# Module 2B of the UK Covid-19 Public Inquiry
# Request for Evidence under Rule 9 of the Inquiry Rules 2006
# Reference for Request - M2/SAGE/01/MXG1
# Professor Michael Gravenor

## Professor of Epidemiology and Biostatistics, Swansea University Medical School

*1. A brief overview of your qualifications, career history, professional expertise and major publications*

Qualifications

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|---|---|
| 1988 – 1991 | *University of Cambridge*<br>BA(Hons) Natural Sciences, First Class |
| 1991 – 1995 | *University of Oxford*<br>DPhil, Department of Zoology<br>NERC Studentship Award |
| 1999 – 2001 | *University of Reading*<br>MSc Biometry, Department of Statistics, with Distinction |

Career History

| | |
|---|---|
| 1995 – 1998 | Medical Research Council (MRC) Personal Fellowship Award<br>*Institute of Molecular Medicine (now Weatherall Institute), University of Oxford*<br>Developed mathematical models to predict total parasite load in cerebral malaria patients |
| 1998 – 2003 | Mathematical Modeller, BBSRC Award<br>*Institute for Animal Health, Compton*<br>Part of large BBSRC TSE programme designing UK scrapie control plan, providing mathematical modelling, statistical support, and extensive field data collection. |
| 2003 – 2007 | Senior Lecturer in Epidemiology<br>*Swansea University Medical School*<br>Medical School foundation appointment, promoted to Reader 2006. Research included HIV evolution, Rabies, Measles, Dengue Virus, Avian Influenza Pandemic Preparedness |
| 2007 – present | **Professor of Epidemiolgy and Biostatistics**<br>*Swansea University Medical School*<br>Head of Data Science (2022-) |

My professional expertise is the application of mathematical and statistical methods to research problems in the medical and biological sciences. I have 30 years experience in the application of mathematical models to the study of infectious disease. I have published over

150 peer reviewed journal papers since 1993. Google Scholar link: https://tinyurl.com/gravenor. Selected outputs are highlighted here, as exemplars of projects in a wide range of disciplines, and having significant impact through fundamental or policy driven science.


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Gravenor, M. B., D. Cox, L. J. Hoinville, A. Hoek and A. R. McLean (2000). "Scrapie in Britain during the BSE years." Nature **406**(6796): 584-585.

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Haydon, D., D. Randall, L. Matthews, D. Knobel, L. Tallents, M. Gravenor, S. Williams, J. Pollinger, S. Cleaveland and M. Woolhouse (2006). "Low-coverage vaccination strategies for the conservation of endangered species." Nature **443**(7112): 692-695.

Hays, G. C., T. Bastian, T. K. Doyle, S. Fossette, A. C. Gleiss, M. B. Gravenor, V. J. Hobson, N. E. Humphries, M. K. Lilley and N. G. Pade (2012). "High activity and Lévy searches: jellyfish

can search the water column like fish." Proceedings of the Royal Society B: Biological Sciences **279**(1728): 465-473.

Hays, G. C., S. Fossette, K. A. Katselidis, G. Schofield and M. B. Gravenor (2010). "Breeding periodicity for male sea turtles, operational sex ratios, and implications in the face of climate change." Conservation Biology **24**(6): 1636-1643.

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Brophy, S., R. Cooksey, M. B. Gravenor, R. Mistry, N. Thomas, R. A. Lyons and R. Williams (2009). "Risk factors for childhood obesity at age 5: analysis of the millennium cohort study." BMC public health **9**(1): 1-7.

Charlton, R., M. B. Gravenor, A. Rees, G. Knox, R. Hill, M. A. Rahman, K. Jones, D. Christian, J. S. Baker and G. Stratton (2014). "Factors associated with low fitness in adolescents–a mixed methods study." BMC public health **14**(1): 1-10.

Jones, S., M. James-Ellison, S. Young, M. Gravenor and R. Williams (2005). "Monitoring trends in obesity in South Wales using routine data." Archives of disease in childhood **90**(5): 464-467.

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Kosakovsky Pond, S. L., S. D. W. Frost, Z. Grossman, M. B. Gravenor, D. D. Richman and A. J. L. Brown (2006). "Adaptation to different human populations by HIV-1 revealed by codon-based analyses." PLoS computational biology **2**(6): e62

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Halcox, J. P., K. Wareham, A. Cardew, M. Gilmore, J. P. Barry, C. Phillips and M. B. Gravenor (2017). "Assessment of remote heart rhythm sampling using the AliveCor heart monitor to screen for atrial fibrillation: the REHEARSE-AF study." Circulation **136**(19): 1784-1794.

Plebanski, M., E. A. Lee, C. M. Hannan, K. L. Flanagan, S. C. Gilbert, M. B. Gravenor and A. V. Hill (1999). "Altered peptide ligands narrow the repertoire of cellular immune responses by interfering with T-cell priming." Nature medicine **5**(5): 565-571.

Flanagan, K. L., E. A. Lee, M. B. Gravenor, W. H. Reece, B. C. Urban, T. Doherty, K. A. Bojang, M. Pinder, A. V. Hill and M. Plebanski (2001). "Unique T cell effector functions elicited by Plasmodium falciparum epitopes in malaria-exposed Africans tested by three T cell assays."

Stallard, N., M. B. Gravenor and R. N. Curnow (2006). "Estimating numbers of infectious units from serial dilution assays." Journal of the Royal Statistical Society: Series C (Applied Statistics) **55**(1): 15-30.

Sazonov, I., M. Kelbert and M. B. Gravenor (2011). "A two-stage model for the SIR outbreak: Accounting for the discrete and stochastic nature of the epidemic at the initial contamination stage." Mathematical biosciences **234**(2): 108-117.

Moller, M., M. B. Gravenor, S. E. Roberts, D. Sun, P. Gao and J. M. Hopkin (2007). "Genetic haplotypes of Th-2 immune signalling link allergy to enhanced protection to parasitic worms." Human molecular genetics **16**(15): 1828-1836.

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Saunders, N. J., E. R. Moxon and M. B. Gravenor (2003). "Mutation rates: estimating phase variation rates when fitness differences are present and their impact on population structure." Microbiology **149**(2): 485-495.

*2. A list of the groups (i.e. TAG / or any of its sub-groups) in which you have been a participant, and the relevant time periods. Please also confirm if you have been a participant in SAGE or other relevant groups.*

- Member of TAG
- Member of the TAG Modelling Sub-group
- Throughout the period I was also a member of the SAGE Group: SPI-M-O (Scientific Pandemic Influenza Group for Modelling)

*3. An overview of your involvement with those groups between January 2020 and February 2022, including:*

*a. When and how you came to be a participant*

I have colleagues in Public Health Wales, with whom I was in informal contact at the very early stages of the pandemic (January and February 2020). Over the next few months I provided informal modelling advice to colleagues and was then formally invited onto the TAG modelling subgroup in May 2020, shortly followed by invitation to the main TAG group by the Chair. I led a small group, "The Swansea Modelling Team" at Swansea University which delivered the research that fed into the TAG groups.

*b. The number of meetings you attended, and your contributions to those meetings*

I personally attended the vast majority of TAG and TAG Modelling Group meetings during the time period. Well over 100. My contribution was to general discussions on most topics, and specific contributions to modelling (see below). For substantial periods The Swansea

Team modelling became essentially a fixed agenda item and I presented in person at most meetings at the crisis points of the period, and would have been among the most frequent scientific presenter at all TAG meetings.

*c. Your role in providing research, information and advice.*

My main role was to contribute mathematical modelling to support understanding the evolving epidemic in Wales, and to provide scenarios to consider the potential impact of the epidemic on severe events on the population and the health service. In particular we focused on how interventions (non-pharmaceutical (NPI), improved therapy and vaccination) might be effective at different stages of the epidemic.

The Swansea Team was established by myself (School of Medicine) and Professor Biagio Lucini (School of Mathematics) to fill a clear gap in Wales for bespoke mathematical pandemic modelling expertise to inform devolved health policy decisions. At all points in the pandemic the modelling results from the large SAGE groups (such as SPI-M-O of which I was a member) were being shared and used in Wales, however it soon became apparent that due to natural factors such as geography and socioeconomics, and also due to different timing of responses across the devolved administrations (DAs), the results obtained from 'scaling' of UK modelling output for Wales were not ideal. The Swansea Team demonstrated we could rapidly provide bespoke models, and were immediately called upon to build on those models and develop them at every subsequent stage of the pandemic.

The Swansea Team was simply myself, Prof Lucini and a seconded Research Software Engineer from Supercomputing Wales at Swansea University. The following colleagues took turns in providing this essential RSE expertise: Drs Mark Dawson, Ed Bennett, Ben Thorpe and Carla White. Supercomputing Wales also provided access to the essential computational hardware. The team produced its first results, a Welsh Policy model used by NHS trusts and Welsh Government (WG), within weeks, then informed the planning for the second wave and introduction of vaccination. The Swansea Team expanded with expertise from Biosciences, Computer Science and Mathematics and established itself as a key provider of support for decisions around COVID-19 response policies in Wales, regularly working to extremely short deadlines on very difficult questions. We presented directly to TAG, NHS, Test and Trace, and Welsh Government. The research and information we provided from modelling and statistical analysis informed many aspects of the pandemic in Wales including:

- Instructing NHS Wales planners / Health Boards / Public Health Wales / WG on methods to estimates the R value
- Assessing the efficacy of Wales Test Trace and Protect system
- Assessing the relevance of the geographical movement rules
- Assessing the impact of WG bubble policy
- Modelling the requirement for plasma
- The Wales Reasonable Worst Case and Most Likely Scenarios. These have been updated weekly throughout and used by WG, all NHS trusts and Wales Ambulance Service Trust
- Designing and assessing the impact of the Wales Firebreak
- Designing and assessing the impact of 20/21 winter/Christmas/new year NPIs

- Designing and assessing the 2021 school re-opening strategy
- Analysing the impact on care homes
- Modelling the impact of hospital discharge on care homes
- Mapping geographical spread in Wales
- Advising on the date of the Welsh Senedd elections by providing early long term forecast of (likely low) prevalence and transmission for the scheduled date of 06/05/2021
- Visualisation for modelling of contact tracing policies.
- Designing and assessing the road map out of lockdown under the impact of the vaccination roll out and under the emergence of the delta variant
- Designing and assessing the relaxation of isolation rules in summer 2021 (first in UK)
- Modelling the expected course, and impact, of the delta wave and Autumn peak
- Estimating the impact of the Immensa laboratory errors on transmission in Wales
- Modelling the emergence of omicron, the interaction between virus strains, continually monitoring severity up to 23/12/21, informing Christmas / new year interventions
- Estimating the efficiency of Alert Level 2 restrictions in Wales over Christmas 2021
- Modelling the impact of new lateral flow device test and release isolation policies for Wales
- Providing a "Medium Term Projection" (MTP) weekly
- Providing long term future scenarios

To expand, briefly, on 8 of the major projects we delivered quantitative scenarios for: **The reasonable worst case**: With very low COVID-19 levels over summer 2020, there was great uncertainty regarding the likely winter epidemic trajectory. Our models showed the very large potential that remained in the epidemic given the relatively small proportion of the population that had been infected up to that point (a value which we estimated for the Welsh Government). There was, at that time, considerable scepticism that a second wave could be so big, so the models were used to inform early planning for hospital capacity and staffing levels, and demand for the Ambulance service. A demand that, in the end, was indeed required. In September and October 2020 our models showed the points at which the increasing prevalence would cause severe events at very high levels and health service capactity would be greatly challenged. **The firebreak**: We provided estimates for the impact of a short NPI used to slow down the epidemic and the amount of time expected after the intervention for the epidemic to return to pre-firebreak levels. The estimates were used in firebreak planning, mapping closely to the outcomes, and were used to assess the impact of this novel type of intervention. **Winter 2020-21 NPIs**: After the firebreak we modelled the rebound in the epidemic and the time available before further interventions might be required based on hospital capacity and severe events. The analysis showed that interventions at previous (Tier 3) levels were having a lesser effect in December 2020 which was likely a combination of winter mixing patterns and especially the emergence of the alpha new variant. The models were used to generate scenarios based on the significant increase in transmissibility and potentially virulence, and these informed the NPI actions taken in December to reduce the R value below 1 and reduce the peak impact and demand on the health service. **Vaccination and School opening NPIs**: During the NPIs over the new year period the prevalence was reduced to very low levels, vaccination programmes began, and the focus was on school openings. We provided extensive scenarios for the relaxation of NPIs to estimate the potential impact on the population and health service after the initial

vaccination of most vulnerable age groups vaccinated, in particular with the increased transmissibility of alpha. Again, it was important to consider the residual susceptible population which remained high enough at key age groups to generate a significant impact. Within these scenarios we focused on school opening and modelled a wide range of scenarios showing the impact in combination with other relaxation of NPIs with the aim of providing the most rapid return to schooling while minimising the overall impact on the population and hospitals at that time. These scenarios were presented to and discussed in detail with the Welsh Government as the phased school opening progressed. **The opening road map**: After the full school opening, attention turned to modelling the exit from all NPIs. Although this was clearly the way forward, following successful vaccination roll out, it also coincided with the emergence of the even more transmittable delta variant. This was the second major point in the epidemic in which key decisions had to be made at a time of very low prevalence. At these points the quantitative analysis is particularly useful, as there can be a false sense of security regarding the potential impact. Our scenarios showed the stark impact of delta, which would clearly lead to a large wave of cases, so it was crucial to provide estimates of the mitigation to clinical and hospital effects that would be provided by the vaccine. We modelled these vaccine effects in detail and how they ramped up over time, and provided these to inform the road map out of all restrictions in summer 2021 (alongside relaxation of isolation guidelines in collaboration with **Test and Trace Wales**). **The delta wave**. Following the end of most restrictions, we modelled the delta wave throughout the Autumn, as the expected very large wave of infections played out, and provided continual estimates of the (reduced) impact on clinical and health services. We provided estimates of the approaching "herd immunity" peak of infections, but also of how that would be impacted by waning immunity from natural infection and from vaccination. This showed scenarios in which there would not be a simple peak and COVID-19 would go away, but a more gradual decline could be expected which could flatten out as a more endemic situation was approached and future waves could still occur as population immunity waned and waxed. **The omicron wave**: In December 2020, at a time of still high, but generally manageable, delta infections, we estimated the growth rate of the emergence of the omicron variant. This was so high, it was very difficult to imagine the huge impact on infections it would cause, even in a population with so much previous exposure and levels of vaccination. We had days to prepare scenarios and also very little data on the likely clinical impact of omicron. We prepared scenarios for the Christmas 2021 period that showed exceptionally high levels of infection were expected, far higher than even seen for delta. This meant that the impact of omicron was going to be very sensitive to its (largely unknown) severity on the population, and how much cross-immunity protection was afforded by previous infection or the multiple vaccine doses. This was another point of exceptional uncertainty in the epidemic, compounded by the lack of data. In late December we provided scenarios for a range of assumed omicron clinical severities. On December 23rd we received enough data on the clinical impact to rule out the worst case impacts, but there still remained considerable uncertainty and these were illustrated in two scenarios (low and medium). The subsequent impact on infections ran close to the high levels of all the model scenarios (infection level estimates were consistent across all scenarios), and clinical and hospital impact ran close to our "low" scenario, these were used to model removal of NPIs in January 2022. All this research has informed our **medium term projection** models which provide short term forecasts for hospital demand and are submitted weekly to the Welsh

Government (and bi-weekly to UKHSA), a project which continues today, and has expanded to include influenza and RSV.

*4. A summary of any documents to which you contributed for the purpose of advising TAG and/or its related subgroups on the Covid-19 pandemic. Please include links to those documents where possible.*

I contributed to many (greater than 50) published outputs from TAG, which have been supplied as part of the TAG response.

In particular, the modelling updates were regularly published, many of which were based directly on the Swansea Team outputs:https://gov.wales/advice-coronavirus-technical-advisory-cell#Modellingupdates .

I contributed to a large number of subject specific Technical Advisory Cell reviews, reports and opinon pieces on other aspects of the epidemiology, collated here: https://gov.wales/advice-coronavirus-technical-advisory-cell.

I have provided a response previously regarding my SPI-M-O involvement. Specific to Wales, this includes:

> I contributed to numerous SPI0M-O Consensus Statements. These were published weekly at peak times. See repository at: https://www.gov.uk/government/collections/scientific-evidence-supporting-the-government-response-to-coronavirus-covid-19
>
> Within the papers are regular "SPI-M-O Consensus Statement on COVID-19" submissions. I also contributed model projections as part of the ensemble model summaries for Wales included in the regular "SPI-M-O: Medium-term projections". For example: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1055473/S1511_SPI-M-O_MediumTermProjections__9_February.pdf
>
> Modelling to support discussion on the Wales Firebreak: https://www.gov.uk/government/publications/welsh-government-tag-fire-breaks-19-october-2020
>
> Modelling Reasonable Worst Case Scenarios in Wales: An October 2020 update to the SPI-M-O July 2020 Models, see: https://www.gov.uk/government/publications/spi-m-o-uk-reasonable-worst-case-scenario-weekly-metrics-30-july-2020

Other specific modelling analyses included work subsequently published with co-authors in peer reviewed journals, in particular several studies of care home transmission and transmission within schools.


Emmerson, C. et al. (2021). "Risk factors for outbreaks of COVID-19 in care homes following hospital discharge: A national cohort analysis." Influenza and Other Respiratory Viruses **15**(3): 371-380.

Emmerson, C. et al. (2022). "The Impact of dementia, frailty and care home characteristics on SARS-CoV-2 incidence in a national cohort of Welsh care home residents during a period of high community prevalence." Age and Ageing **51**(12).

Hollinghurst, J. et al. (2021). "The impact of COVID-19 on adjusted mortality risk in care homes for older adults in Wales, UK: a retrospective population-based cohort study for mortality in 2016–2020." Age and ageing **50**(1): 25-31.

Hollinghurst, J., et al. (2022). "Intensity of COVID-19 in care homes following hospital discharge in the early stages of the UK epidemic." Age and ageing **51**(5): afac072.

Lyons, J., et al. (2020). "Understanding and responding to COVID-19 in Wales: protocol for a privacy-protecting data platform for enhanced epidemiology and evaluation of interventions." BMJ open **10**(10): e043010.

Hollinghurst, J. et al. (2022). "COVID-19 infection risk amongst 14,104 vaccinated care home residents: a national observational longitudinal cohort study in Wales, UK, December 2020–March 2021." Age and Ageing **51**(1): afab223.

Marchant et al. (2022). "COVID-19 mitigation measures in primary schools and association with infection and school staff wellbeing: an observational survey linked with routine data in Wales, UK. Plos One 17 (2), e0264023.

Hollinghurst, J. et al. (2022). "SARS-CoV-2 infection risk among 77,587 healthcare workers: a national observational longitudinal cohort study in Wales, United Kingdom, April to November 2020." Journal of the Royal Society of Medicine: 01410768221107119.

Thompson, D. A., et al. (2021). "Staff–pupil SARS-CoV-2 infection pathways in schools in Wales: a population-level linked data approach." BMJ paediatrics open **5**(1).

Perry et al. (2022). "COVID-19 vaccine uptake and effectiveness in adults aged 50 years and older in Wales UK: a 1.2 m population data-linkage cohort approach". Human Vaccines & Immunotherapeutics **18** (1), 2031774

Gibson et al. (2022). An interactive tool for enhancing hospital capacity predictions using an epidemiological model. Proceedings of the Genetic and Evolutionary Computation Conference.

Torabi, F. et al (2021). Impact of COVID-19 pandemic on community medication dispensing: a national cohort analysis in Wales, UK. International Journal of Population Data Science **5** (4).

Perry et al. (2022). Inequalities in coverage of COVID-19 vaccination: a population register based cross-sectional study in Wales, UK. Vaccine **39** (42), 6256-6261

Fry et al. (2022). "Assessing the impacts of COVID-19 on Care Homes in Wales". International Journal of Population Data Science **7** (3).

*5. A summary of any articles you have written, interviews and/or evidence you have given regarding the work of the above-mentioned groups and/or the Welsh Government's response to the Covid-19 pandemic. Please include links to those documents where possible.*

I have written numerous research publications on COVID (see above) and contributed interviews and written advice on many occasions to a number of agencies in Wales (Public Health Wales, Wales Technical Advisory Cell, NHS Wales Trusts). I was contacted many times by media for interviews and quotes (BBC, ITV, Channel 4, Wales Online, Wired, newspapers).

*6. Your views as to whether the work of the above-mentioned groups in responding to the Covid-19 pandemic (or Wales's response more generally) succeeded in its aims. This may include, but is not limited to, your views on:*

a. *The composition of the groups and/or their diversity of expertise*;

TAG had excellent expertise, was large and diverse, with an exceptional inclusive and collegiate approach. A key aspect was the close involvement of colleagues 'on the ground'. Not just policy decision makers, but colleagues in the NHS, Ambulance Service, Test and Trace, Vaccination.

*b. The way in which the groups were commissioned to work on the relevant issues;*

Generally very good.

*d. The resources and support that were available;*

The administrative support was excellent
The Chairs were excellent
Resources were not made available at the start of the period for a very large amount of modelling that was conducted. The resources for this were undertaken in substantial personal time by a small group under considerable pressure (late evenings and weekends non-stop from August 2020 to February 2021), and also underpinned by the University (and Supercomputing Wales). Resources became available to the modelling team from August 2021.

*d. The advice given and/or recommendations that were made;*

Given the uncertainties at many key points in the epidemic the advice given was generally good and as in-depth as it could be. The speed at which much of the work was generated was remarkable.

*e. The extent to which the groups worked effectively together;*

Very good collaboration across institutions, an outstanding collegiate environment

*f. The extent to which applicable structures and policies were utilised and/or complied with and their effectiveness.*

Generally good, though uncertainties of a new pathogen and unique situation throughout impacted on the effectiveness of applicable structures.

*7. Your views as to any lessons that can be learned from the Welsh Government's response to the Covid-19 pandemic, in particular relating to the work of the above-mentioned groups. Please describe any changes that have already been made, and set out any recommendations for further changes that you think the Inquiry should consider making.*

The main positive lesson I learned was that the chain of information between experts and decision makers in Wales was impressively short. I believe this was extremely beneficial, as difficult decisions needed to be made in the face of considerable uncertainty. By having exceptionally close links with the science, that could be questioned rapidly, this added to clarity and speed of the advice. One example of this would be the composition of the modelling sub-group which included representatives from the Ambulance Service and all Wales NHS trusts. This meant that our modelling scenarios could be explained directly to people helping make key planning decisions. But also, we could quickly find out what exactly people were using the models for, which was essential for us to focus our efforts. Under the extreme time pressures it was important that our efforts were spent on modelling questions that were actually pertinent. This is harder to achieve than one might imagine, and it is very easy for academic research to go on a tangent from what is required right at that point in time. Time and time again this communication was useful for keeping us on track with our modelling and not waste time. In a similar manner, there was a very short chain between TAG chairs/secretariat and the Cabinet of the Welsh Government. This allowed many back and forth discussions with the Swansea Team, via the TAG Chairs and the modelling sub group Chair in particular. This, again, kept us on track and allowed our results to be explained clearly. At times of particular importance we were invited to explain results directly to the First Minister, Education, Economy and other Ministers. This is important given the technical nature of scientific evidence, and allowed direct questioning, which we again found very useful, and also served to focus and push our efforts along. Similarly, we often presented directly to the Wales Test and Trace. Perhaps benefiting from the size of the DA, the structure allowed good communication.

A lesson I will take from the TAG modelling sub group was the importance of a challenging, but collegiate working environment. Modelling output can be difficult to interpret and the output always needs to be challenged in terms of both the assumptions of the model and the mathematical approaches. We were always challenged, in particular on the epidemiological assumptions. The modelling was never accepted on face value without continuous challenge and appraisal. This was particularly important if it was feeding into decision making.

A similar point is how friendly the groups were. This may sound trivial, but these were groups that were required to operate effectively over a period of years. And almost everyone involved was a volunteer. If that collegiate atmosphere had not been maintained then I believe many individuals would have drifted away rather than remaining properly engaged. This does not mean that challenging discussion could not be had (as mentioned above) rather that Chairs and other organisers were able to maintain an environment in which volunteers were willing to keep contributing and important arguments could be had. I do not think this was an easy balance to keep for such a long period.

A provision should be made for modelling support within Welsh Government / Public Health Wales / University sectors. The number of times the Swansea Team was asked for support shows a requirement and our input would not be sustainable over a longer period. A modelling unit could provide background infrastructure for future pandemic preparedness, and support should be made available to Supercomputing Wales to underpin a pandemic response.

A general lesson of the pandemic has been the importance of mathematical modelling. However I am not a fan of the term 'modelling'. Really, the field I am involved with (and colleagues in SPI-M-O) is Quantitative Infectious Disease Epidemiology. This was rather a specialised field, and, as the experience showed, experts in public health epidemiology and virology rarely have expertise in this particular area. Mathematical and computer modelling is involved, and is indeed central, because there is no way to provide quantitative scenarios of epidemic spread and how it might be impacted by policies, without using underpinning mathematical models. But the aim of everything the Swansea Team did was to understand the epidemiology, and modelling was simply the key tool we used. The use of the term "modelling" can imply it is somehow different from epidemiology or there is some alternative, but I believe it is at the heart of the epidemiology if quantitative questions regarding disease spatial and temporal spread are to be asked. The use of 'modelling' can imply there is some alternative method for such quantitative questions, and there simply is not.

Finally, support should have been made available for all the time that was given by so many volunteers, many of whom had no time off their usual duties. For example, university academics were dealing with the consequences of the epidemic in their institutions (staff shortages, moving teaching to online at short notice, extra student support, all on top of usual duties). On top of these challenges they were working very long extra hours providing pressing analysis leading to the advice. I worked 7 day weeks long into the night with no let up between August 2020 and February 2021. This was an exceptional burden of work that was offered for free. Very few individuals were on secondment from their normal duties.

*8. A brief description of documentation relating to these matters that you hold (including soft copy material held electronically). Please retain all such material. I am not asking for you to provide us with this material at this stage, but I may request that you do so in due course.*

I have repository records of model development and scenario runs supporting advice. In particular Reasonable Worst Case, Firebreak, School Openings, Road Map scenarios, vaccination impact, and weekly Medium Term Projections for Wales.