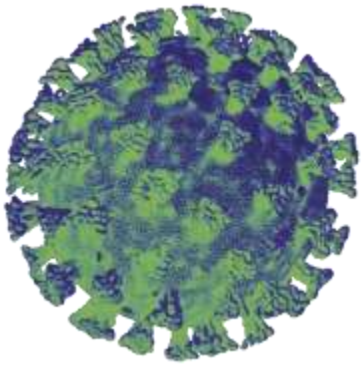
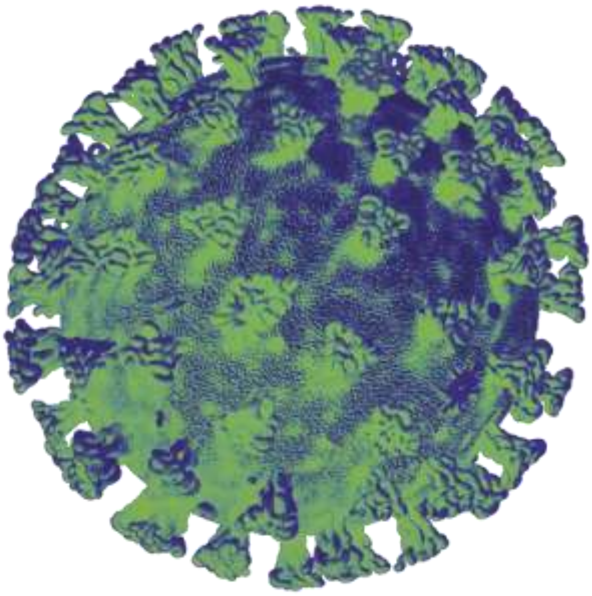
Llywodraeth Cymru
Welsh Government

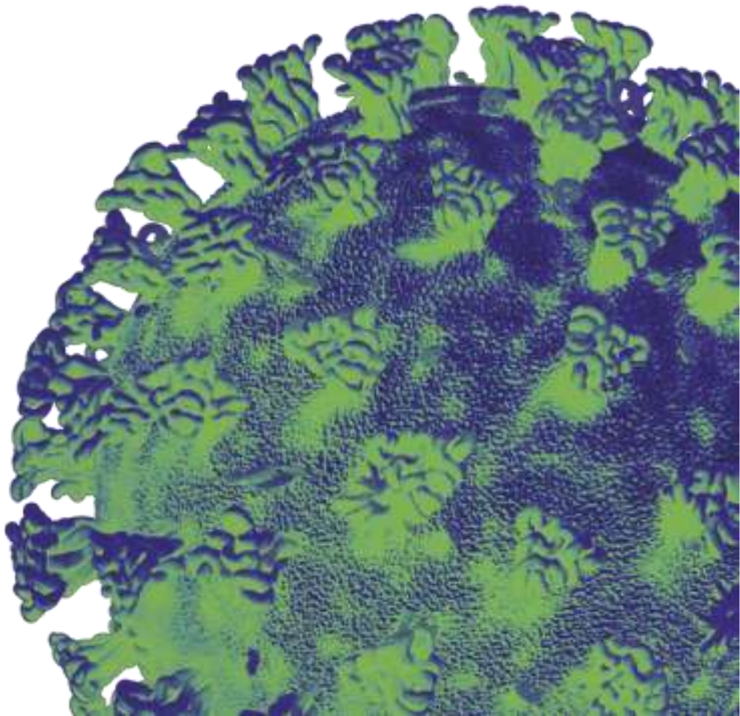
Technical Advisory Cell

Modelling Update

7 May 2020







Foreword

You will have heard people talk about “following the science”. The information in this document is a snapshot of that science - the information that is being used by ministers to make informed decisions in the best interest of the Welsh population, to respond to the Covid-19 pandemic.

There is still a lot we don’t know about Covid-19. But, by using a range of models and taking advice from a broad group of scientists, we can have robust discussions before providing advice to ministers.

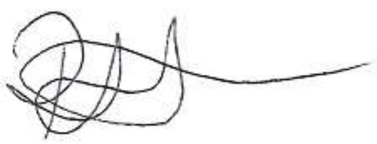
I have been joining meetings of the UK Government’s Scientific Advisory Group for Emergencies (SAGE) since February. The Welsh Government is using information from SAGE - as well as modelling from our own Technical Advisory Cell (TAC) - to make important interventions in our response to Covid-19.

We also make sure the latest science and technical information is available to Welsh Government and Public Health Wales, and is used to inform NHS, social care and local resilience planning.

Now, in the interests of transparency, we are publishing some of the key evidence, where information has a specific Welsh context. It’s important to note that these statistics and evidence are collated independently of ministers, and provided as advice to inform decision-making. Scientists advise and politicians decide, so they say.

Our advisory group (TAC) is made up from Welsh Government, Public Health Wales, Cardiff University, Bangor University and Swansea University with expertise covering: public health, health protection, medicine, epidemiology, modelling, technology, data science, statistics, microbiology, molecular biology, immunology, genomics, physical sciences and research.

Further information on the methods we’ve used and any limitations of our data will be made available, but the aim of this publication is to make the science behind key decisions accessible, open and informative.



Dr Rob Orford
Chief Scientific Adviser for Health

Authors of this report

This report has been developed by Dr Brendan Collins and Craiger Solomons, who lead the TAC Modelling sub-cell. This work has been carried out in partnership with colleagues in Public Health Wales and London School of Hygiene and Tropical Medicine.

Future Publications

New scientific briefings produced by the Technical Advisory Cell will be published in the coming weeks.

Definitions and terms used in this publication

Incubation / pre-symptomatic period	The period between becoming infected with the virus and showing symptoms. *For Covid 19 this is 5-6 days on average, but can be as long as 14 days*
R_0	The initial reproduction number. The average number of people an infected person transmitted the disease to at the start of the epidemic, before anyone has immunity to it. *This has been estimated to be 2.8 for Covid-19 in Wales*
R_t	The reproduction number at a point in time; the average number of people an infected person transmitted the disease to at some point in the epidemic. *This is currently estimated to be 0.7 - 0.9 for Covid 19 in Wales*
Susceptible person / population	An individual or group at risk of becoming infected by a disease

COVID-19 characteristics

COVID-19 is the name given to the disease caused by the SARS-CoV-2 virus. The main steps in infection are exposure (where someone comes into contact with virus due to direct or indirect contact); incubation period, whilst the virus is replicating in the patient; then development of symptoms, immune response, and recovery or other outcome.

The **incubation period** for COVID-19, which is the time between exposure to the virus (becoming infected) and symptom onset, is on average 5-6 days, however can be up to 14 days. An additional step, during the incubation period, is the onset of infectiousness, which is the point at which the patient can pass on the disease to someone else. This contrasts with SARS-CoV (the outbreak from 2003) which became infectious after symptom onset.

Patients with COVID-19 will either show symptoms (symptomatic) or not show symptoms (asymptomatic). International evidence suggests that approximately a third of people with COVID-19 will not show symptoms.[1] Unpublished modelling by academic groups uses an assumption that 33% of cases are asymptomatic.[2] The majority of COVID-19 patients are not likely to require hospital treatment. Asymptomatic patients may still contribute to transmission.

Why the 'R' number matters

The importance of R in describing an outbreak such as COVID, where person-to-person transmission is the driver, is in the impact on increasing or decreasing case numbers.

Put simply, if R is below 1, each case will give rise to fewer than one additional case, so over time case numbers will dwindle to zero. However, if R is above 1, case numbers will increase exponentially. The higher the R, the faster this increase will occur.

For a completely uncontrolled infection with $R_0>1$, infections rise exponentially until most of the population has been infected, then R_t falls below 1 and cases decrease back to baseline. The reason for this fall in R_t and case numbers is that those infected are no longer susceptible to repeat infection, for a short or longer period, so the number of people left to infect is not sufficient to maintain transmission. In a population where everyone is infected or has just recovered (and so are not susceptible), one infection will not give rise to any more cases as there is no-one left to infect.

Measles is one of the most infectious common diseases with an R_0 value of 12-18. R_0 for COVID-19 has been estimated as 2.8 (but has been estimated as high as 4 or more), which means that in the absence of immunity or mitigation measures, each

[1] https://www.cebm.net/covid-19/covid-19-what-proportion-are-asymptomatic/
[2] SAGE reasonable worst case (RWC) planning assumptions – 29 March 2020

case would pass on the virus to a further 2.8 people on average.[3] This R_0 value also means that around 64% of people need to have antibodies for the virus to see herd protection effects.

The R_t value may assume some of the population has recovered from the virus and has some immunity, and may assume that the impacts of the behavioural measures designed to control the spread have started to take effect. R_t is not a constant. It depends on the biology of the disease and human behaviours. As such it can vary depending on the susceptibility, size and density of the population that the infection is introduced into, in particular mixing patterns for people in close proximity. R_t also depends on the infectiousness of the virus itself at the start (R_0).

The higher R_0, the larger the reductions in transmission (through social distancing, contact tracing and other measures) and in susceptibility (through natural infection or vaccination) need to be to get Rt below 1.

Use of models

Models can be used to predict the outcome of applying various packages of control measures over a long period. The main example is the Imperial College London model which helped to shape decisions around lockdown for the UK, based on estimates of case and death numbers over time. These models have been developed over a long time by specialist academic teams, but are becoming available for local use.

Simpler modelling methods can be applied to make short-term predictions based on growth of cases, and also to make estimates more timely by adding in known delays between onset of the virus and hospitalisation (so-called "nowcasting").

How is R_t calculated, and what are its limitations?

R can be calculated using multiple methods. The differences in the approach are typically based on which data source is used to consider growth or decline of the virus, as Rt cannot currently be measured directly.

For this publication, R_t has been measured by the Welsh Government, Public Health Wales and leading academics across the UK (e.g. Imperial[4], LSHTM[5], Bristol[6] and others). All contributors use a different methodology for modelling R_t and their results are brought together for a consensus view. The models use new hospital admissions where the patient has tested positive for COVID-19, new confirmed cases (where a patient has been tested positive for COVID-19), and deaths where the deceased has been tested positive for COVID-19. We also consider that – due the hibernation

[3] SPI M O consensus 25th March 2020. Published at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882723/26-spi-m-o-working-group-scenario-planning-consensus-view-25032020.pdf

[4] https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/

[5] https://www.lshtm.ac.uk/research/research-action/covid-19

[6] Challen et al. (2020) Estimates of regional infectivity of COVID-19 in the United Kingdom following imposition of social distancing measures. https://www.medrxiv.org/content/10.1101/2020.04.13.20062760v2

period – there will always be a time lag in reporting R_t and therefore caution will always be needing interpreting the value as representing the position at any current time.

Each of the methods used has its own strengths and weaknesses, and as with any modelling mean that care should be taken in interpretation of the results.

The **number of cases** (tested positive for COVID) will present the most rapid estimate of Rt. This measure includes all people that are aware that they have the virus, so may also include some who are in the hibernation period. It is very likely that the estimate is an undercount. However, we can follow the data over time to show the relative change in this measure. Notably, whether the number of cases is increasing or decreasing, and therefore how quickly the virus is spreading. As the number of people tested for the virus increases, we expect these estimates to improve.

The **number of hospital admissions** (tested positive for COVID) is a less timely measure but more accurate. However, this measure only includes those with symptoms who have presented to hospitals. This measure only includes people who have developed symptoms requiring hospital treatment. This value also depends on the number of tests carried out and is likely to be based on an undercount. However, we can follow the data over time to show the relative change in this measure. Notably, whether the number of hospital admissions is increasing or decreasing, and therefore how quickly the virus had spread to cause these admissions.

The **number of deaths** (tested positive for COVID) is the least timely estimate of R_t. The accuracy of this figure is dependent on the source of the data. Using hospital deaths provides a quicker estimate, however ONS statistics will provide records for the whole population of Wales. Again, this may be impacted by the number of people tested. However, we can follow the data over time to show the relative change in this measure. Notably, whether the number of deaths is increasing or decreasing, and therefore how quickly the virus had spread to cause these deaths.

Estimating R in different settings

In Wales, Public Health Wales (PHW) are estimating R_t using new admissions to hospital with confirmed COVID-19 infection. Infections likely acquired in hospital, and those tests not done in hospital (for example key worker testing) are excluded, leaving only those cases who have probably contracted infection in the community, deteriorated, and required hospital admission. This is likely to represent around 4% of community symptomatic cases (Source: PHW analysis). As the probability of hospitalisation for a case should remain constant (as long as the virus has similar characteristics, and criteria for hospitalisation do not change), this is a stable sample of all community-onset COVID-19 cases and so estimates community transmission rates.

R can also be estimated in people in hospital (nosocomial transmission), which are a separate population of up to 10,000 (max bed capacity), or in closed settings such as care homes. As Welsh Government measures are applied separately in these settings, considering these separate estimates is helpful. For example, community social distancing will reduce R in the community, but not in hospital- and hospital infection control measures will reduce R in the hospital setting without requiring intervention in the community.

At the moment, we are likely to be seeing three different epidemics for specific groups of the population in Wales. These have been categorised into three areas:

- the **community** or general population in Wales;
- **hospitals and healthcare settings** – where there is a high volume of COVID cases in one place and therefore a higher risk of onwards transmission.
- **care homes** –where infection can spread rapidly with a close.

There is some interdependence, in that infections in care homes and hospitals can “seed” infections into the community. However, if control measures in the community are such that R_t is below 1, this seeding should not cause exponential growth (and similarly in each setting).

Other methods use overall case numbers, or reported hospitalisations with COVID, as the data to model.

What is the impact of R on healthcare demand?

As above, case numbers in the community give rise to hospital admissions, and also to requirement for ventilation and ICU admission for worsening cases. For each outcome, there is a distribution of lengths of stay leading to an accumulation of new cases in various levels of care. This means that there is a lag between increases in community cases and hospitalisations, and also a lag whilst admitted cases recover- so bed occupancy can rise even while community transmission is falling.

The NHS England model that has been adapted for Wales applies probabilities of these outcomes, and lengths of stay, to case numbers estimated from the Imperial model (or others if available) at a Wales level. These have been scaled for lower geographic levels for planning, but the underlying case numbers are not modelled based on the actual situation in Wales so local extrapolations are likely to be inaccurate. Analysis of actual local data on admissions and other outcomes is likely to be a better source of short-term predictions.

Interpretation of the impact of lockdown measures on R_t

Decisions will need to be made on which lockdown measures to relax and when. Most models are developed based on previous events. As these measures have been introduced for the first time, it is not yet clear what will happen to R_t if interventions are switched on or off. Most studies suggest that lifting lockdown may lead to a rapid increase in R_t. This can be partially offset by other interventions like track and trace.

Analyses for Wales

Reproduction Ratio

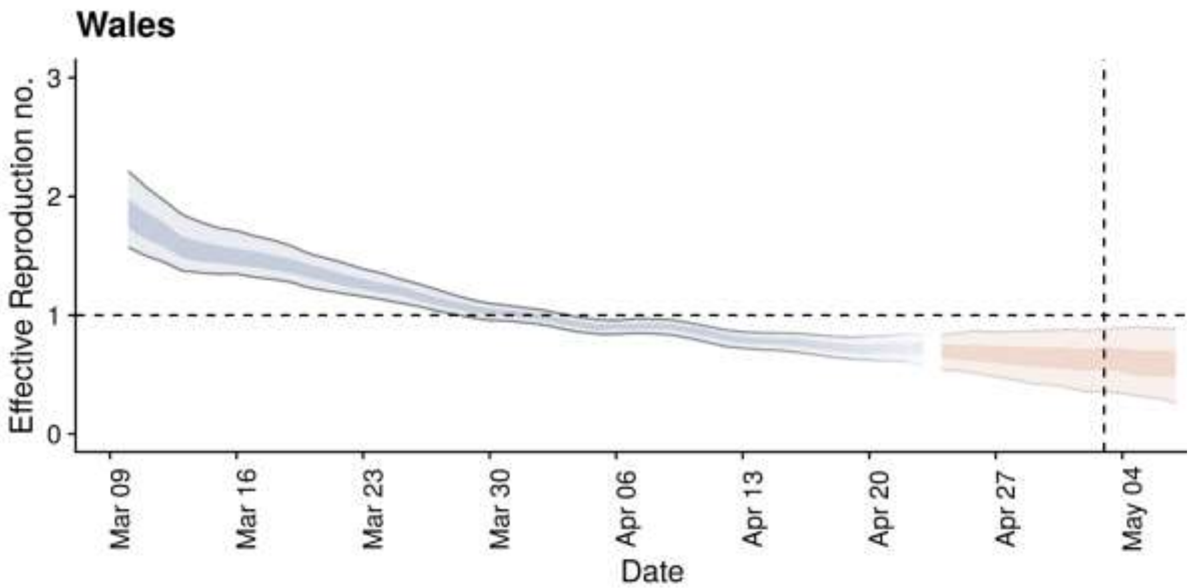
R_t = 0.7-0.9, this means the number of cases is **decreasing** in Wales.

The value of 0.7-0.9 was agreed as the consensus value on 6th May 2020. Most recent estimates from LSHTM as of 7th May (which use data up to 24th April 2020) suggests that R_t = 0.7 for Wales, with 90% credible intervals of 0.6 to 0.8. This means for every ten people that are infected, seven further people are infected.

Current estimates of R_t reflect cases from around two weeks ago. There is a delay in estimating R_t due to the 'incubation period' and the time it takes to be tested for the virus.

Because R_t is below 1, it is expected that the number of new cases of COVID-19 are decreasing. When excluding hospital-acquired cases, the community Rt is lower.

Figure 1: Rt in Wales



Source and further information: National and Subnational estimates for the United Kingdom https://epiforecasts.io/covid/posts/national/united-kingdom/

R_t has decreased in Wales since social distancing and lockdown measures were introduced. R_0 for COVID-19 has been estimated as 2.8 (but has been estimated as high as 4 or more).

These R_t estimates are for the whole population, however may be slightly higher due to a bias towards health care workers who have had proportionately more tests. Hospital admissions from 24th March to 27th April also gave an R_t value of around 0.9. Admissions data suggested the previous R_t value had hovered around 1 since lockdown.

We are likely to be seeing three different outbreaks at the moment:

1. Community where R_t is falling and is likely to be below 1

2. Hospital/healthcare setting where R_t may be between 0.1 and 0.25. The R_t value varies with some hospitals having larger outbreaks.

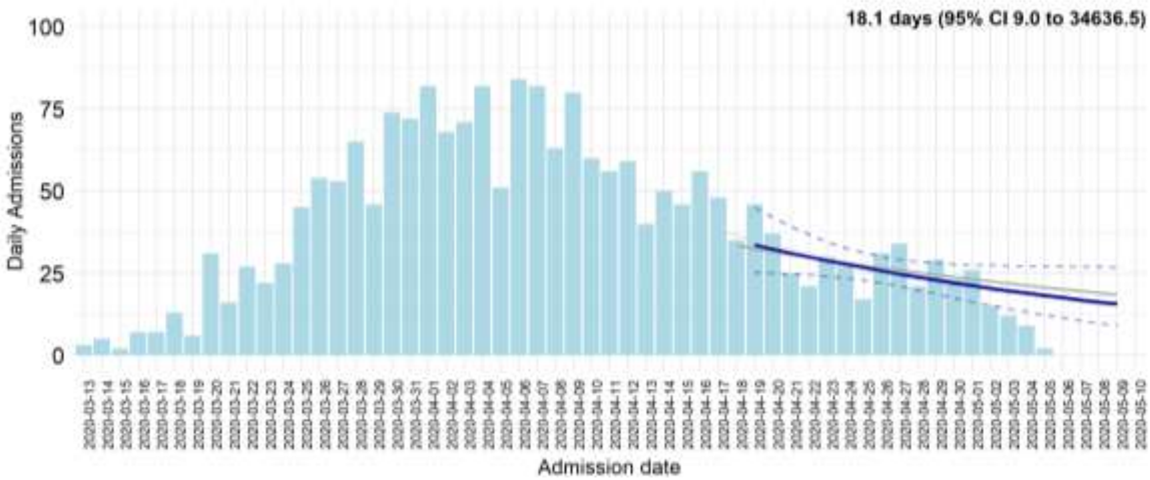
3. Care homes where infection can spread rapidly. High prevalence of infection has been found in some investigations.

Infections in health and social care workers may contribute as well. The dynamics between these outbreaks can be unpredictable.

Halving times (in Wales)
About 10.1 days: Good

The number of new hospitalisations for COVID-19 in Wales has passed the first peak and is estimated to be falling. So, instead of talking about 'doubling times', we now talking about 'halving times' – the time it takes for the number of cases to halve. From 22 March to 10th April, the estimated doubling times increased from 7.6 to 92.1 days. This was based on community acquired hospital admissions. Halving time estimates as at 05/05/2020 (based on admissions from 19/04/2020 to 02/05/2020) suggest the time taken for the number of new cases to halve is approximately 18.1 days.

Figure 2: Estimated doubling time for new hospital admissions for community acquired COVID.



Footnotes:
Community acquired cases are assumed to be those where the time between admission and sample date is less than four days. This subset of data has been used for the purposes of estimating changes in transmission in the community and the number of new COVID diagnoses in patients in hospital will be higher than presented in this chart.

Doubling/halving time estimates are sensitive to the time period chosen. For the purpose of this analysis 14 day's worth of data has been used. Halving time estimates as at 05/05/2020 and are based on admissions from 19/04/2020 to 02/05/2020. 95% confidence intervals are indicated by dashed lines. These data exclude patients where the hospital admission date is more than 14 days after the specimen date. These are assumed to be non-COVID related admissions.

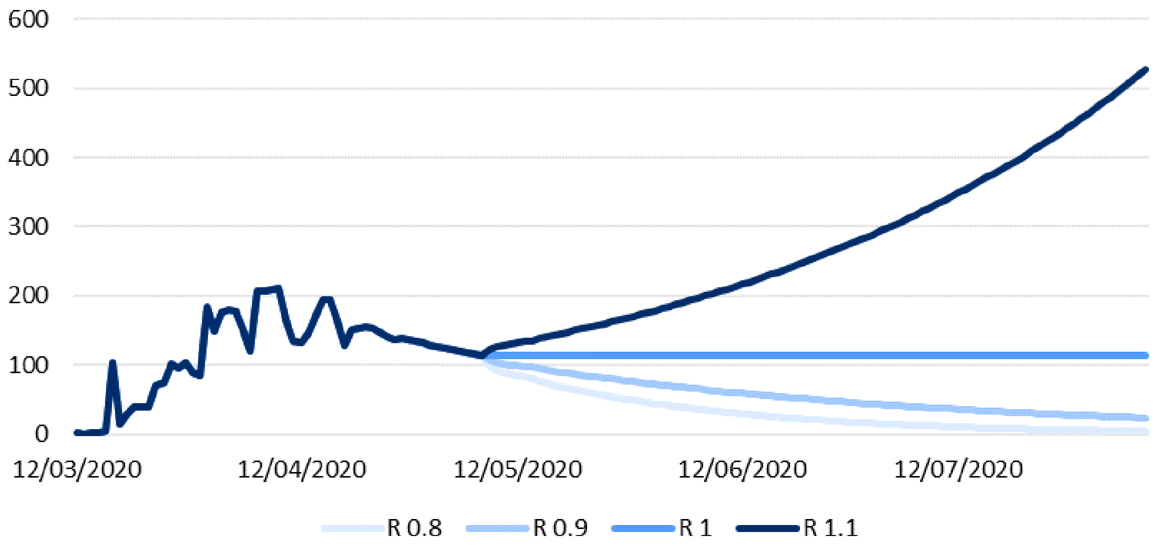
Source: All Wales Hospital Case Management System, Public Health Wales – as at 05/05/2020.

Hospital capacity

Demand and capacity in hospitals: Falling but could increase if restrictions are lifted.

A small increase in R_t above 1, maintained for 3 months, can have a huge impact on hospital demand. It can greatly increase the number of hospital admissions and deaths.

Figure 3: Admissions per day under different scenarios of Rt.



Source: Welsh Government, TAC

	Cumulative for the time period 8th May – 7th August		
Rt scenario	Confirmed cases	Hospital admissions	Deaths
0.8	5,100	2,800	800
0.9	9,300	5,000	1,400
1.0	19,600	10,600	2,900
1.1	47,600	25,700	7,200

It is difficult to model future hospital demand. In some Health Boards, the increase in capacity has been moving a step ahead of demand for a couple of weeks. This has been the case for Aneurin Bevan and Cardiff and the Vale Health Boards.

On 23rd March, lockdown, and chose to shield the most vulnerable people in our population. The number of cases per population in Wales was lower than some parts of the UK, notably London. In Wales, we are not seeing similar levels of predicted critical care demand for older people although there has been a high rate of deaths in care homes since mid-March compared to the same time period for previous years.

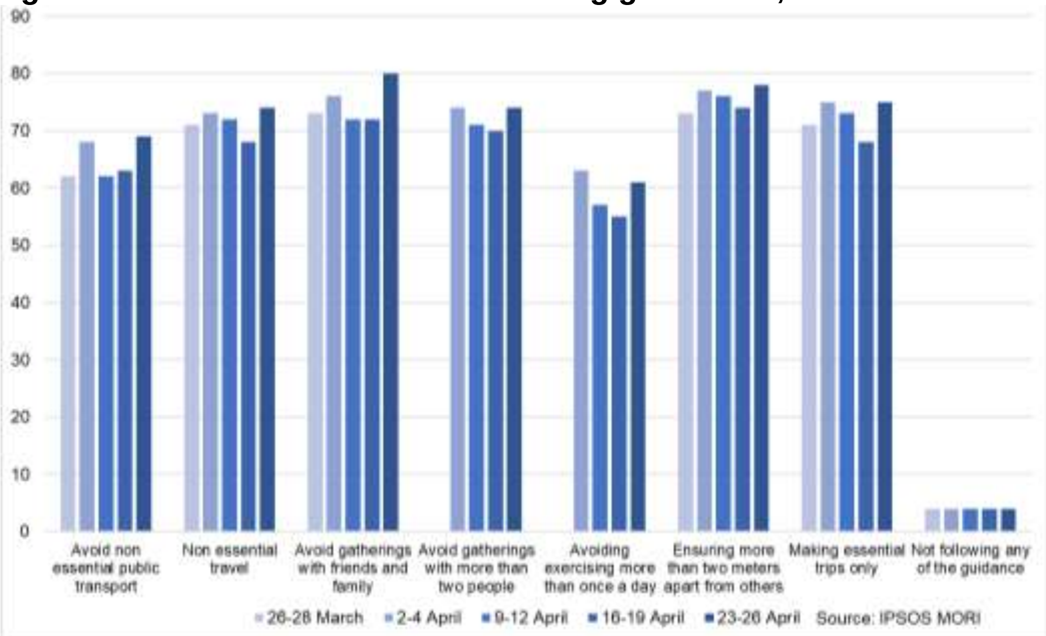
The modelling suggests that there will be an ongoing need for specialist hospital treatment for COVID-19 patients for some time. However that the number of new cases, and therefore hospital treatment, is reducing. The number of beds required will depend on planning decisions made. For example, separate facilities could be used for people with COVID-19. This way, there may be less risk of infection. However, more beds may be required.

Social Distancing Adherence

Over 70% : Good

The assessment of this comes from survey data that asks if individuals in Wales are following the guidelines. Those who state they are following the guidelines is mostly around or over 70% with only 4% saying they are not following any of the guidance.

Figure 4: Adherence to social distancing guidelines, Wales



Data collected online by Ipsos as part of a multi-country survey on the Global Advisor platform. Each of the past five waves have included c.600 respondents in Wales. The sample is broadly representative of the adult population aged 16-74. Data is weighted to reflect the age and gender profile of the Welsh population aged 16-74. All samples have a margin of error around them. For a sample of around 500, this is +/- 4.8 percentage points.

For further information on public views on COVID-19, please see: https://gov.wales/survey-public-views-coronavirus-covid-19

Alongside the survey data, a range of other mobility information is also used. This shows large reductions in movement/travel in Wales since the middle of March. However, recent weeks have shown some increases in mobility. This may not mean that people are following the guidelines less. For example, some businesses have re-opened in recent weeks (e.g. hardware and some food stores). Data from Google shows large reductions in people using public transport and going to workplaces.

Figure 5: Change in mobility.