SPI-M-O: Summary of further modelling of easing restrictions – Roadmap Step 4 on 19th July 2021

Date: 7th July 2021

Summary

1. The scale of the resurgence in hospital admissions after 19th July is highly uncertain and depends on unknowable factors including how behaviours change in the coming weeks and months. Many modelled scenarios show a peak in hospital admissions well below that of January 2021, but SPI-M-O cannot rule out a wave of a similar or even larger scale.

2. Exponential growth means that very small changes in assumptions on vaccine effectiveness and behaviours after Step 4 is taken lead to very large differences in the trajectories observed here. Uncertainty means it will not be possible to project which of these scenarios will likely occur nor can the peak's timing be predicted until it has passed.

3. Given this uncertainty, it would be prudent for contingency plans to be put in place for how to respond if hospital admissions approached levels that could disrupt the smooth functioning of health services.

4. If behaviours take longer to return to pre-pandemic levels (and / or if the seasonal effect of transmission is higher), then the peak of the summer resurgence is likely to be lower. This would result in a wave that is broader, or partially shifted to autumn and winter.

5. The next peak in deaths will almost certainly be considerably smaller than that of January 2021.

6. The prevalence of infection will almost certainly remain extremely high for at least the rest of the summer.

7. SPI-M-O's best estimate for R in England is between 1.2 and 1.5, reflecting the epidemiological situation approximately two to three weeks ago (late June).

Key changes since the paper of 9th June:

- The four-week delay to Step 4 has resulted in a larger proportion of the population being protected by vaccines. Between 21st June to 5th July, approximately a further four million vaccinations were given.

- The extent to which transmission had increased after Step 3 could not previously be estimated due to time delays, and the confounding by the emergence of the B.1.617.2[1] (delta) variant. There has been relatively little change in contacts since mid-May, so modelling groups' scenarios have accounted for transmission changing relatively little since Step 3 was taken on 17th May in their central scenarios.

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[1] The World Health Organisation recently recommended using letters of the Greek alphabet when referring to SARS-CoV-2 variants. Current variants of concern labelling stands as B.1.1.7 as alpha, B.1.351 as beta, P.1 as gamma, and B.1.617.2 as delta.

- Data from Public Health England (PHE) has now become available on the effectiveness of vaccines against hospital admission, but not death, with the delta variant. Although confidence intervals are wide, models' central estimates for this parameter have increased.
- Warwick (and Imperial College London in a sensitivity analysis) have modelled a gradual change in behaviour after Step 4, instead of a step change as previously.
- Sensitivity analysis from Imperial has highlighted the importance of cross-protection against different viral variants, for example the immunity to delta created by infection with B.1.1.7 (alpha)[1].

Key assumptions in the central scenarios

These are for the central scenarios and relate to the delta variant. A full set of assumptions, including for sensitivity analyses are given in Appendix 1 and the respective modelling papers.

|		Against infection		Against hospitalisation	
Cross-protection against delta after infection with alpha	Imperial	85%		95%	
	LSHTM	100%		100%	
	Warwick	100%		100%	
		AZ		**Pfizer / Moderna**	
Vaccine reduction in risk of infection		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	33%	58%	33%	85%
	LSHTM	43%	62%	47%	80%
	Warwick	34%	64%	56%	80%
		AZ		**Pfizer / Moderna**	
Vaccine reduction in risk of onwards transmission if infected (in addition to transmission reduction from lower infection risk)		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	40%	40%	40%	40%
	LSHTM	47%	57%	47%	57%
	Warwick	45%	45%	45%	45%
		AZ		**Pfizer / Moderna**	
Vaccine reduction in risk of symptomatic disease		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	33%	58%	33%	85%
	LSHTM	43%	71%	47%	84%
	Warwick	34%	70%	56%	88%
		AZ		**Pfizer / Moderna**	
Vaccine reduction in risk of hospital admission (or severe disease)		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	80%	90%	85%	95%
	LSHTM	85%	90%	85%	90%
	Warwick	81%	94%	90%	98%
		AZ		**Pfizer / Moderna**	
Vaccine reduction in risk of death		Dose 1	Dose 2	Dose 1	Dose 2
	Imperial	80%	95%	85%	95%
	LSHTM	85%	95%	85%	95%
	Warwick	81%	95%	90%	98%

Current epidemic estimates

8. SPI-M-O's best estimate for R in England is between 1.2 and 1.5 and the growth rate is between +3% and +7% per day, based on data available up to 5th July. Estimates for NHS England regions are given in Appendix 2. R is a lagging indicator, reflecting the state of the epidemic approximately two to three weeks ago.

Medium term projections and scenarios

9. Each week, SPI-M-O combines estimates from several independent models to project the trajectory of the epidemic **if no further changes in behaviour or policy take place**. They represent what the trajectory might be if the epidemic continued to follow the trends seen in the latest available data up to 5th July. **They are neither forecasts nor predictions** and cannot fully reflect recent changes in transmission that have not yet filtered through into surveillance data. They are released separately as SPI-M-O medium-term projections.

10. Four of these same models have further been used to explore the potential impact of a range of scenarios following changes in transmission. These scenarios assume changes in behaviour result in R values of 1.1, 1.5, 1.8, or 2.1 on 19th July[2], and are run for a further six weeks. These scenarios are shown **on a logarithmic scale** in Figure 1 (R=1.1 – green; 1.5 – blue; 1.8 – orange; 2.1 – red) for England's hospital admissions alongside the latest medium-term projection of current trends (grey) for comparison.

11. The duration and timing of the peak in each scenario is highly uncertain and varies across the individual models. As a result, the combination of these individual model scenarios produces a longer and flatter peak than might be expected.

12. A doubling time in infections of around one week is consistent with growth in hospitalisations akin to the blue line (R=1.5) in Figure 1. Faster growth in infections will cause faster growth in hospitalisations a few weeks later.

13. Figure 1 shows that the ongoing vaccine rollout programme means that a period with R around 1.1 or 1.5 would result in a small increase in hospital admissions followed by a turnover due to accumulation of immunity. An increase of R to 1.8 or 2.1 would result in larger increases that continue beyond the period of these scenarios.

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[2] In each of these scenarios, R drops over time after 19th July as vaccination and infection reduce the number of people who remain susceptible.

Figure 1: Eight-week scenarios for daily hospital admissions in England over a range of R values (1.1 – green; 1.5 – blue; 1.8 – orange; 2.1 – red) reflecting the possible impact of the easements from 19th July. The grey line is SPI-M-O's medium-term projection of current trends. All scenarios show interquartile ranges of model combinations as the shaded band. Note the logarithmic scale.
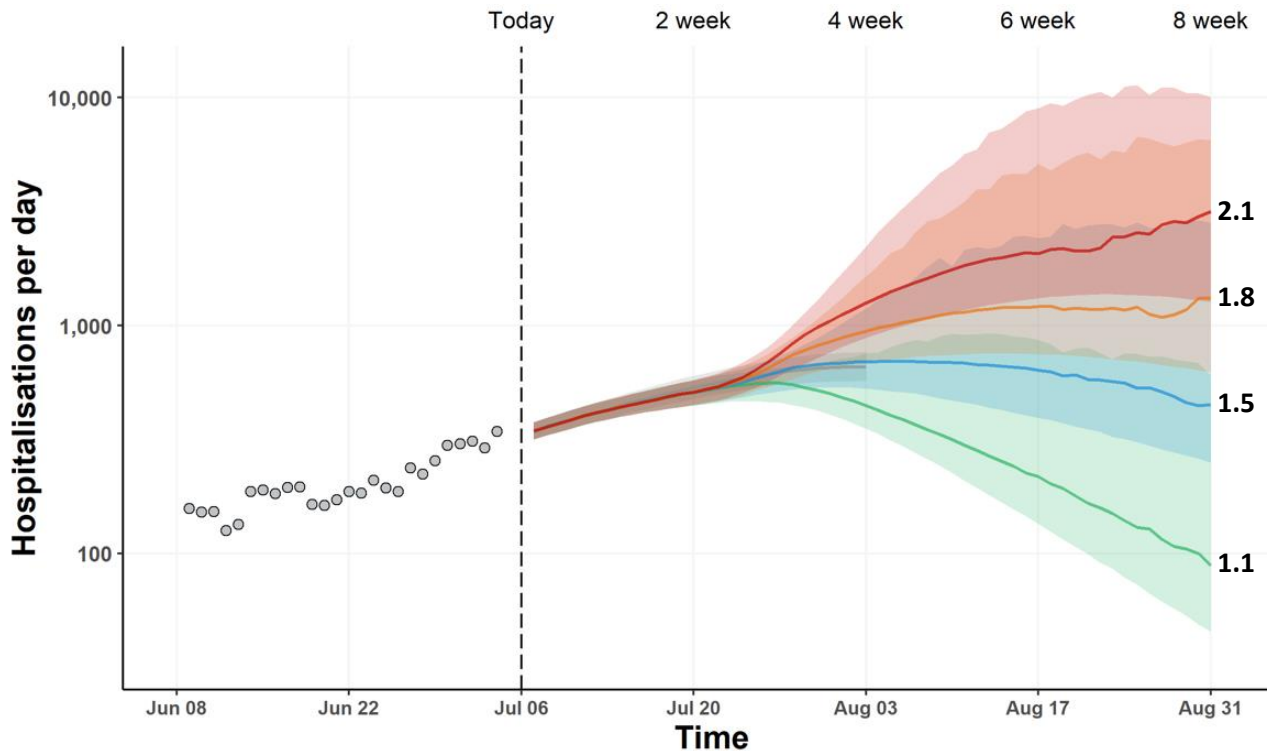
14. These scenarios assume a step change in transmission from 19th July. In reality, in addition to a change in behaviour from a given date, there will likely be gradual increases in transmission in different parts of the country at different times. This variation in hospital admissions has been seen across the country and is currently settled at a consistent trajectory across the country.

Modelling Step 4 of the Roadmap

15. SPI-M-O has considered the results from three academic groups who have independently modelled taking Step 4 of the Roadmap on 19th July. These groups have made assumptions in the central scenarios that include:

- Once removed, social distancing measures are never re-imposed. Behaviours do not change in response to rising prevalence.

- The delta variant remains dominant.

- Under 18s are not vaccinated as, at the time of writing, the Joint Committee on Vaccinations and Immunisations (JCVI) have not published their advice on this.

- There is little waning immunity over the next few months and no booster vaccinations take place over the timescale of the modelling, as the timing and speed of this programme is not yet known.

- London School of Hygiene and Tropical Medicine (LSHTM) and Imperial have modelled single step changes (or near-step changes) in transmission on 19th July, with some transmission reduction remaining as a result of Test, Trace, and Isolate and behaviour change. Warwick (and Imperial in sensitivity analysis) have modelled a range of scenarios with a gradual return to pre-pandemic behaviours at different times from August 2021 until March 2022.

16. **All results are highly sensitive to the modelling assumptions, and extensive sensitivity analyses have been performed.** The key uncertainties are laid out in this summary; full details are given in the accompanying modelling papers.

Key conclusions

17. All models show a period of extremely high prevalence of infection lasting until at least the end of August. There is high uncertainty around both the scale of the peak in prevalence and in the number of confirmed cases that this would correspond to. This would also depend on people's willingness to be tested and, potentially, on capacity to test them. SAGE has previously highlighted considerations as to what measures may be required beyond the end of the Roadmap in different situations[3].

18. **The scale of the next wave in hospital admissions is highly uncertain. While most modelled scenarios have peaks lower than in January 2021, a resurgence of this scale of hospitalisations cannot be ruled out. It is almost certain that, with the delta variant dominant, the peak in deaths will be well below the levels seen in January.**

19. An independent group from the JUNIPER Consortium have applied a completely different, simpler approach to project the total numbers of deaths, if the epidemic continues to its final size. The results of this modelling are comparable with the Warwick scenarios, providing a separate reassurance of these results.

20. The main reasons for continued uncertainty are:

- It is not possible to predict how behaviours will change after 19th July. The closer that behaviours are to those seen before the pandemic and the more rapidly this state is reached, the larger the resurgence will be.

- While the first estimates of vaccines' effectiveness against hospitalisation with the delta variant have become available after the previous iteration of modelling, precise values for this cannot be determined from observational studies to date. Models are very sensitive to the assumptions used. For example, the number of infected

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[3] EMG, SPI-M and SPI-B: Considerations in implementing long-term 'baseline' NPIs; SAGE 87 22nd April 2021

vaccinated people who go on to be admitted to hospital with a 94% effective vaccine would be *triple* that with a 98% effective one.

- While the number of vaccinated people is precisely known, the number of *unvaccinated* people is not, so estimates of vaccine uptake are uncertain. Models are also very sensitive to this; for example, there would be *twice* as many unvaccinated people in an age group if its uptake is 92% compared to if uptake is 96%.

- The proportion of the population who have previously been infected cannot be precisely determined and yet influences the extent to which the epidemic can grow before herd immunity is reached.

21. It is very difficult to forecast the peak of an epidemic in real time, and it will take several weeks after 19th July before it will be clear whether or not hospitals will be put under severe pressure. It is therefore important to closely monitor the epidemic so contingency plans can be rapidly put in place if needed.

22. **The resurgences in hospitalisations are smaller than seen in SPI-M-O's modelling on 9th June.** This is because:

- Delaying Step 4 by four weeks has allowed many more vaccinations to be administered and moved the end of restrictions to a time point close to the school holidays, where transmission is expected to be lower.

- As of 9th June, it was not possible to determine the extent of transmission from Step 3 due to confounding effects of the emergence of the delta variant. Recent data from the CoMix study has shown that, since late April to mid-May, there has been little change to the number of contacts that adults make, and these remain well below pre-pandemic levels. Models have now been fitted to data that show lower than expected transmission, and therefore prevalence, after Step 3.

- As of 9th June, no data were available on vaccines' effectiveness against hospital admission with the delta variant. PHE have since published these estimates and, while their confidence intervals are very wide, they are broadly in line with the optimistic vaccine effectiveness scenarios previously modelled.

23. Some, but not all, scenarios discussed here and in the underlying papers show further waves in autumn and / or winter, although they are all considerably smaller than in winter 2020/21, and in these scenarios the summer wave is correspondingly broader and flatter. The modelled winter waves are larger if a) the extent of seasonality in transmission is higher and b) the summer wave is smaller, so fewer people are immune by winter. Note that these models have not incorporated an autumn booster vaccine campaign, and waning is not considered in the Warwick model.

Summary of Warwick modelling

24. In contrast to their previous work, Warwick have not modelled a single change in transmission on 19th July. Instead, a gradual return to pre-pandemic behaviours over a range of dates from August 2021 to March 2022 is modelled. Some, but not all, scenarios assume there is also a significant (but partial) initial step change in behaviour on 19th July before the gradual changes take place.

25. A selection of these results is illustrated in Figure 2 below. With vaccine effectiveness assumptions in line with PHE's central estimates, peak (mean) daily hospital admissions range from around 500 to 950 with the slowest return to pre-pandemic behaviours which take approximately seven months after taking Step 4. This compares to around 1,300 to 4,800 for the most rapid return to pre-pandemic behaviours, over the course of one month. Peaks are higher where vaccine effectiveness assumptions are towards the lower end of PHE's estimates; even then, most scenarios result in smaller resurgences than January 2021 unless there is a rapid return to pre-pandemic behaviour.

Figure 2: Infections, hospital admissions and occupancy, and deaths in England as estimated under five different behavioural scenarios as modelled by Warwick, assuming default vaccine effectiveness. Lines indicate the median of the distribution; shaded regions show the 95% prediction interval.

(Purple – small drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over one month; Red – as purple, but gradual reduction to pre-pandemic levels over three months; Blue – as red, but gradual reduction to pre-pandemic levels over five months; Orange - large drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over three months; Cyan - medium drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over five months)
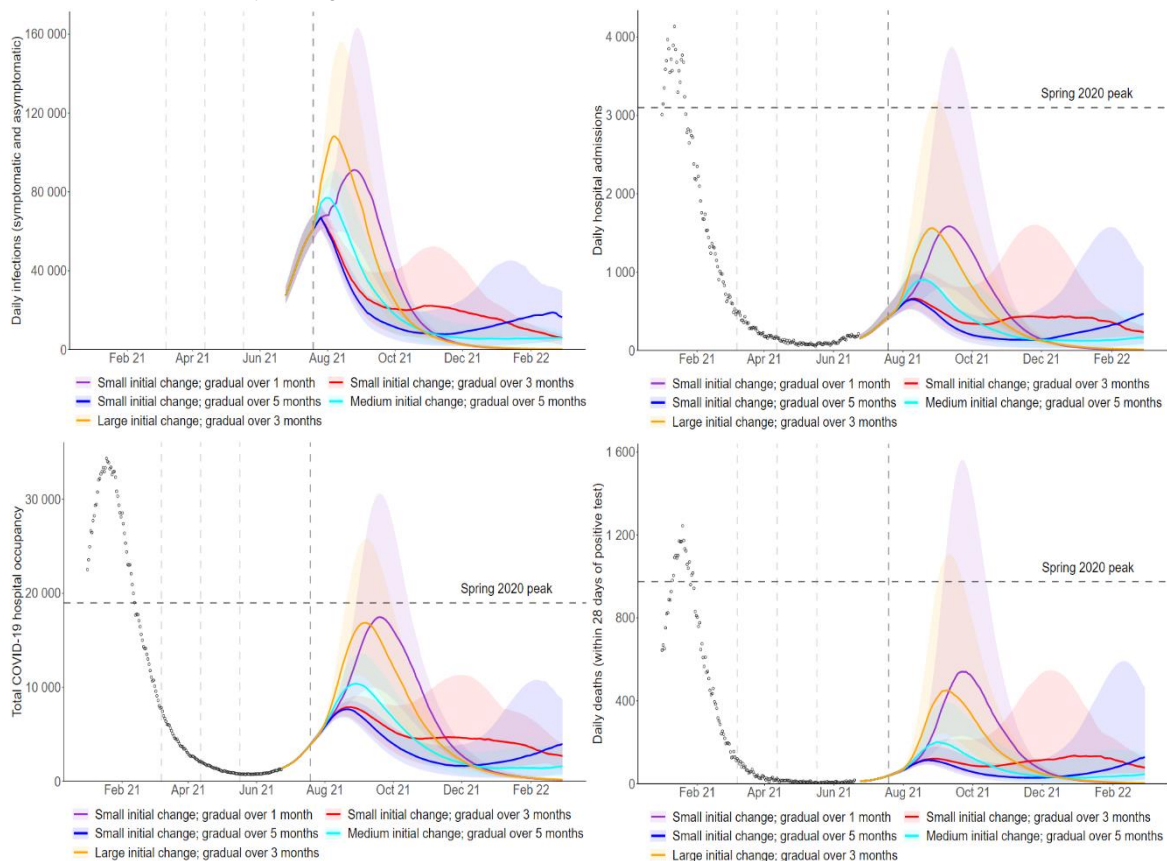
26. It is noticeable that very small changes in assumed behaviour lead to very different epidemic trajectories of infections, hospitalisations, and deaths, as a result of exponential growth. Some, but not all, of Warwick's scenarios see a further resurgence in autumn or winter (Figure 2, red and blue). The fewer people that are infected during the wave that is currently happening, the more are infected in the next one. Neither Imperial nor LSHTM's scenarios show a significant additional, distinct autumn or winter wave. Any contingency planning will need to be able to flex to a wide range of scenarios.

27. Daily hospital admissions that are lower than the spring 2020 or January 2021 peak could still cause severe disruption for the NHS. For example, if the average length of stay is nine days, 1,000 hospitalisations per day for a sustained period would lead to hospital occupancy due to COVID-19 of 9,000 individuals. In Warwick's results, under the central and optimistic assumptions on vaccine effectiveness, half of the scenarios generate extended periods with more than 1,000 hospital admissions a day. Under the cautious assumptions on vaccine effectiveness, all behavioural scenarios breach 1,000 hospitalisations a day. It is highly likely that any such pressure on the NHS would vary regionally and temporally.

28. Given the delay between infection and hospitalisation, increases in admissions for the coming two to three weeks are already determined by infections to date. Consequently, whilst cases continue to increase exponentially, admissions are expected to double (regardless of any measures put in place). While SPI-M-O does not know what threshold of daily hospital admissions would lead to unsustainable pressure for the NHS, the moment when half that level is reached would be the time at which contingency plans would need to be implemented.

29. Warwick's central case assumes a 10% peak-to-trough seasonal variation in transmission. They also considered sensitivities of 20% and 40% variation. The non-linear interaction between seasonality and behaviour, however, is a complex one. As it is currently summer, the higher seasonality scenario would require existing behaviour to be close to pre-pandemic levels, with little scope for increased mixing after 19th July. This means that, in these scenarios, the ongoing wave rapidly diminishes, yet there is always a winter wave (Figure 3).

Figure 3: Hospital admissions in England as estimated by the Warwick model for four different behaviour scenarios for after Step 4 is taken, each with either 10% (default solid line), 20% (dotted line), or 40% (dashed line) peak to trough seasonality. Default vaccine effectiveness assumptions. Lines indicate means; shaded regions show the 95% prediction interval.

(Top left purple – small drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over one month; Top right red – as purple, but gradual reduction to pre-pandemic levels over three months; Bottom left orange - large drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over three months; Bottom right cyan - medium drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over five months)
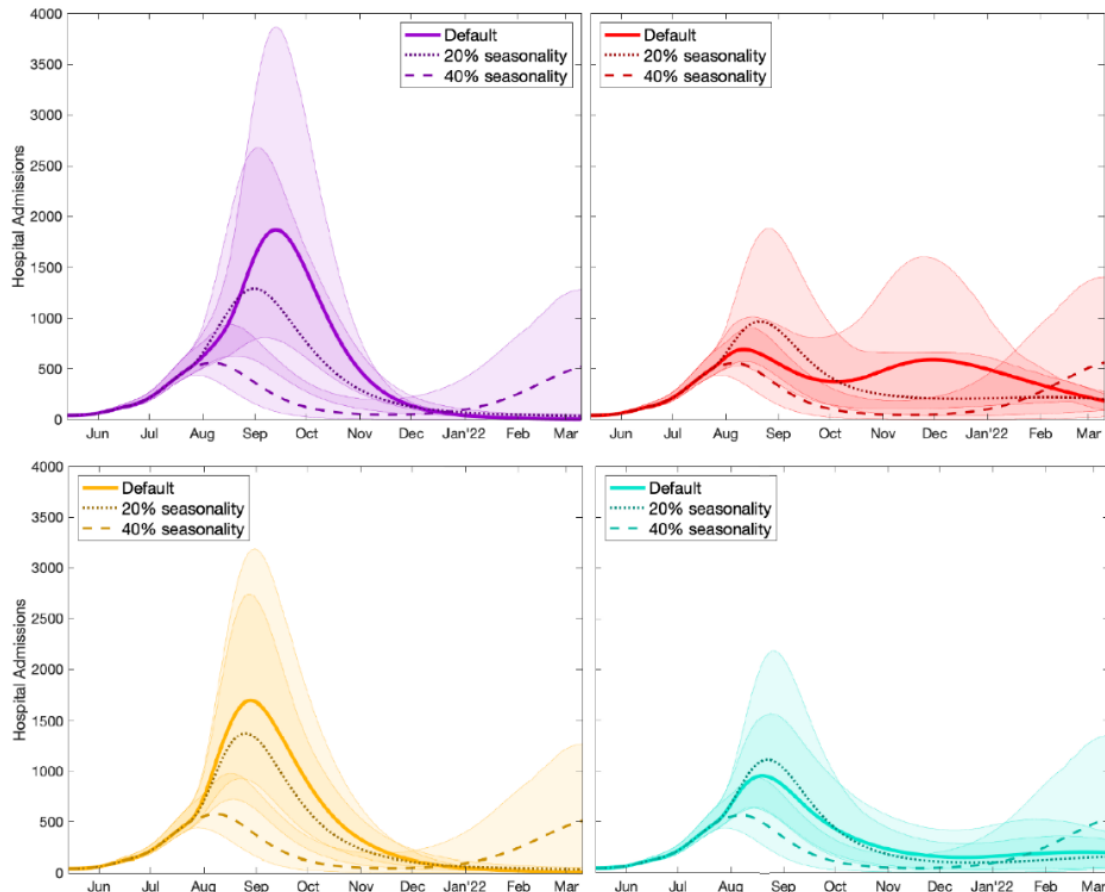
30. Warwick have also highlighted the sensitivity of models to the precise uptake achieved in older people. Although the number of doses administered is known, the overall population size and hence the number of unvaccinated people is not. As of 1st July, more first doses have been administered to 75- to 79-year olds in England (1.98m)[4] than the number of people of that age estimated by ONS's mid-2019 population estimates (1.94m), so NHS England report an uptake of over 100%. PHE, however, base their estimates[5] on the National Immunisation Management System (NIMS) database in which there are 2.08m 75- to 79-year olds, giving an estimated uptake of 95%. It is a general pattern that PHE estimates of coverage are lower than those calculated using ONS's population estimates.

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[4] NHS England COVID-19 vaccination statistics; 1st July
[5] Public Health England COVID-19 vaccine surveillance report Week 26

31. Although such differences may appear unimportant, models are very sensitive to the precise uptake used. For example, there are twice as many unvaccinated people in a high-risk age group that had 92% uptake compared to if uptake were 96%, meaning there would be many more people at risk of hospitalisation. The resulting increase in hospitalisations due to assumed lower vaccine uptake historically under various behavioural scenarios is illustrated in Figure 4.

Figure 4: Hospital admissions in England as estimated by the Warwick model for four different behaviour scenarios for after Step 4 is taken, each with either default (solid line), 5% lower (dotted line), or 10% lower (dashed line) vaccine uptake to date. Default vaccine effectiveness assumptions. Lines indicate means; shaded regions show the 95% prediction interval.

(Top left purple - small drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over one month; Top right red – as purple, but gradual reduction to pre-pandemic levels over three months; Bottom left orange - large drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over three months; Bottom right cyan - medium drop in precautionary behaviour from 19th July then gradual reduction to pre-pandemic levels over five months)
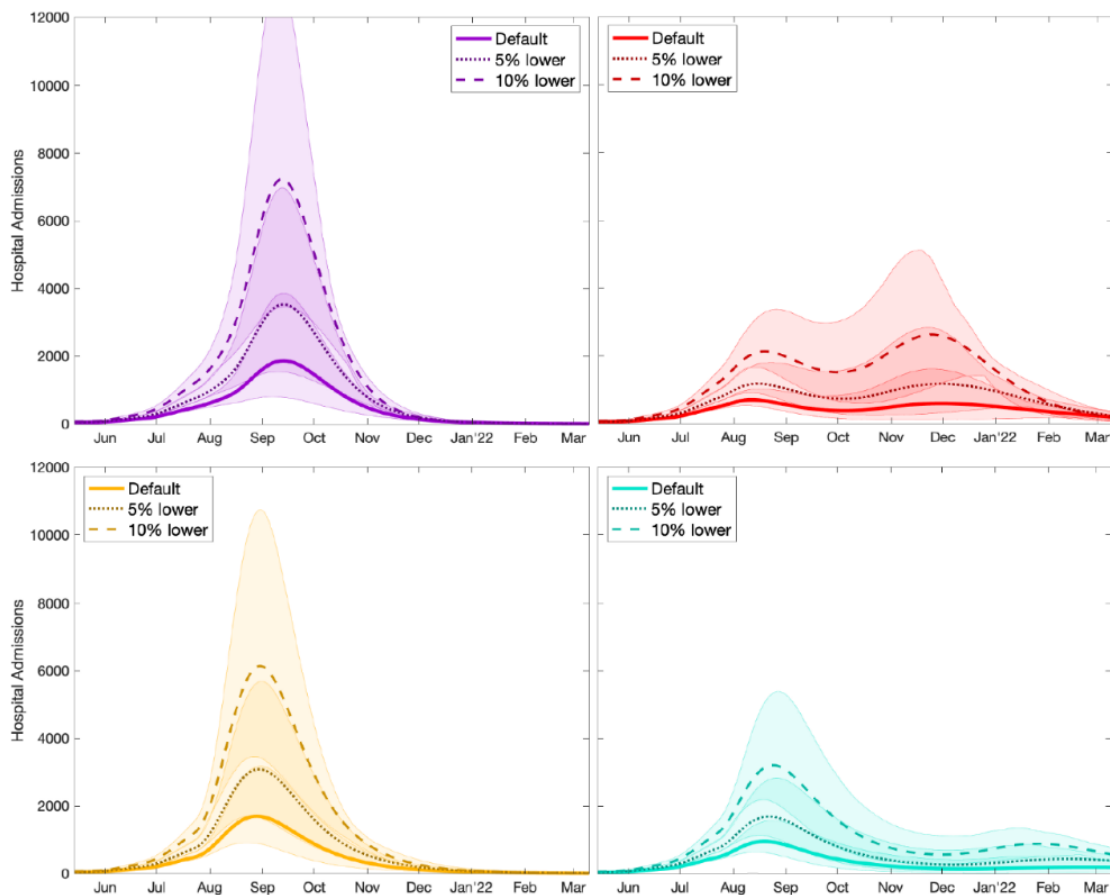
Summary of Imperial College London modelling

32. Imperial have considered step changes occurring on 19th July that take R (excluding the effect of immunity from vaccines or natural infection[6]) in school term time to 5.5 (central, with contacts approximately doubling), 4.5 (low R, with contacts increasing by

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[6] Note, the transmission advantage of delta over alpha is included in these R excluding immunity estimates.

approximately 50%), or 7.0 (high R). As a sensitivity analysis, they also modelled a gradual change in behaviours so that R (excluding immunity) reaches 5.5 on 1st September.

33. Imperial have used their own estimates of vaccine effectiveness to account for admissions whose first positive test is in hospital. Their central scenario uses vaccine effectiveness assumptions that are lower than Warwick's, but still within PHE's confidence intervals (see appendix 1 for details). This central scenario assumes that 15% of people who have recovered from an infection with alpha are nevertheless susceptible to a second infection with delta if they are unvaccinated. Imperial's optimistic vaccine assumptions assume perfect cross protection and use PHE's point estimates (and are therefore similar to Warwick central scenarios).

34. Figure 5 shows the Imperial model with their optimistic (left) and central (right) vaccine effectiveness assumptions[7]. As with Warwick, if vaccine effectiveness against hospital admission is in line with PHE's point estimates, then a rapid return to pre-pandemic behaviours leads to a peak in hospitalisations broadly similar to that of January 2021 (blue line in left hand plot). If baseline behaviour change leads to more significant transmission reduction (green or purple lines in left hand plot) then the peak is significantly smaller. As with Warwick, a more gradual change in behaviour extends and flattens the peak (yellow line compared to blue line, where R=5.5 happens suddenly).

Figure 5: Hospital admissions in England as estimated by the Imperial model under optimistic (left) and central (right) vaccine effectiveness assumptions for different behaviours after Step 4 is taken (blue – high R excluding immunity of 7.0; purple – central R excluding immunity of 5.5; green – low R excluding immunity of 4.5; yellow – gradual change in behaviours reaching R excluding immunity of 5.5 on 1st September, rather than 19th July). Note the different y-axes between the two plots. Lines indicate the median of the distribution and shaded regions the 95% credible interval.


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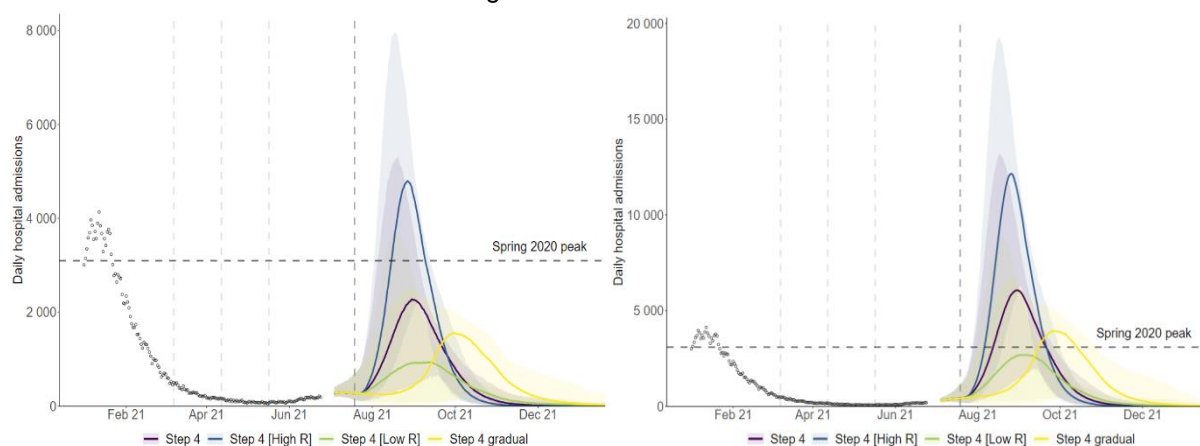
[7] Further scenarios with more pessimistic vaccine effectiveness assumptions are given in the accompanying modelling paper.

Summary of LSHTM modelling

35. LSHTM have modelled the changes after Step 4 as happening in two ways. Firstly, the model is fitted to historical Google mobility data, which is assumed to increase in low, medium, and high scenarios towards or above pre-pandemic baseline levels after Step 4 of the roadmap is taken on 19th July. Secondly, the model fits a reduction in the per-contact transmission risk of approximately 25% to represent the combined effect of Test, Trace, and Isolate and other mitigating behaviours that are not captured by mobility changes alone. LSHTM scenarios consider various reductions in this mitigation parameter following Step 4 to mimic the reduction in self-protective measures that may occur as requirements such as mask wearing are relaxed. LSHTM's central and optimistic assumptions for two dose vaccine effectiveness against admission with delta are 90% and 96% respectively.

36. Firstly, the sensitivity to the mobility parameter is shown in Figure 6. In this plot, the mitigation parameter reduces the per-contact transmission risk by approximately 15%. In the "high mobility" scenario, transit and workplace mobility both reach 90%; in the "medium mobility" scenario, it is 80% and 85% respectively, and in the "low mobility" scenario, they are 75% and 80%.

Figure 6: Hospital admissions (top left), occupancy (top right), ICU occupancy (bottom right) and deaths (bottom left) in the LSHTM model assuming high (red), medium (green), or low (blue) mobility July 19th, and with Test and Trace and baseline behaviour change reducing R by 15%. Two doses of either vaccine are assumed to be 90% effective against hospital admission with delta, and there is waning of natural or vaccine-induced immunity. Lines indicate the median of the distribution and shaded regions the 90% credible interval.
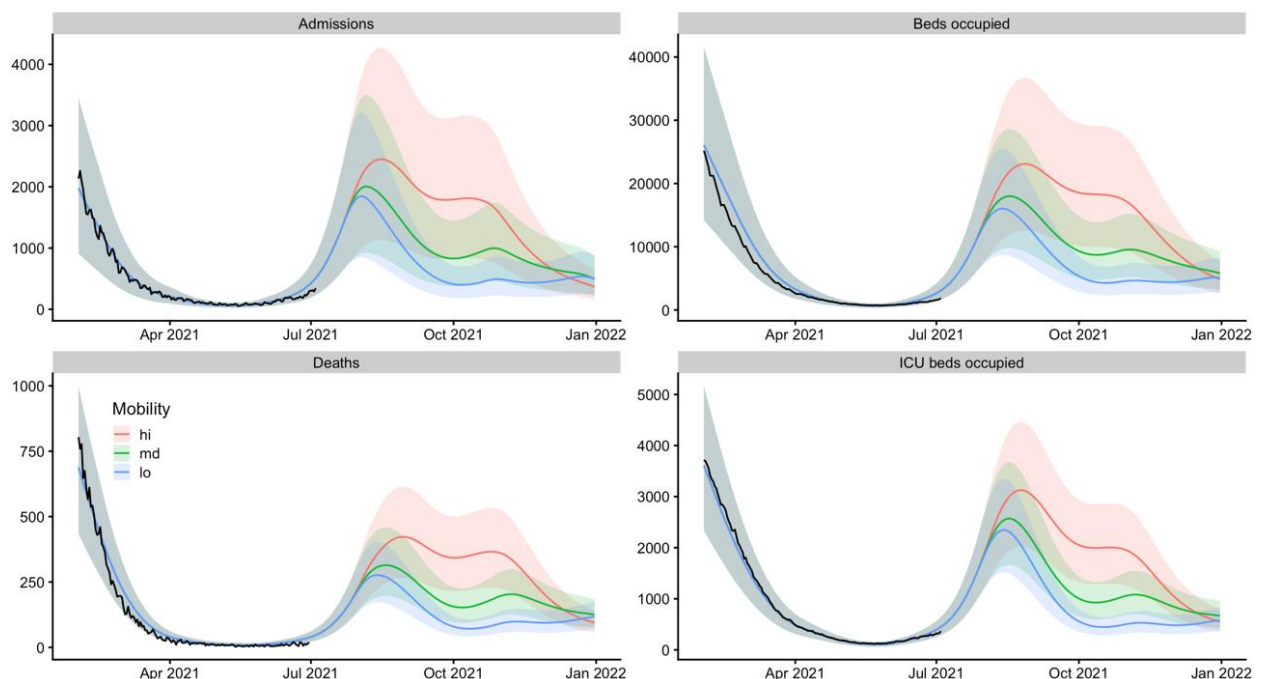
37. The sensitivity to this "mitigation parameter" is demonstrated in Figure 7. Here, the per-contact transmission risk is reduced from pre-pandemic levels by approximately 20%

(purple), 15% (blue), 10% (green), or 5% (red) after 19th July by Test, Trace, and Isolate and baseline behaviours. With the least effective mitigating behaviour, hospital admissions are similar to the level seen in January (and deaths around half that level), but more significant behaviour change sees hospital admissions peak well below 2,000.

Figure 7: Hospital admissions (top left), occupancy (top right), ICU occupancy (bottom right) and deaths (bottom left) in the LSHTM model assuming a 20% (purple), 15% (blue), 10% (green), or 5% (red) reduction in transmission post July 19th as a result of Test, Trace, and Isolate, and baseline behaviour change. Two doses of either vaccine are assumed to be 90% effective against hospital admission with delta, there is waning of natural or vaccine-induced immunity, and medium mobility is assumed. Lines indicate the median of the distribution and shaded regions the 90% credible interval.
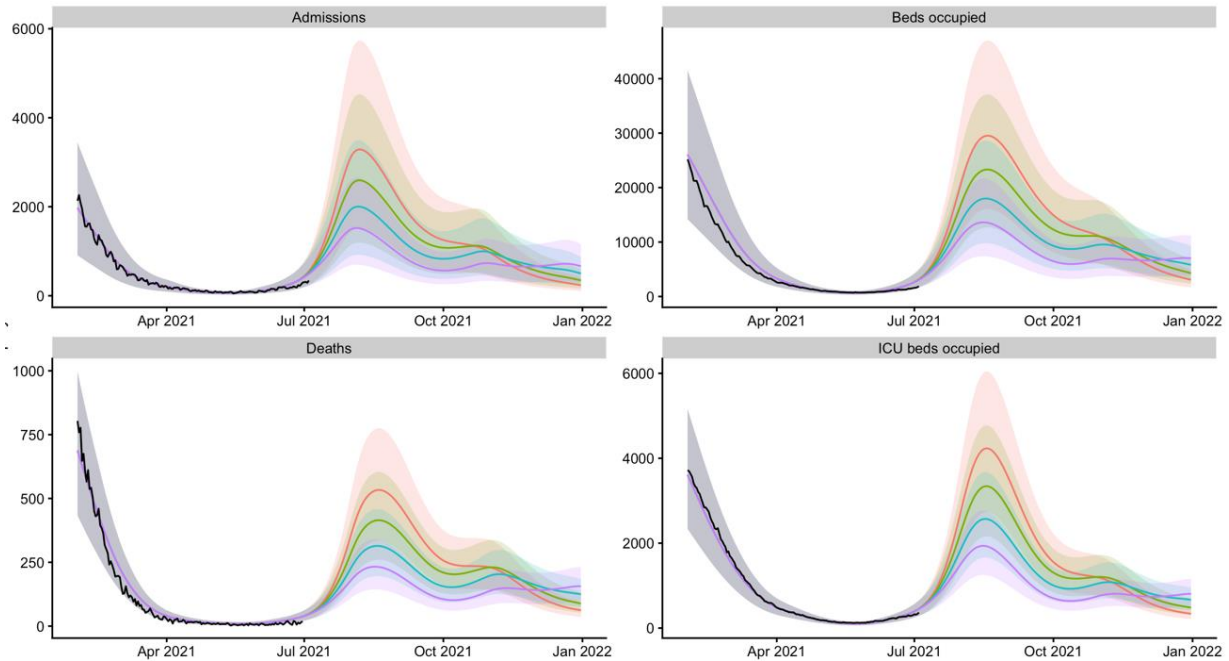
38. Other scenario analyses reiterate the sensitivity of modelled outcomes to the assumptions used for vaccine effectiveness, uptake achieved, the duration of immune protection, and whether the delta variant is associated with a higher risk of hospitalisation and death than alpha.

Appendix 1: Model assumptions

Given the dominance of the delta variant, parameter values shown here are for this strain of SARS-CoV-2. Other parameter values for alpha are given in the respective modelling papers, alongside further details of the models.

Parameter	Imperial College				LSHTM			Warwick			
		Central	Pessimistic	Optimistic		Central	Optimistic		Central	Pessimistic	Optimistic
Cross-protection against delta after infection with alpha or other strain	Against infection	85%	75%	100%	Against infection	100%	100%	Against infection	100%	100%	100%
	Against hospital admission	95%	90%	100%	Against hospital admission	100%	100%	Against hospital admission	100%	100%	100%
		Central	Pessimistic	Optimistic		Central	Optimistic		Central	Pessimistic	Optimistic
Vaccine reduction in risk of infection	AZ 1 dose	33%	20%	45%	AZ 1 dose	43%	48%	AZ 1 dose	34%	31%	37%
	AZ 2 dose	58%	45%	70%	AZ 2 dose	62%	63%	AZ 2 dose	64%	61%	65%
	PF/MD 1 dose	33%	20%	45%	PF/MD 1 dose	47%	52%	PF/MD 1 dose	56%	53%	59%
	PF/MD 2 dose	85%	78%	90%	PF/MD 2 dose	80%	81%	PF/MD 2 dose	80%	80%	80%
		Central	Pessimistic	Optimistic		Central			Central	Pessimistic	Optimistic
Vaccine reduction in risk of onward transmission if infected (additional to transmission reduction due to reduced infection risk)	AZ 1 dose	40%	35%	45%	AZ 1 dose	47%		AZ 1 dose	45%	40%	45%
	AZ 2 dose	40%	35%	45%	AZ 2 dose	57%		AZ 2 dose	45%	40%	45%
	PF/MD 1 dose	40%	35%	45%	PF/MD 1 dose	47%		PF/MD 1 dose	45%	40%	45%
	PF/MD 2 dose	40%	35%	45%	PF/MD 2 dose	57%		PF/MD 2 dose	45%	40%	45%
		Central	Pessimistic	Optimistic		Central	Optimistic		Central	Pessimistic	Optimistic
Vaccine reduction in risk of symptomatic disease	AZ 1 dose	33%	20%	45%	AZ 1 dose	43%	48%	AZ 1 dose	34%	31%	37%
	AZ 2 dose	58%	45%	70%	AZ 2 dose	71%	72%	AZ 2 dose	70%	68%	77%
	PF/MD 1 dose	33%	20%	45%	PF/MD 1 dose	47%	52%	PF/MD 1 dose	56%	53%	59%
	PF/MD 2 dose	85%	78%	90%	PF/MD 2 dose	84%	85%	PF/MD 2 dose	88%	84%	89%

Parameter	Imperial College				LSHTM			Warwick			
Vaccine reduction in risk of hospitalisation admission		Central	Pessimistic	Optimistic		Central	Optimistic		Central	Pessimistic	Optimistic
	AZ 1 dose	80%	75%	81%	AZ 1 dose	85%	85%	AZ 1 dose	81%	70%	85%
	AZ 2 dose	90%	85%	94%	AZ 2 dose	90%	96%	AZ 2 dose	94%	90%	97%
	PF/MD 1 dose	85%	80%	93%	PF/MD 1 dose	85%	85%	PF/MD 1 dose	90%	75%	96%
	PF/MD 2 dose	95%	90%	98%	PF/MD 2 dose	90%	96%	PF/MD 2 dose	98%	90%	99%
Vaccine reduction in risk of death		Central	Pessimistic	Optimistic		Central	Optimistic		Central	Pessimistic	Optimistic
	AZ 1 dose	80%	75%	81%	AZ 1 dose	85%	85%	AZ 1 dose	81%	75%	85%
	AZ 2 dose	95%	95%	95%	AZ 2 dose	95%	98%	AZ 2 dose	95%	92%	97%
	PF/MD 1 dose	85%	80%	93%	PF/MD 1 dose	85%	85%	PF/MD 1 dose	90%	80%	96%
	PF/MD 2 dose	95%	95%	98%	PF/MD 2 dose	95%	98%	PF/MD 2 dose	98%	95%	99%
Rollout speed (England basis)	Per Cabinet Office scenario: An average of 2m doses per week in England until week commencing 12th July and 2m per week thereafter. Sensitivities of 25% faster and slower rollout are explored by Warwick. Warwick: 8-week period between doses. Imperial: 11-week period between doses. LSHTM: First doses are followed up with equivalent second doses according to measured delays between first and second doses using data up to 30th June 2021.										
Time to full vaccine protection	3 weeks (dose 1); 1 week (dose 2)				4 weeks (dose 1); 2 weeks (dose 2)			2 weeks (dose 1); 2 weeks (dose 2)			
Coverage achieved (all ages)		Central				Central			Central		
	80 and over	Per actuals			40+	Per actuals (PHE first dose uptake data from 30 June 2021)		40+	Per actuals (PHE first dose uptake data from 2 July 2021)		
	50-79	Per actuals									
	40-49	90%			18-39	80%		18-39	80%		
	<40	Minimum of actuals or 80%									
	Care home residents	95%									
	Care home workers	86%									

Parameter	Imperial College	LSHTM	Warwick
R <u>excluding the effect of immunity</u> after Step 4 of easing	In terms of B.1.617.2 R excl. immunity: With schools open: • (central): 5.5 (95% CI 4.2 to 7.1) • (lower R; higher impact from measures): 4.5 (95% CI 3.2 to 6.1) • (higher R; lower impact from measures): 7.0 (95% CI 5.6 to 8.6) With schools closed: • (central): 5.0 (95% CI 3.7 to 6.6) • (lower R; higher impact from measures): 4.0 (95% CI 2.7 to 5.7) • (higher R; lower impact from measures): 6.5 (95% CI 5.2 to 8.1)	Approx. 25% reduction in per-contact transmission risk from baseline measures, with 15% in the central scenario after step 4 and sensitivity analyses of 5%, 10% and 20% all considered. In addition, there is a reduction in the rate of interpersonal contact represented by fitting to mobility data (relative to baseline mobility in early 2020, pre-epidemic) |	Low	Medium	High
Grocery and pharmacy	105%	105%	105%
Retail and recreation	Aug 2020	95%	105%
Transit	Sept 2020	80%	90%
Workplace	80%	85%	90%	 R (excluding immunity) reduced by 0.2 to 0.3 during school holidays in all scenarios.	Worst case scenario (full relaxation on 19 July): 6.92 (95% CI 6.53 to 7.39) Additional scenarios have also been modelled.
Transmission advantage of Delta over Alpha		Scenarios consider a 40-80% transmission advantage of Delta over Alpha.	Central scenario 61% (CI 38%-86%) transmission advantage over alpha.
Additional risk of hospital-isation given infection for delta compared to alpha	85%	80% (partially counteracted by the model fitting to lower prevalence) ; sensitivities without additional risk also considered.	Inferred within code; 87% (48%-134%).
Seasonality	20% peak (February) to trough (August) in central scenario.	20% peak to trough seasonality in central scenarios.	10% seasonality (transmission in summer trough is 90% of winter transmission) in central scenarios. 20% and 40% accompanying scenarios.
Waning immunity	Exponential decay in infection-induced immunity with an average time to loss of protection of 3 years	Waning of natural and vaccine-induced immunity by 15% over 1 year; sensitivity analysis without waning also included.	None over the timescale modelled

Appendix 2: Regional estimates of R and growth rates

Table 1: Combined estimates of R values and growth rates in England, and NHS England regions (90% confidence interval)[8]. These estimates represent the transmission of COVID-19 two to three weeks ago, due to the time delay between someone being infected, developing symptoms, and needing healthcare.

Nation	R	Growth rate per day	Doubling time
England	**1.2 to 1.5**	**+3% to +7%**	**11 to 20 days**
NHS England region	**R**	**Growth rate per day**	**Doubling time**
East of England	1.1 to 1.5	+2% to +7%	11 to 33 days
London	1.1 to 1.4	+2% to +6%	13 to 33 days
Midlands	1.2 to 1.5	+4% to +8%	9 to 16 days
North East and Yorkshire	1.3 to 1.6	+5% to +8%	8 to 13 days
North West	1.1 to 1.2	+1% to +4%	19 to 35 days
South East	1.3 to 1.6	+4% to +9%	8 to 16 days
South West	1.3 to 1.6	+5% to +8%	9 to 14 days

Appendix 3: Roadmap steps

Full details of the Roadmap for England are available[9]. A summary is given here.

Step 1a: 8th March
- Schools and colleges return
- Higher education on practical courses return
- Recreation and exercise outdoors with household or support bubble, or with one person from outside their household
- Care home residents allowed one regular visitor

Step 1b: 29th March
- Outdoor sport and leisure facilities
- Rule of 6 or two households outside

Step 2: 12th April
- Non-essential retail
- Personal care
- Indoor leisure facilities
- Outdoor attractions
- Outdoor hospitality

Step 3: 17th May
- Indoor hospitality, entertainment, and leisure
- 30-person limit outside
- Rule of 6 or two households advised inside
- Return to face-to-face teaching for all higher education
- Large events (outdoor 50% capacity, limit 4,000; indoor 50% capacity, limit 1,000)

Step 4: No earlier than 19th July
Full unlock with long-term mitigations and guidance

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[8] The estimated intervals for R and growth rate may not exactly correspond to each other due to the submission of different independent estimates and rounding in presentation.

[9] Further details can also be found at COVID-19 Response – Spring 2021 (Summary)