much higher at 1.9 million.

The maximum number of COVID-19 weekly infections estimated to occur between 1st July 2020 and 31st March 2021 is 28,400 for the SAGE RWC and 202,000 for the Armakuni 40/40/70 RWC. The peaks are predicted to occur in early December 2020 for the Armakuni 40/40/70 RWC compared with late February for the lower SAGE RWC peak.

Figure 1: Weekly COVID-19 Infections

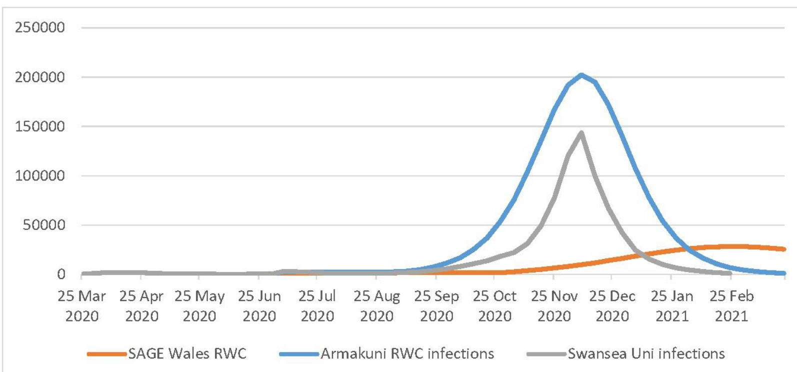
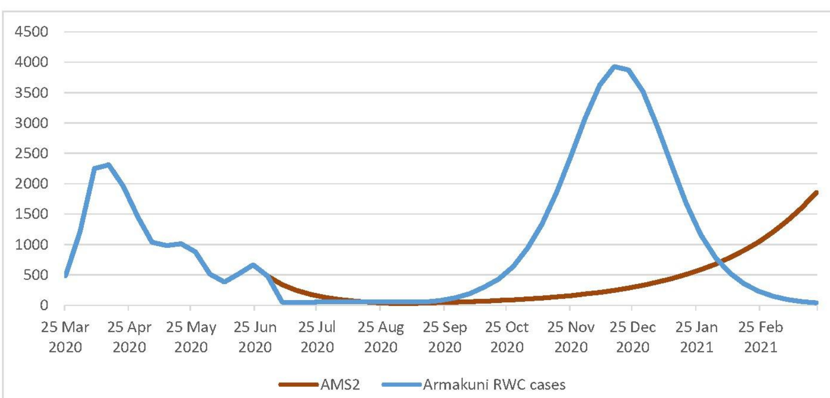


Figure 2: Confirmed cases of COVID-19

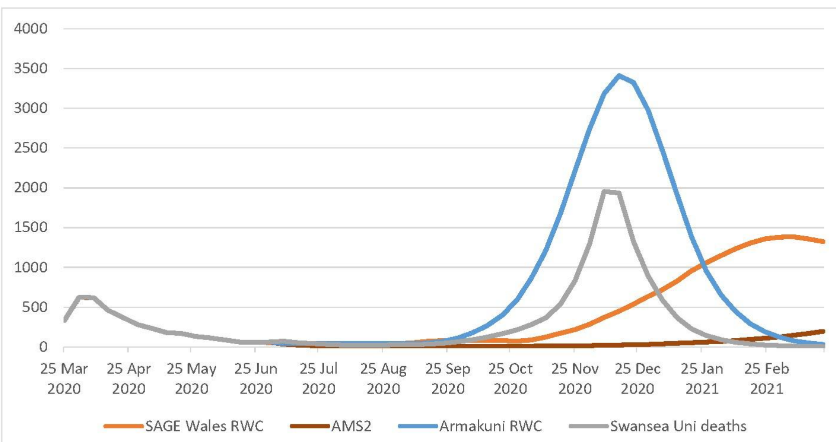


Confirmed COVID-19 Hospital Admissions (source for real data: PHW)
For the AMS scenarios below, a ratio[9] of past confirmed covid-19 hospital admissions to past confirmed cases were used to estimate the future confirmed admissions. Again, the number of hospital admissions are far greater for the AMS and internal WG models than the CO and SAGE models.

Between 1st July 2020 and 31st March 2021, the SAGE RWC estimates 18,000 hospital admissions due to COVID-19 compared with 1,600 for the AMS2 RWC. The Armakuni 40/40/70 RWC predicted a higher figure of 32,400 over the same period.

The Armakuni 40/40/70 RWC peaks earliest (mid December 2020) and reaches a higher level (3,400 admissions per week) compared with the SAGE RWC and Armakuni RWC which reach peaks of 1,400 and 200 per week respectively between 1 July 2020 and 31st March 2021.

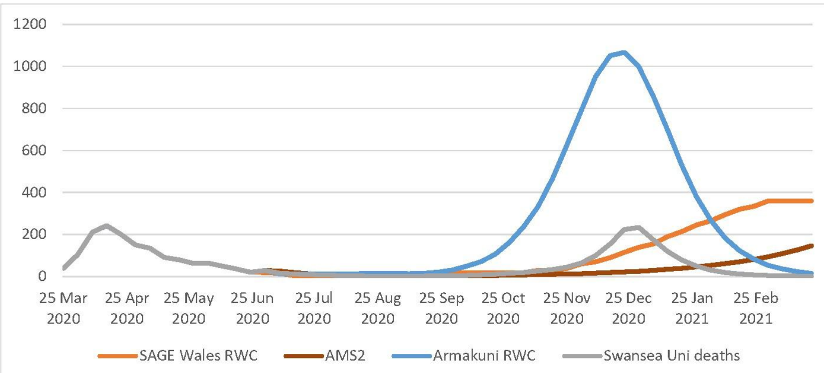
Figure 3: Confirmed COVID-19 Admissions (per week)



[9] A ratio is calculated from past data using a weekly moving average of the latest number of admissions (with a 9 day lag) to the most recent number of confirmed cases.

COVID-19 Deaths (source for real data: PHW)

Figure 4: Number of COVID-19 deaths (per week)



For the SAGE Wales RWC, the weekly deaths for Wales has a higher second peak of around 360 deaths per week verses the peak of 240 a week in April. The AMS2 scenario reaches a maximum of around 150 weekly deaths in the same period. However, the maximum weekly number of deaths estimated by the Armakuni RWC is much higher at 1,100 and occurs months earlier.

The estimated deaths between 1 July 2020 and 31st March 2021 total 4,200 for the SAGE Wales RWC, 1,100 for the AMS2 RWC, and 10,400 for the Armakuni RWC. Between 23rd March 2020 and 30th June (inclusive), there were 1,526 recorded deaths[10] due to COVID-19 in Wales.

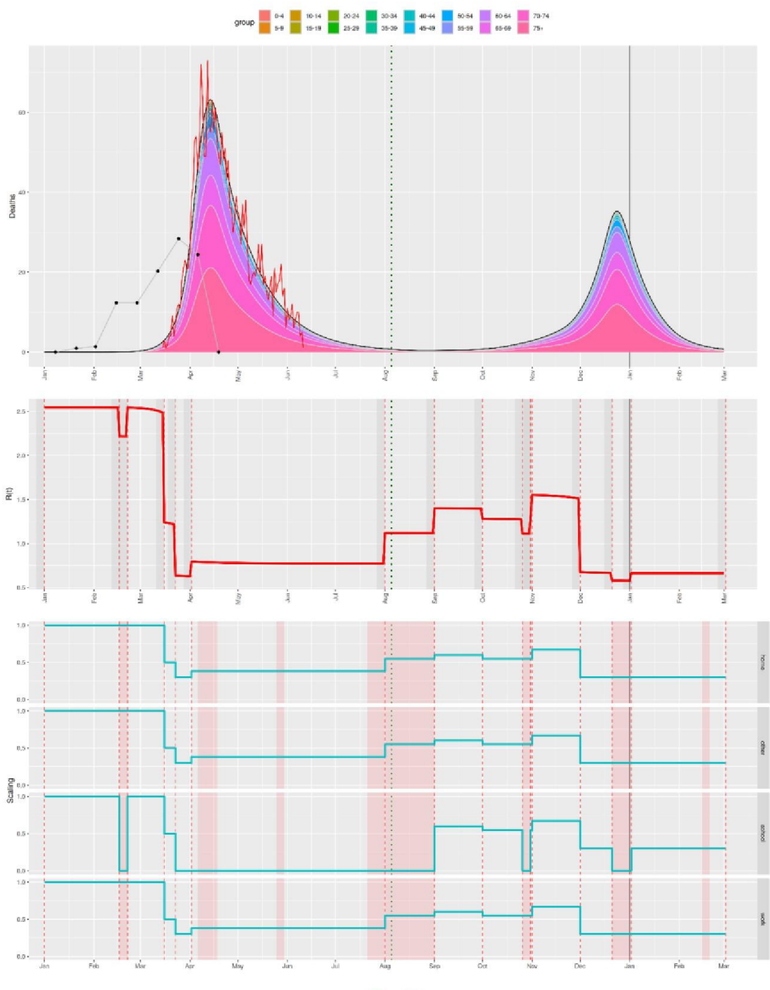
For the SAGE Wales RWC, the number of deaths in Wales is estimated to be higher for Wales than for Scotland and Northern Ireland between 1st July 2020 and 31st March 2021. This is due to the initial higher number of cases at the start of July in Wales compared to the other nations. A large number of these cases are known to have come from the spread of COVID-19 in meat factories in Wrexham and Anglesey which are now under control. Therefore, the RWC may be overly pessimistic for Wales compared to other nations because of this as the data it is based on does not separate out these outbreaks from the impact of continuous community transmission. See Annex 1 for a chart showing the number of deaths for the SAGE RWC scenarios for the devolved administrations.

The Swansea University Baseline RWC scenario shows a second peak of around 35 daily deaths near the end of December 2020 (see Figure 4 below). This is around half of the peak daily deaths of just above 60 in April 2020. However, this figure is not comparable to the deaths in figure 3 above since a different source is used for the deaths in the Swansea University model and we are considering daily (rather than weekly) deaths in the Swansea University model in Figure 5.

[10] Figure from the Public Health Wales tableau, accessed on 2nd August 2020.

However, 2 further scenarios are considered showing different (rapid and delayed) response times of 15 and 45 days respectively in December 2020. The rapid response will reduce the second peak daily deaths figure to around 13, occurring earlier in December 2020, and the delayed response will increase the peak daily deaths to over 80, occurring at the beginning of January 2021. See Annex 2 for charts showing these figures. This conveys the importance of acting quickly once an increase in COVID-19 cases is detected.

Figure 5: Baseline RWC Number of Deaths (modelled by Swansea University)



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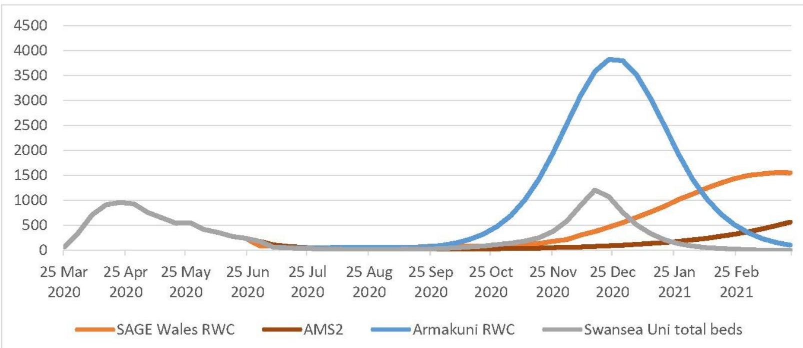
Confirmed COVID-19 total[11] bed occupancy (source for real data: NWIS)

The SAGE RWC estimates a peak total bed occupancy of 1,600 in the week commencing 17 March 2021. By the end of March 2021, the AMS2 scenario reaches a peak total bed occupancy of 570 for confirmed COVID-19 patients.

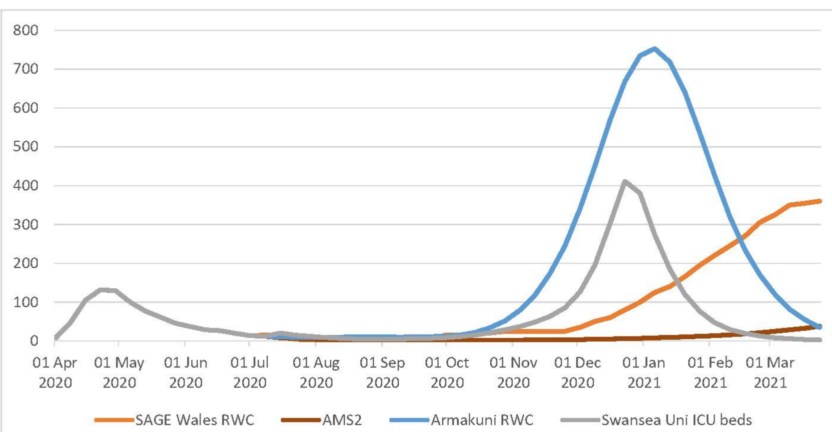
Figure 6: Total bed occupancy (confirmed covid-19)



Confirmed COVID-19 ICU[12] bed occupancy (source for real data: NWIS)

The SAGE RWC estimates a peak ICU bed occupancy of 360 in the week commencing 17 March 2021. By the end of March 2021, the AMS2 scenario reaches a peak ICU bed occupancy of 40 for confirmed COVID-19 patients.

Figure 7: ICU bed occupancy (confirmed covid-19



[11] Total beds includes ICU beds.
[12] ICU beds refers to invasive ventilated beds in the AMS2 scenario.

Assumptions and Limitations

The SAGE RWC figures were based on numerous assumptions detailed in Annex 1.

For the AMS2 model, the actual data for confirmed COVID-19 cases were used up to July first, then the assumption was made that R would remain at around 0.9 up until September 2020. Then daily increases were applied at a rate that equates to R=1.1 according to our internal Welsh Government model.[13] To obtain the number of hospital admissions, deaths, and maximum bed occupancy due to COVID-19, ratios were applied to the modelled confirmed cases each day

Lag and ratio assumptions
The ratios were determined by dividing a weekly average of the number of admissions/deaths/bed occupancy by a weekly average of the number of confirmed cases (to 1st July). However, a lag was also applied to allow for the amount of time between showing symptoms, being admitted to hospital, being admitted to ICU, and dying. For example, we assume a 9 day lag between having covid-19 confirmed by a test and being hospitalised. The ratio of the confirmed admissions to confirmed cases is:

$$\frac{Weekly\ average\ of\ confirmed\ COVID-19\ hospital\ admissions\ (to\ 1st\ July\ minus\ 9\ days)}{Weekly\ average\ number\ of\ confirmed\ COVID-19\ cases\ (to\ 1st\ July)}$$

The following assumptions from days a COVID-19 case is confirmed positive, and then becomes a hospital admission, death etc, and the associated ratio is shown in the table below. Only confirmed covid-19 patients are included:

	Lag behind a COVID-19 case testing positive	Moving ratio to confirmed cases
hospital admissions	9	0.11
Total bed occupancy	9	2.13
ICU bed occupancy	14	0.16
Death	21	0.08

SIR model assumptions
We have made the assumption that after an infection, a recovered person becomes immune to COVID-19 and is no longer susceptible to it. When taking susceptibility to COVID-19 into account, the number of daily infections begin to reduce as lack of susceptibility is approached. The lack of susceptibility threshold is estimated to be (1-(1/R0)) where R0 for COVID-19 is estimated at around 2.4 to 2.8 meaning a lack of susceptibility threshold of 58% to 64%, however there is debate around whether some people have some level of immunity due to exposure to other coronaviruses.[14]

In our modelled AMS2 scenario, we have used a SIR model, but a peak is not reached by 31st March 2021 since not enough people are infected.

[13] See the 'Further internal WG Models' section in Annex 2 for a full explanation of the model.
[14] https://www.immunology.org/news/coronavirus-immunology-qa-what-you-need-know-about-our-new-report

Evaluation Criteria

To determine which RWC is most appropriate to choose as the RWC for Wales, we have evaluated each model according to an objective evaluation criteria. To assess the suitability of each model, we have compared them to the previous spike of infections we saw in April 2020. This will help evaluate how realistic the results are since SAGE/SPI-M have confirmed the second peak is unlikely to exceed the initial peak. We also took the circuit breakers into account, considering the impact of reacting to a breach of a trigger point in certain differing amounts of time. Finally, we compared the outcomes of each model to the outcomes observed from the particularly bad regular flu season observed in 2017/18.

Comparisons to previous peaks:

Confirmed cases of COVID-19 aren't necessarily the best data source to use when comparing the first peak to the possible upcoming second peak as the number of confirmed cases depends heavily on testing. Instead, hospital admissions, bed occupancy in hospital/ICU and deaths would be better metrics to use.

Peaks for weekly real data and predicted peaks of weekly modelled data:[15]

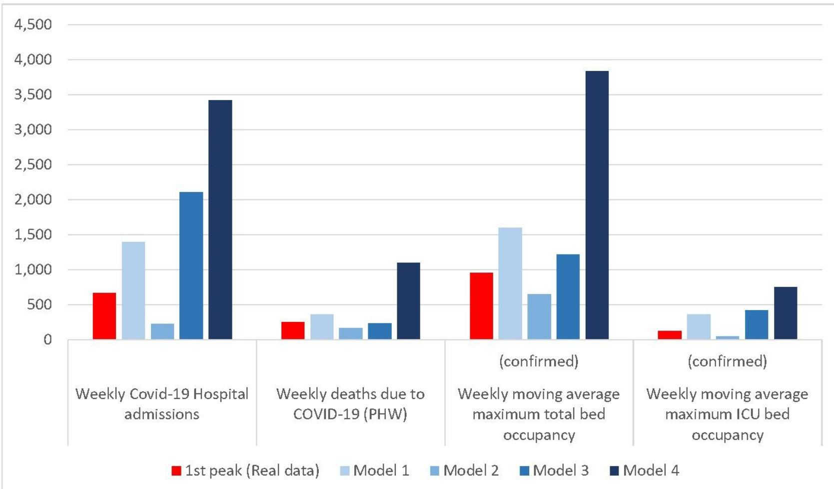
	Weekly Covid-19 Hospital admissions	**Weekly deaths due to COVID-19 (PHW)**	**Weekly moving average maximum total bed occupancy (confirmed)**	**Weekly moving average maximum ICU bed occupancy (confirmed)**
Initial Peak:				
Real data (2020)	670 (4th April)	250 (13th April)	960 (25th April)	130 (18th April)
2nd peak:				
Model 1: SAGE RWC	1,400	360	1,600	360
Model 2: AMS2 RWC	230	170	650	50
Model 3: Swansea University RWC	n/a	240	1,220	420
Model 4: Armakuni RWC	3,420	1,100	3,840	750

The SAGE RWC and Swansea University RWC give results for the second peak most similar to the levels of the initial peak observed in April 2020. The AMS2 RWC gave results that were lower for the second peak across all four metrics whereas the Armakuni RWC gave results for the second peak at a much higher level than initial peak.

The Swansea University RWC gave a similar level of deaths for both peaks, though slightly lower for the second peak.

[15] Figures in the table are rounded to the nearest 10.

Figure 8: Comparisons of weekly peaks



Circuit breaker trigger points reaction times:
Once a circuit breaker trigger point has been hit, it will take a certain amount of time to detect the trigger point, react to it and enact a change. During this time, the levels of COVID-19 may continue to rise. The speed of reaction is extremely important as the longer it takes to react, the worse the situation: there is a significant impact on the numbers of cases, admissions, deaths and bed occupancy as time progresses once a trigger point is hit as can be seen from the figures in the tables below.

For each of the models[16], the first circuit breaker[17] to be breached was when the R rate rose to or above 1.1. However this was not provided for all of the models so was estimated by dividing the number of cases/infections by the number 5 days prior.

Following this, the next trigger point hit was 100 COVID-19 confirmed ICU beds followed by the I COVID-19 confirmed total beds. Since the only data provided/modelled for all 4 RWCs that directly related to a circuit breaker are bed occupancy for COVID-19 confirmed patients, the impact of breaching only these 2 indicators have been considered:

[16] Excluding the AMS2 RWC where a circuit breaker trigger point was never hit
[17] Note that, the doubling time circuit breaker and the bed occupancy indicator which includes Non-COVID patients are not taken into account as the models don't provide the relevant data.

The subsequent tables outline the impact on the figures 1 week, 3 weeks and 6 weeks after the bed occupancy trigger points are hit highlighting the need to react as quickly as possible:

Table 1: The maximum number of ICU beds required 1 week, 3 week and 6 weeks after the trigger point of 100 COVID-19 confirmed ICU beds have been reached

	Trigger hit on:	1 week	3 weeks	6 weeks
Model 1: SAGE RWC	27th Jan 2021	1015	1240	1495
Model 2: AMS2 RWC	-	0	0	0
Model 3: Swansea University RWC	7th Dec 2020	1231	1242	1242
Model 4: Armakuni RWC	6th Nov 2020	1230	2264	3,762

Table 2: The maximum number of total beds required 1 week, 3 week and 6 weeks after the trigger point of 900 COVID-19 confirmed Total beds have been reached

	Trigger hit on:	1 week	3 weeks	6 weeks
Model 1: SAGE RWC	23rd Dec 2020	100	140	220
Model 2: AMS2 RWC	-	0	0	0
Model 3: Swansea University RWC	19th Nov 2020	150	359	427
Model 4: Armakuni RWC	30th Oct 2020	147	299	629

Comparison to 2017/18 flu season: Potential impact of other major respiratory viruses on surveillance, testing and services directed at SARS CoV-2 mitigation.

COVID-19 is one area that needs to be carefully planned for during the winter of 2020/21. However, with the flu season approaching, rising cases of the flu need to be taken into account, particularly as flu and COVID-19 present with similar symptoms. The following subsection[18] outlines how flu has presented over a 30 year period to 2016/17:

It has been demonstrated that the initial symptoms of infection with SARS CoV-2 are varied and can often be confused with other common respiratory pathogens; Influenza, Respiratory Syncytial Virus, Adenovirus, Parainfluenza and Rhinoviruses, all of which can commonly circulate in winter months. This confusion over the coming autumn and winter period, when the nation will be on heightened alert for a resurgence in COVID-19 cases, can lead to increased demands on Test, Trace and Protect efforts. As health boards and local government start to formulate their response plans for a potential 'second wave' of COVID-19 there exists the additional burden from these other viral diseases that need to be factored in.

[18] Kindly provided by Professor John Watkins (PHW).

Of all the common respiratory pathogens that cause increased demand during the autumn and winter periods, Influenzas A, B and RSV are responsible for the most significant impact on healthcare. These viruses are known to increase morbidity and mortality amongst the very young, the elderly and those with underlying chronic conditions, increasing attendance at GP surgeries, hospital admissions and deaths.

Public Health Wales has (with its predecessor organisations) monitored influenza activity and other respiratory pathogens, for over 30 years and has a comprehensive database of respiratory consultations with GPs, in Wales, see Table 1 and Figure 1.

Currently, Influenza activity in the Southern Hemisphere has been very low, compared to previous seasons, with Australia reporting activity of respiratory viruses well below season norms, this observation may well be due to the social distancing measures that have been introduced for COVID-19, as all these respiratory pathogens share common transmission mechanisms. This could bode well for reduced levels of other respiratory viruses in Wales during this coming season.

Since there has been no significant drift seen in the four Influenza A and B viruses that commonly circulate and with the widening in the cohorts of the population recommended for vaccination, estimates of the reasonable worst case scenario, for the additional impact of Influenza, can be arrived at by averaging the attack rates seen in previous winters, Table 1 and Figure 1 below. *Welsh GP Surveillance Scheme*

The other major respiratory pathogen RSV causes significant disease in the very young and the elderly most winters and in some years exceeds the cases admitted to hospital and deaths from Influenza, Figure 2 below, taken from the gov.uk website, illustrates this point. However, hospital admissions and deaths from RSV rarely exceed, on average, that of Influenza and so one can again estimate, for planning purposes, this additional burden from the available, averaged, influenza data.

The approach outlined above is likely to be more fruitful and realistic than reverting to modelled scenarios and, for reasons outlined above with regard to social distancing, likely to overestimate the true impact that will be seen.

Table 1

Flu Season (Oct-Apr)	Peak Seasonal Rate (per 100,000 population)	Week (week beginning)	Predominant Seasonal Flu Type/s
1987/88	61	12 (16/03/88)	B
1988/89	161	49 (30/11/89)	A
1989/90	586	50 (13/12/90)	A
1990/91	159	07 (13/02/91)	B
1991/92	66	02 (08/01/92)	A and B
1992/93	16	14 (31/03/93)	A
1993/94	78	47 (17/11/93)	B
1994/95	80	05 (01/02/95)	A
1995/96	63	51 (20/12/95)	A and B
1996/97	108	01 (12/01/97)	A
1997/98	24	51 (28/12/97)	A and B
1998/99	95	01 (10/01/99)	A
1999/00	190	01 (09/01/00)	A and B
2000/01	18	10 (11/03/01)	A
2001/02	10	06 (10/02/02)	A
2002/03	8	53 (05/01/03)	A
2003/04	12	47 (30/11/03)	A and B
2004/05	10	07 (20/02/05)	B
2005/06	16	06 (12/02/06)	A
2006/07	18	07 (18/02/07)	A and B
2007/08	9	01 (01/01/08)	A
2008/09	25	01 (04/01/09)	A
2009 Pandemic (May 09-Aug 10)	79 (1st wave)	30 (02/08/09)	A(H1N1)
	66 (2nd wave)	42 (18/10/09)	A(H1N1)
2010/11	93 (3rd wave)	01 (09/01/11)	A(H1N1)
2011/12	11	08 (20/02/12)	A(H3N2)
2012/13	26	02 (07/01/13)	B (yamagata lineage)
2013/14	9	08 (10/02/14)	A(H3) and A(H1N1)
2014/15	23	02 (05/01/15)	A(H3)
2015/16	26	11 (14/03/16)	A(H1N1)
2016/17	25	01 (02/01/17)	A(H3)

Source: *Welsh GP Surveillance Scheme, Public Health Wales Communicable Disease Surveillance Centre*

Figure 1

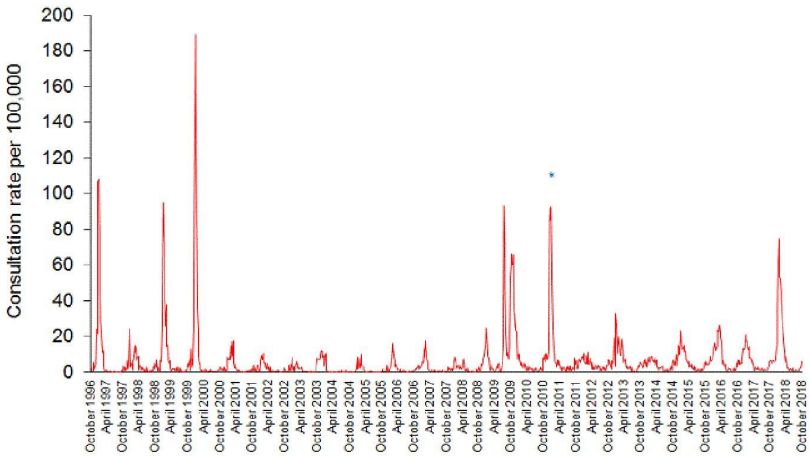
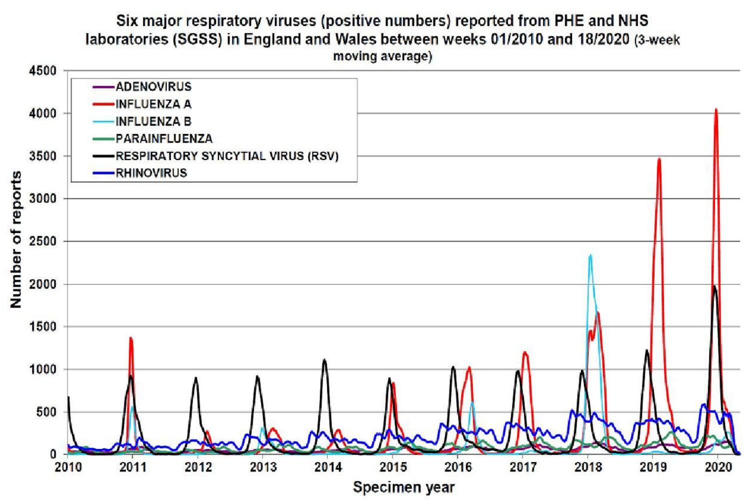


Figure 2



Source: https://www.gov.uk/government/publications/respiratory-virus-circulation-england-and-wales/six-major-respiratory-viruses-reported-from-phe-and-nhs-laboratories-sgss-in-england-and-wales-between-week-1-2009-and-week-23-2019

Conclusion

When considering all 4 models, in general, the AMS2 RWC gives the lowest values, the Armakuni RWC gives the highest values and the SAGE RWC and Swansea University RWC give figures in between that appear to be more in line with the previous peak. Out of these latter two models, the Swansea University model is seeded to Wales whereas the SAGE RWC is not. Combining 4 models takes into account the uncertainty in the time it may take to identify and react to a change. The higher the number of cases that are seeded into the model, the quicker the exponential growth that are observed.

The Swansea University model could be chosen as the reasonable worst case scenario for these reasons but also because it provides further analysis to just the baseline scenario covered in the main body of this report. Annex 2 also contains different versions of this same model conveying the outputs based on differing response rates to hitting circuit breaker trigger points. You can consider the most suitable version of this one RWC depending on whether you can respond quickly or less rapidly when trigger points are hit. Additionally a 4th version of this Swansea University is provided taking shielding into account which could also be useful to consider.

Therefore we consider the most value can be taken from the Swansea University model and we would recommend it as our official RWC for Wales.

Next steps

Quality assurance of models with:

- SPI-M/ SAGE,
- WG Modelling Assurance groups; and the
- all Wales Modelling Forum

Seeking Ministerial approvals.

Applying the Welsh RWC to local geographies to support local planning.

Annex 1: SAGE RWC – Further Detail

Figure 1 conveys how COVID-19 progresses for the SAGE RWC. The below chart shows the estimated incidence of COVID-19 in the UK from 1 July 2020 to 31st March 2021:

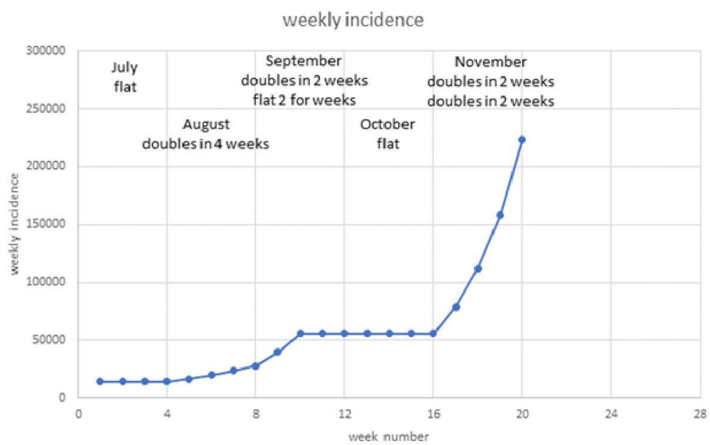


Figure 9: Weekly Incidence of COVID-19 under the RWCS (in the UK)

SAGE RWC in detail:

The following bullets describe the way the SAGE RWC model develops over time:

- Incidence continues as per current trends until the end of July 2020 with all non-household contact assumed to be approximately 70% of "normal" pre-lockdown levels119
- Incidence doubles once by the end of August 2020
- Incidence doubles during the first two weeks of September, after which policy measures reduce R to around 1, until the end of October.
- A two-week doubling time for incidence returns throughout November
- At the end of November, policy measures are put in place which:
  - SCENARIO A: All non-household contacts are reduced to 25% of their normal (pre-lockdown) levels
  - SCENARIO B: All non-household contacts are reduced to 35% of their normal (pre-lockdown) levels
  - SCENARIO C1: All non-household contacts (including school contacts) are reduced to 50% of their normal (pre-lockdown) levels

[19] Current contact rates are significantly lower than 70% of their pre-lockdown levels. To remain consistent with current trends, this element of the commission has not been followed.

- **SCENARIO C2: All non-household contacts are reduced to 50% of their normal (pre-lockdown) levels; all school contacts are maintained. Scenario C2 is chosen as the RWC Scenario.**

- These measures are sustained until the end of March 2021
- An improved standard of care during this period with generalised use of dexamethasone is also assumed.

Assumptions

The following assumptions were stated in the RWC consensus statement for SAGE on 30th July 2020:

Table 1: Severity estimates for stages of COVID-19

Risk	Proportion (range)
Proportion of infections which have symptoms	66%
Infected people hospitalised	2.4% (0.0% – 8.9%)
Hospitalised (non-ICU) patients transferring to ICU (HDU/ITU)	20.5% (1.5% – 35.2%)
All hospitalised patients dying	23.3% (1.2% – 43.3%)
Overall infection fatality rate	0.7% (0.0% – 9.7%)

Table 2: Average length of stay for COVID-19 hospitalisation phases

Period	Mean length of stay in days (range)
Hospital (non-ICU) admission to transfer to ICU (HDU/ITU)	2.0
Hospital (non-ICU) admission to death or discharge *without* an ICU (HDU/ITU) admission	8.7 (7.9 – 9.2)
ICU (HDU/ITU) stay	10.6 (8.9 – 12.1)
Hospital (non-ICU) admission to death or discharge *with* an ICU (HDU/ITU) admission†	19.0 (17.3 – 20.5)

† Includes step-down care in hospital (non-ICU) following ICU stay but prior to discharge of 6.4 days.

COVID-19 Deaths ccross the Devolved Administrations

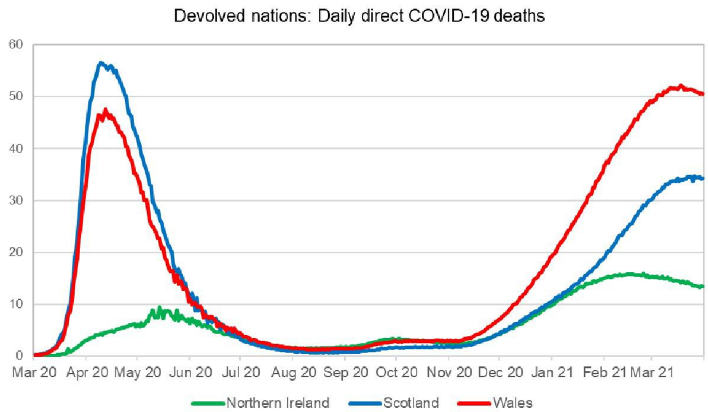


Figure 10: RWCS daily direct COVID-19 deaths for Scotland, Wales and Northern Ireland, actual data to end of June, RWCS estimation from 1 July 2020 to 31 March 2021

Further Considerations

Due to the pessimistic outcome of this modelling by Imperial where measures in Scenario C do not bring the second wave under control despite starting incidence around that currently estimated, and the scale of the sustained pressure on the health and care system, this model and scenario have been chosen as the revised RWCS by SPI-M-O.

SPI-M consider a worse scenario than that agreed by COVID-S is a realistic possibility. The outbreak could manifest in different ways, and this is a reasonably, bad scenario to plan for. Local planners should be able to respond to this scenario and also be able to flex those plans if the outbreak develops in a different way, particularly earlier

Annex 2: Swansea University Model – Further Detail

At the UK level, SAGE and the modelling group SPI-M have provided a number of very detailed simulation models for COVID-19 analysis and forecasting. Swansea University explored a range of these models, available on the code open access repository GitHub, for use in analysing the outbreak in Wales. The analysis provided here is based on the dynamic transmission model COVID-UK, prepared and published by Davies et al at the Centre for Mathematical Modelling of Infectious Disease (CMMID, London School of Hygiene and Tropical Medicine). Full details of the model are available in Davies et al[20], and https://github.com/cmmid/covid-uk. Briefly, the COVID-UK model structure is:

- Stochastic, tracking up to 66.4 million people at the UK level over time steps of 6 hours, hence the output is probabilistic and a distribution of outcomes can be obtained from a fixed set of parameters.
- Age-structured into 16 age bands, with demographics provided at the local authority level.
- There are 6 Disease states: Susceptible (S), and after successful transmission Exposed (E) but not infectious. After a latent period approximately 50% of infectious individuals are asymptomatic (I_s), while the rest enter a pre-clinical, but infectious state (I_p) followed by a clinical symptomatic infectious state (I_c) followed by isolation and recovery (R). The waiting times in each state are gamma distributed[2].
- Age-specific hospitalisation rates, fatality rates, and duration of hospital stay, estimated from the early stages of the pandemic are used to monitor the impact of the epidemic and health service capacity[2].
- A detailed description of the transmission between individuals based on measured social mixing patterns provided by the POLYMOD study[21]. Contact matrices are provided for home, school, work and community, all stratified by age band.
- The force of infection at time t for an individual is then given by the product of the susceptibility to infection upon contact and the number of contacts per day (all age specific).
- Scenarios are explored by scheduling changes to the number of contacts expected in each age group, and how this varies over time, for example when schools open/close, when lockdown measures dramatically decrease contacts, and when relaxation gradually increases the contact rate.
-

Following modifications to allow for flexible initial conditions and flexible scheduling of combinations of interventions over long time periods, the version of the model being used is available on Swansea University's code repository (https://github.com/sa2c/covid-uk).

The Baseline RWC scenario shows a second peak of around 35 daily deaths near the end of December 2020. However, 2 further scenarios are considered showing

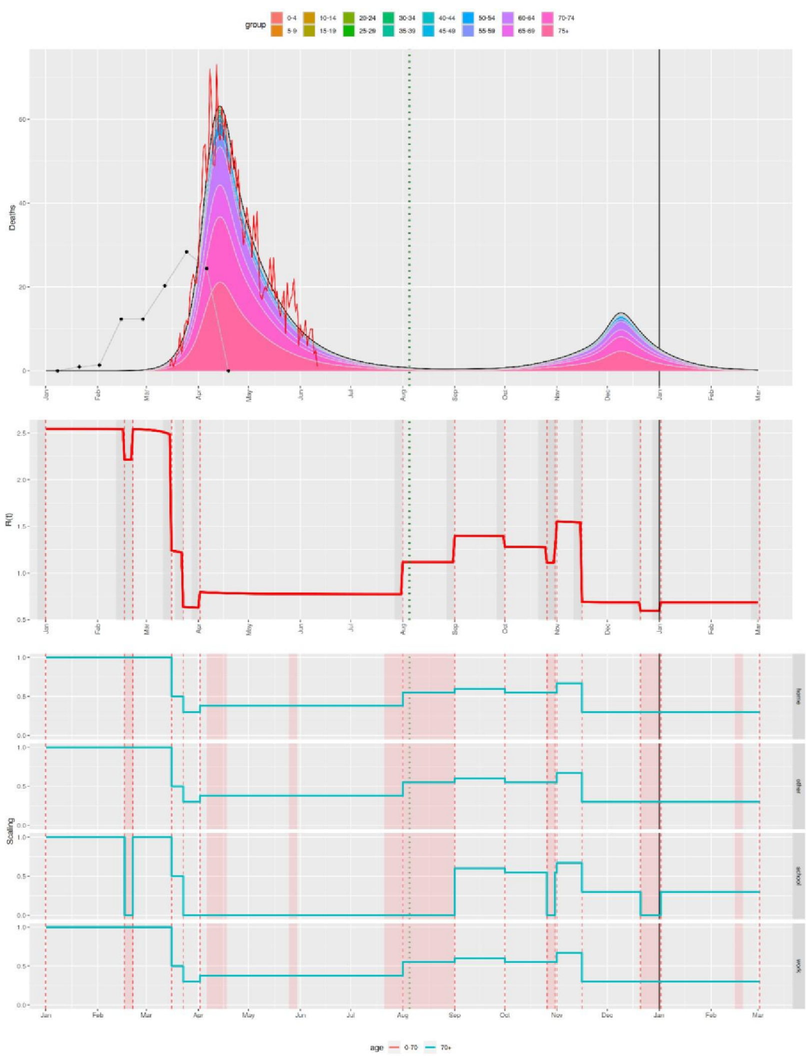
[20] N Davies et al (2020). Effects of non-pharmaceutical interventions on COVID-19 cases, deaths, and demand for hospital services in the UK: a modelling study. *The Lancet Public Health* 5 (7) E375-E385. DOI:https://doi.org/10.1016/S2468-2667(20)30133-X

[21] Mossong et al (2008). Social contacts and mixing patterns relevant to the spread of infectious diseases. *PLoS Medicine* 5 e74.

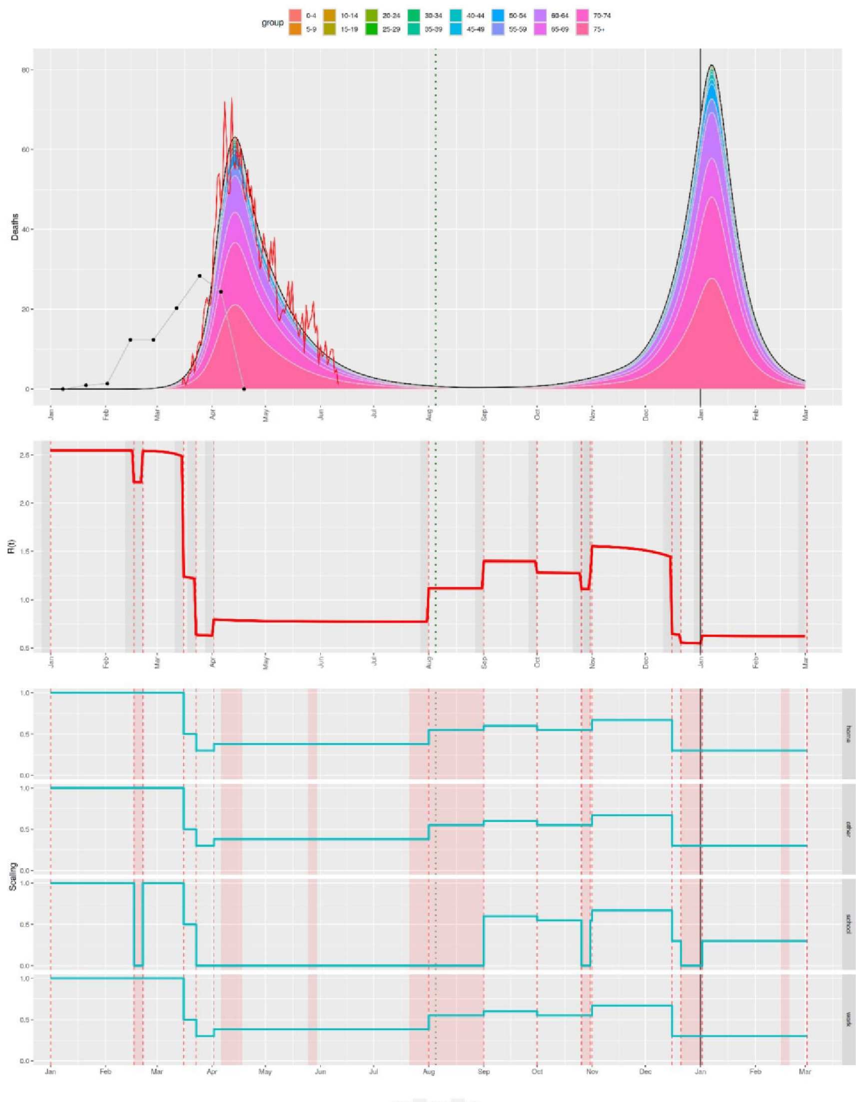
different (rapid and delayed) response times of 15 and 45 days respectively in December 2020.

The rapid response will reduce the peak daily deaths to around 13, occurring earlier in December 2020, and the delayed response will increase the peak daily deaths to over 80, occurring at the beginning of January 2021. This conveys the importance of acting quickly once an increase in COVID-19 cases is detected.

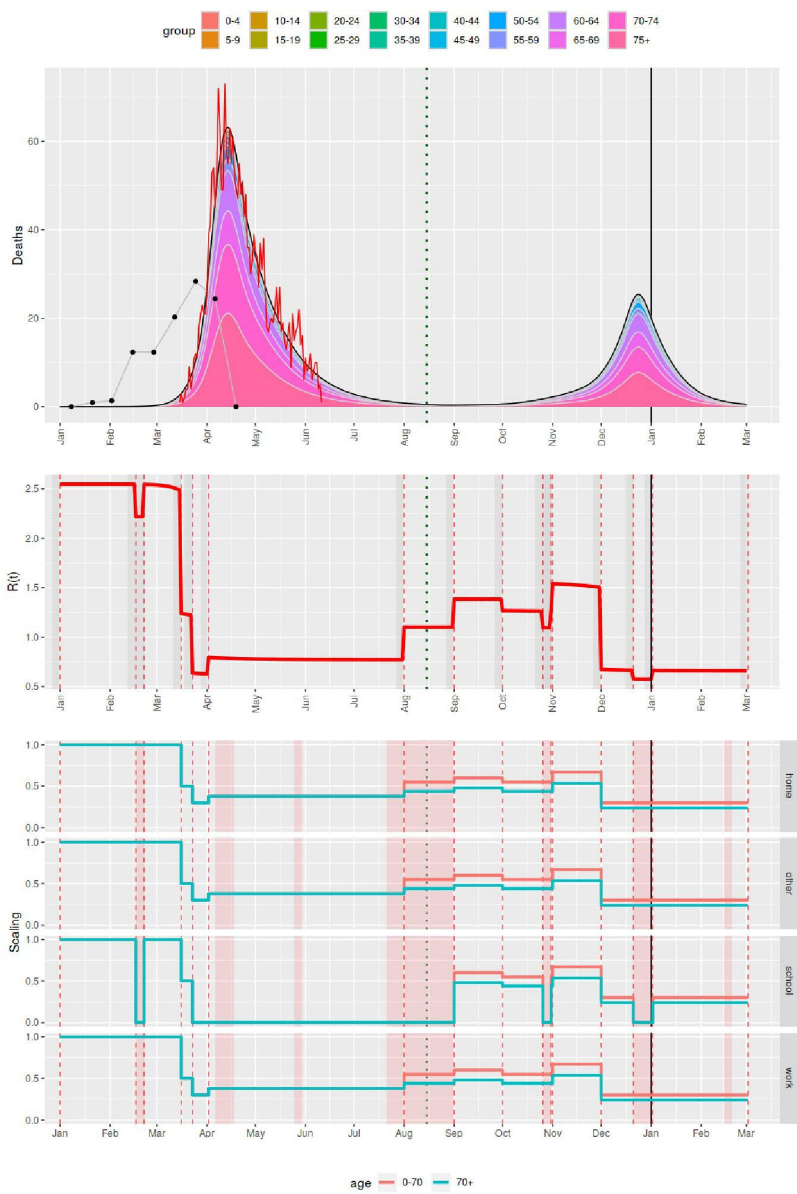
RWC Baseline + Rapid December Response



RWC Baseline + Delayed response



RWC Baseline + Shielding



Annex 3: Armakuni Model – Further Detail

The below records important aspects of the model inputs, process, and significant assumptions when using it in Wales. This should be read in conjunction with the core documentation of the OpenABM model[22], which explains how the generic model is set up.

Inputs

- We are using weekly data for all UK from the CoMix study to determine multipliers on random, workplace, and quarantine interactions by age group during the lockdown period, interpolating for missing weeks in May. We have found that using 'pure' CoMix data for lockdown interactions leads to underestimation of the ongoing infection levels (and consequent hospitalisations and deaths) during the lockdown period, so are multiplying the data by a constant of 1.4 to more realistically reflect actual behaviour.
- We are not using CoMix for household contacts data, as we do not have a comparable baseline for this data - we are using the original model assumption that all members of a household will mix
- For the "% of deaths in ICU" figures, we are using the defaults plus some adjustments in the oldest age groups to create internal consistency with RWCS papers, since no other authoritative source is currently available, and death location is not a key concern for Wales
- All other inputs are informed by Welsh Government views on the most reliable recent source for each.

Process

- The model was run 25 times[23] and the average and standard deviation (sd) of these runs were used as the output for a given set of inputs. At Wales scale, the standard deviation of key measures (e.g. number of daily infections) begins to stabilise for sample sizes greater than 20, and Armakuni do not see significant improvements in the stability of the mean or sd after 25.
- The model timeline is aligned by tracking cumulative hospital admissions up until the first "lockdown policy change" on 12th March. At that date there had been 551 cumulative admissions according to PHW data, so whenever running a simulation we align calendar time to model time based on when the simulation first hits that figure.
- In order to ensure the model fits as well as possible to Wales' real situation, it was calibrated by:
    - allowing the mean infectious period and infectious rate of the disease to vary using a 'grid search' until we find the best fit to Wales' real cumulative deaths and cumulative hospital admissions figures.

[22] OpenABM model version: eu.gcr.io/wales-gov-covid-dashboard/wg-model:v0.2
[23] See the Variance Jupyter Notebook - variance.ipynb) for the experiment used to arrive at this conclusion

- measuring fit by checking the total mean squared error between these real figures and those output by the model (both normalised, so total error is in the range 0-2), and finding values of infectious period and infectious rate that minimise the error over the March-June period
- beginning our search for these parameter values at the initial assumptions used UK-wide. These were chosen to vary as this is the approach approved by BDI and Faculty.ai for their England implementation, and we know that these parameters can reflect underlying structural social factors such as comorbidities.

Key risks and assumptions

- Parameters on human behaviour (e.g. levels of social contact over time) are heavily based on UK-wide survey data, and are not Wales-specific.
- There are very wide error bounds on aspects of the disease, in particular the prevalence of coronavirus - that is, we cannot be sure of the difference between the number of known cases and the number of people affected, and are updating our assumptions based on the most recent scientific data.
- The model relies on assumptions about social network structures within home, work, and the wider community, which leads to emergent findings about the apparent Rt and level at which 'lack of susceptibility' arises. Changes to assumed social network structure would change these outcomes.
- The model is based on a single geographic area, and does not look at cross-border interactions or at geographic divisions within an area.

Sense checking

Armakuni's latest "stable" model inputs and outputs are stored at gs://wales-gov-covid-modelling-openabm-output/20200724-fix-params/, and should be used for comparison with any proposed policies

Annex 4: Further RWC models considered

The following RWC scenarios were analysed but were not chosen:

Academy of Medical Sciences (AMS)

The AMS published a paper called: "Preparing for a Challenging Winter 2020-21" which considered 4 scenarios for the UK. One of these (AMS2 - where R rises to 1.1 from September 2020 through to July 2021) was chosen as a Wales RWC and is included in the main body of this report.

The AMS models are:

AMS1. A RWC where Rt rises to 1.7 from September 2020 onwards – suggests a peak in hospital admissions and deaths in January/February 2021 of a similar magnitude to that of the first wave in spring 2020. Eventually cases fall from February 2021 as lack of susceptibility effects start to come into play.

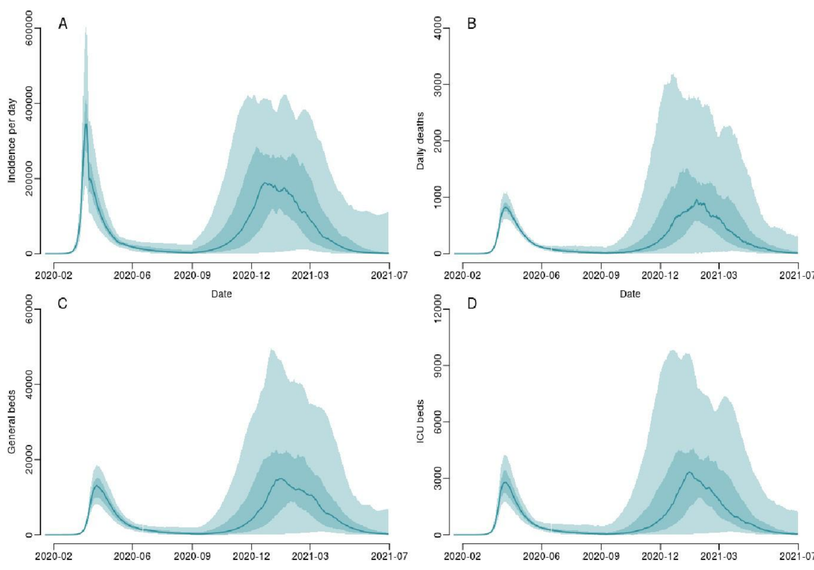


Figure 11 RWC scenario for the winter COVID-19 epidemic in the UK. The model assumes that Rt rises to 1.7 from September 2020 through to July 2021. (A) Daily infections, (B) COVID-19-attributable deaths in hospital (i.e. excluding care homes and excess deaths in

AMS2. This model assumed Rt = 1.1 from September 2020 through to July 2021.

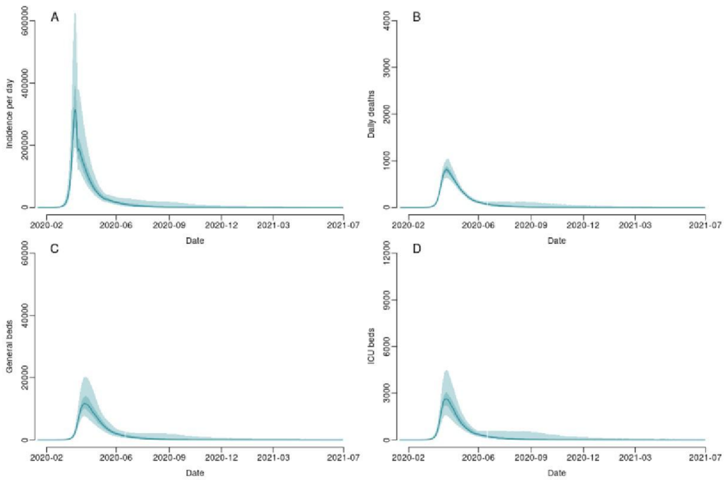


Figure 12: This model assumes that Rt = 1.1 from September 2020 through to July 2021. (A) Daily infections, (B) COVID-19-attributable deaths in hospital (i.e. excluding care homes and excess deaths in the community), (C) general beds occupied and (D) Critical Care

AMS3. This model assumes Rt = 1.5 from September 2020 through to July 2021.

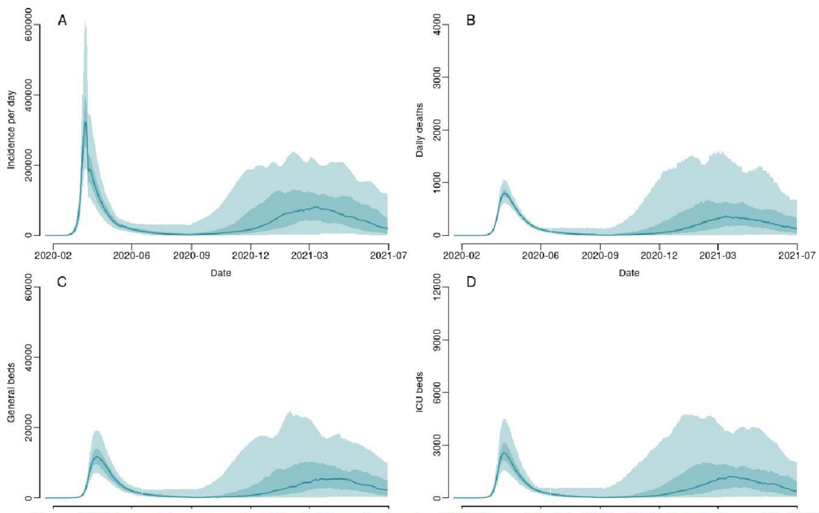


Figure 13 This model assumes that Rt = 1.5 from September 2020 through to July 2021. (A) Daily infections, (B) COVID-19-attributable deaths in hospital (i.e. excluding care homes and excess deaths in the community), (C) general beds occupied and (D) Critical Care

AMS4. The AMS report suggests using the winter of 2017/18 as a RWC scenario as it was a particularly difficult winter for NHS admissions/care/demand as a result of a bad flu season. We are currently waiting on historic data for Wales to be able to model this.

Cabinet Office scenario
By 17 July new daily hospital admissions are sustained at less than 0.5 per 100k per week (or 48 per day across the UK);

From November onwards we face the beginnings of a second peak, with daily incidence rising above 2,000 per day confirmed cases and new hospital admissions to above 5 per 100k per week by the end of November.

As early as mid-July we face the beginnings of a second peak, with daily incidence rising above 2,000 per day confirmed cases and new hospital admissions to above 5 per 100k per week. From November onwards, daily incidence rises further to over 3,000 per day confirmed cases.

Scotland Scenario
Scottish Government have produced their own RWC which may be useful to consider. It uses this scenario:

- A resurgence starting at the beginning of September leads to a small peak, and thus a higher number of infected people by the beginning of winter
- Test and Protect is fully mature, and rapidly identifies new cases once they develop symptoms
- Control measures are less effective than previously, increasing R0 to around 1.1 for a month at the beginning and end of winter, and around 1.5 for two months in the middle of winter
- Peak incidence reaches around 3 times the height of the original peak

Further internal WG Models
The Welsh government have adapted a method from Maynooth University which uses the R0 package[24] to produce likelihood based, time-varying estimates of R[25]. To create an epidemiology model, the R programme used a generation time code with a Gamma (4.7, 2.9) distribution to determine the R value where 4.7 refers to the serial interval (in days), and 2.9 days is the standard deviation. For the RWC

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[24] Thomas Obadia, Romana Haneef and Pierre-Yves Bo?lel, The 'R0' package: a toolbox to estimate reproduction numbers for epidemic outbreaks, *BMC Medical Informatics and Decision Making*, 2012, 12:147 (http://www.biomedcentral.com/1472-6947/12/147)

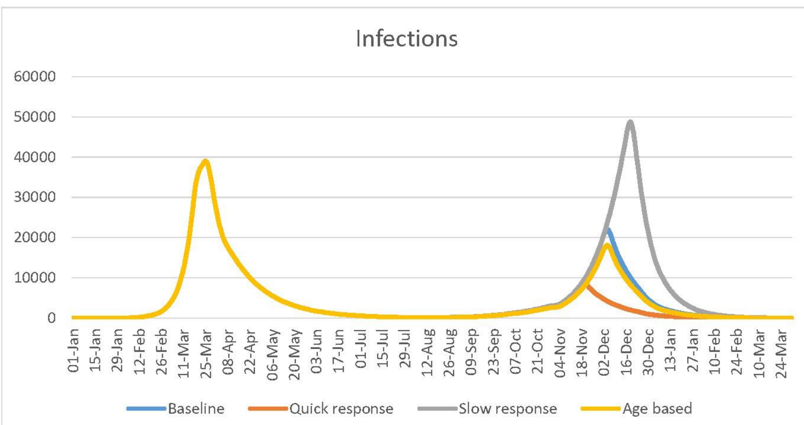
[25] Jacco Wallinga, Peter Teunis, Different Epidemic Curves for Severe Acute Respiratory Syndrome Reveal Similar Impacts of Control Measures, *American Journal of Epidemiology*, Volume 160, Issue 6, 15 September 2004, Pages 509–516, https://doi.org/10.1093/aje/kwh255

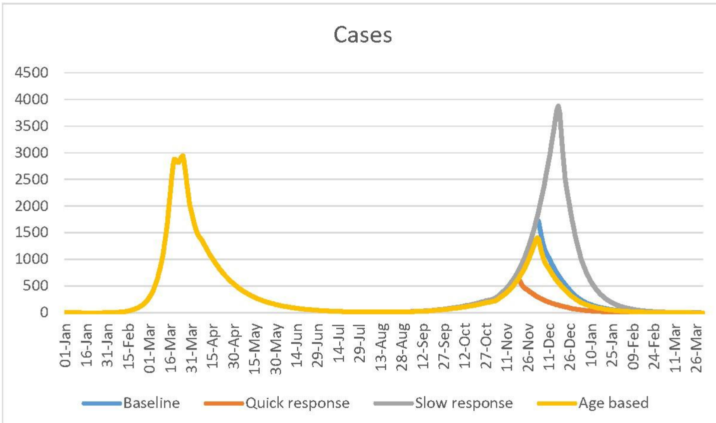
scenario, we use an R value of 1.7 from September onwards which equates to a daily growth rate of around 13%.

Two further scenarios using a daily growth rate of 8% and 12% respectively have been used. These value are chosen as the upper and lower growth rate values for R=1.7 using different model parameters in a model carried out by academics (sent to us by Mike Gravenor at Swansea University).

Annex 5: Swansea Uni RWC combined

To accompany the baseline RWC provided by Swansea Uni, we received additional scenarios where there was a quick response to circuit breakers being triggered (15 days), a slow response (45 days), and a further scenario where age (and shielding) were taken into account. These 4 scenarios can be considered together for each of the indicators to help determine which outcome is most likely depending on how quickly a reaction to a trigger point can be enacted:




Cases
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01-Jan
16-Jan
31-Jan
15-Feb
01-Mar
16-Mar
31-Mar
15-Apr
30-Apr
15-May
30-May
14-Jun
29-Jun
14-Jul
29-Jul
13-Aug
28-Aug
12-Sep
27-Sep
12-Oct
27-Oct
11-Nov
26-Nov
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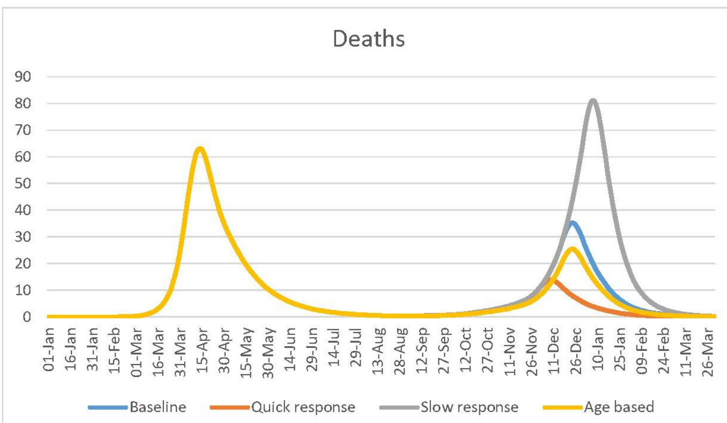
26-Dec
10-Jan
25-Jan
09-Feb
24-Feb
11-Mar
26-Mar
Baseline
Quick response
Slow response
Age based


Deaths
90
80
70
60
50
40
30
20
10
0
01-Jan
16-Jan
31-Jan
15-Feb
01-Mar
16-Mar
31-Mar
15-Apr
30-Apr
15-May
30-May
14-Jun
29-Jun
14-Jul
29-Jul
13-Aug
28-Aug
12-Sep
27-Sep
12-Oct
27-Oct
11-Nov
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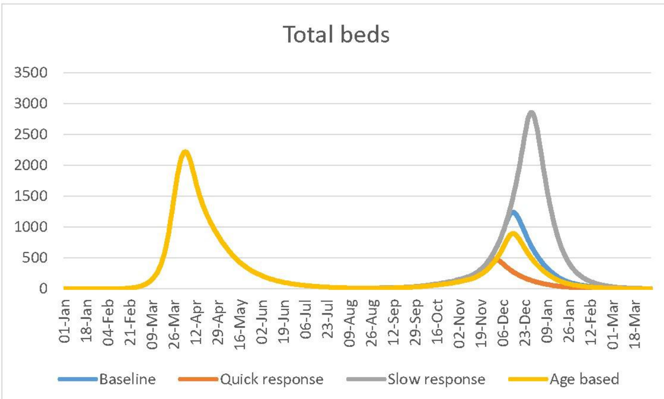
11-Mar
26-Mar
Baseline
Quick response
Slow response
Age based


Total beds
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3000
2500
2000
1500
1000
500
0
01-Jan
18-Jan
04-Feb
21-Feb
09-Mar
26-Mar
12-Apr
29-Apr
16-May
02-Jun
19-Jun
06-Jul
23-Jul
09-Aug
26-Aug
12-Sep
29-Sep
16-Oct
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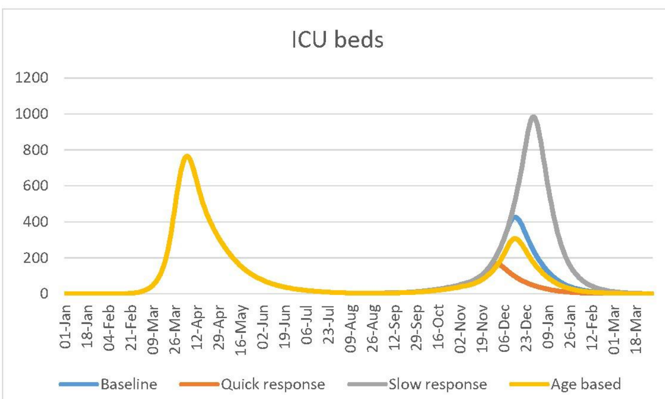
01-Mar
18-Mar
Baseline
Quick response
Slow response
Age based


ICU beds
1200
1000
800
600
400
200
0
01-Jan
18-Jan
04-Feb
21-Feb
09-Mar
26-Mar
12-Apr
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16-May
02-Jun
19-Jun
06-Jul
23-Jul
09-Aug
26-Aug
12-Sep
29-Sep
16-Oct
02-Nov
19-Nov
06-Dec
23-Dec
09-Jan
26-Jan
12-Feb
01-Mar
18-Mar
Baseline
Quick response
Slow response
Age based