Research Impact Case Study - MACSI – Mathematical and Statistical Modelling During the COVID-19 Pandemic

Title of the case study: MACSI – Mathematical and Statistical Modelling During the COVID-19 Pandemic

Details of staff conducting the underpinning research (names, job titles):

- Professor James Gleeson (MACSI, Irish Epidemiological Modelling Advisory Group (IEMAG) member)
- Professor Cathal Walsh (MACSI, IEMAG member)
- Professor Norma Bargary (MACSI, IEMAG Collaboration Group)
- Dr David J. P. O'Sullivan (MACSI, IEMAG Collaboration Group)
- Dr Joseph D. O'Brien (MACSI PhD Alumnus, IEMAG Collaboration Group)
- Dr James A. Sweeney (MACSI)
- Dr Kevin Burke (MACSI)
- Dr Fatima-Zahra Jaouimaa (MACSI),
- Professor Stephen O'Brien (MACSI)
- Dr Romina Gaburro (MACSI),
- Dr Pádraig MacCarron (MACSI)
- Dr Elizabeth Hunter (TU Dublin, MACSI Alumnus)
- Dr Iain Moyles (Assistant Professor. York University, Canada, member of the Canadian Epidemiological Modelling Advisory Group, MACSI Alumnus)
- Dr Catherine Timoney (Programme Manager Data Science in HSE West, MACSI Alumnus)
- Prof Brendan Murphy (School of Mathematics and Statistics, UCD)
- Prof Chris Brunsdon (National Centre for Geocomputation, NUIM)
- Prof. Jim Duggan (Information Technology, University of Galway

Images: https://www.gov.ie/en/collection/4b505-slides-from-the-nphet-press-briefings/

Underpinning research linked to UN Sustainable Development Goals

- Goal 3 Good Health and Well-being
- Goal 9 Industry, Innovation, and Infrastructure
- Goal 17 Partnerships for the Goals

Summary of the impact (100 words maximum)

During the COVID-19 pandemic, the National Public Health Emergency Team (NPHET), chaired by Chief Medical Officer (CMO) Dr Tony Holohan, recognised the need for mathematical and statistical models to assist the Government when making difficult decisions. The Irish Epidemiology Modelling Advisory Group (IEMAG), rapidly convened under Professor Philip Nolan, was charged with developing and implementing these models.

Professor James Gleeson led the collaborative effort to generate the models that guided the majority of NPHET recommendations to government on mobility restrictions, lockdowns, and easing restrictions. The work was supported by a team in University of Limerick's Mathematics Applications Consortium for Science and Industry (MACSI) and other Irish institutions. They developed and extended models that assisted decision-making, providing visualisations and evidence that the CMO and Professor Nolan used directly in cabinet and media briefings.

Countries where the impact occurred: *Ireland and international*
Beneficiaries: *list beneficiaries of the research related to the impact study. Do not include personal information, beneficiaries should be listed as categories e.g., students, patients, policy-makers etc.*

- Irish Government
- National Public Health Emergency Team in Ireland and similar bodies abroad
- Department of Health, Ireland
- General Public
- Policymakers
- Academia
- Patients and Medical Staff

Description of the impact (500 words maximum)

Since March 2020, the MACSI team led by Professor James Gleeson dedicated time and expertise to protecting the health and wellbeing of communities across Ireland. In what were very uncertain times, they provided thorough well-researched models and data analysis associated with COVID-19. Their work was used to plan healthcare demand and investigate the impact of mitigation measures throughout the pandemic.

Collaborating with other researchers in Ireland and modelling groups around the world, the MACSI team were involved in developing mathematical and statistical models for each stage of the COVID-19 pandemic. These models simulated physical, social, and biological systems, based on the best available data, providing valuable guidance for decision-makers.

Decision-makers used these models to understand changes and observations, to evaluate probable scenarios of new case numbers over time, and ultimately protect our population. For example, some models drew on the analysis of traffic data, using expertise in statistical analysis. Based on changes in traffic in different periods of lockdown and opening, they used this data to help monitor how the virus might spread (Source 1).

Professor Philip Nolan, Chair of IEMAG and a key member of NPHET (and now Director General of SFI), has spoken several times about Professor Gleeson and the MACSI team's significant contribution to these models and communication of the results. As an example of such a contribution, in a paper published in November 2021 in the journal *Philosophical Transactions of the Royal Society A,* Professor Gleeson and the collaboration team described a method of estimating the now-famous reproduction or 'R-number' in COVID-19 cases, the number that describes the likelihood of a virus increasing or decreasing in a population. Their paper described a population-based model called the susceptible-exposed-infected-removed – or *SEIR* – that was implemented by IEMAG. The SEIR model was used regularly to provide up-to-date scenario analysis to NPHET. The results were reported in media briefings throughout the pandemic (Source 2).

In addition, MACSI researchers had notable impact on the media around the pandemic. For example, on RTE, Padraig MacCarron showcased his research on the deadliness of COVID-19 (Source 3). Professor Stephen O'Brien published an informative YouTube video on false positives during the pandemic (Source 4).

Finally, at the *Statistical Approaches to Understanding the COVID-10 Pandemic on the Island of Ireland* conference, MACSI PI's Professor Cathal Walsh and Dr James Sweeney reflected on the challenges and successes while modelling COVID-19, a talk noted by Professor Philip Nolan on Morning Ireland (Source 5).

Evidence of impact (up to 6)

Source 1. 'The Mathematical and Statistical Modelling Collaboration Guiding Ireland's Covid-19 Response', Research Impact Podcast, University of Limerick, 18th February 2023.

URL = https://www.podomatic.com/podcasts/universitylimerick/episodes/2023-02-15T07_51_47-08_00

Source 2. '3,200 excess deaths linked to pandemic - new analysis', RTE's Prime Time and RTE website, 21st April 2021.

URL = https://www.rte.ie/news/primetime/2021/0420/1211072-covid-19-excess-deaths-mortality/

Source 3. 'What death notices tell us about the coronavirus across Ireland'. RTE's *Brainstorms* and RTE website, 7th May 2020.

URL = https://www.rte.ie/brainstorm/2020/0505/1136496-death-notices-ireland-coronavirus/

Source 4. ['False Positives'?]. Stephen O'Brien. YouTube video. 2021.

URL = https://www.youtube.com/watch?v=5dldBjWniko&t=8s

Source 5. Interview. Morning Ireland, 25th April 2022

Source 6. 'National Public Health Emergency Team', Dáil Éireann Debate, 1st December 2020

Source 7. Formal letter. School of Mathematics and Statistics, University College Dublin

Source 8. Formal letter. School of Computer Science, National University Galway

Source 9. Formal letter. Chair, Irish Epidemiological Modelling Advisory Group

Research description (250 words maximum)

During the COVID-19 pandemic, Irish people all over the world responded to the challenge to help others - working on the front line, volunteering in hospitals and care settings, developing solutions to problems, and working together as multidisciplinary communities in response to COVID-19. MACSI's response to the COVID-19 crisis was comprehensive and timely, supporting and feeding directly into the work of the National Public Health Emergency Team (NPHET).

The underpinning research conducted by MACSI during this time developed the population-based susceptible-exposed-infected-removed (SEIR) model. This mathematical model assumes a time-varying effective contact rate (equivalent to the now famous time-varying reproduction number - R-number) to model the effect of non-pharmaceutical interventions on the spread of the virus.

However, the history of the disease strongly affects predictions of future scenarios. For example, on Monday, a model may predict what is likely to happen on Tuesday and Wednesday. However, if the virus is found to be spreading more quickly on Tuesday than Monday's model assumed, then the information used to make predictions about Tuesday and Wednesday must change. As such, a crucial challenge with such models is accurately calibrating them to observed data, for example, updating model parameters based on a changing daily number of confirmed new cases, as well as dealing with the uncertainty inherent in making predictions.

MACSI PIs developed a novel approach based on inversion of the SEIR equations in conjunction with statistical modelling and spline-fitting of the data to produce a robust methodology for calibration of a wide class of models of this type. This approach enabled rapid and effective updates of such models based on the latest data.

Research outputs (up to 6)

1. Walsh, C., Sweeney, J. (PIs) (2022) Conference: *Statistical Approaches to Understanding the COVID-19 Pandemic on the Island of Ireland*. URL = https://rss.org.uk/training-events/events/events-2022/rss-events/statisticalapproaches-to-understanding-the-covid/#fulleventinfo
2. Gleeson JP, Murphy TB, O'Brien J, Friel N, Bargary N, O'Sullivan D. (2021) 'Calibrating COVID-19 susceptible-exposed-infected-removed models with time-varying effective contact rates'. *Philosophical Transactions of the Royal Society A,* 380:20210120.
DOI: http://doi.org/10.1098/rsta.2021.0120
3. Gleeson JP, Murphy TB, O'Brien J, O'Sullivan D. (2021) "A population-level SEIR model for COVID-19 scenarios (updated)," URL = https://assets.gov.ie/122667/8379f0cc-5be3-4c89-9a1e-3b7328ae03af.pdf
4. Jaouimaa FZ, Dempsey D, Van Osch S, Kinsella S, Burke K, Wyse J, Sweeney JA. (2021) 'An age-structured SEIR model for COVID-19 incidence in Dublin, Ireland with framework for evaluating health intervention cost'. *PLOS One*, 16 (12), 20260632. [main authors, team leads].
DOI: https://doi.org/10.1371/journal.pone.0260632
5. Comunian A, Gaburro R, Giudici M. (2020) 'Inversion of a SIR-based model: A critical analysis about the application to COVID-19 epidemic'. *Physica D.* 413:132674. Epub 2020 Aug 12. PMID: 32834252; PMCID: PMC7419377.
DOI: http://doi.org/10.1016/j.physd.2020.132674
6. IEMAG Epidemiological Modelling Subgroup (2020) "A population-level SEIR model for COVID-19 scenarios," URL: https://assets.gov.ie/74595/e10ea7bb423c4110839e2f30c3817dc7.pdf

Research grants

The MACSI group has drawn funding from a wide variety of sources of the last 10 years. Here are some examples:

- 2021 – 2022: SFI Insight TU Dublin Collaboration Fund €50,000
- 2021 – 2022: IRC Government of Ireland Postdoctoral Fellowship €99,513
- 2020 – 2021: IRC Government of Ireland Postgraduate Scholarship €110,000
- 2020 – 2021: SFI Public Service Fellowship Programme €88,275
- 2019 – 2020: EU H2020 MSCA Cofund €63,000
- 2019 – 2020: Industry Funded Research €116,940
- 2019 – 2020: SFI COVID-19 Rapid Response Programme €54,242
- 2019 – 2020: SFI Frontiers of the Future €606,040
- 2019 – 2020: SFI Industry Fellowship Programme €88,380
- 2018 – 2002: HRB Applied Partnership Programme €119, 837
- 2018 – 2019: SFI Centre – Insight Phase 2 €2,025,182
- 2018 – 2019: SFI Centre for Research Training €8,452,886

Total Value 2018 - 2022: €11,874,295

3.0 Records

Records management is in accordance with UL Record Management and Retention Policy. The following records relevant to this process are maintained: ·

1. Final version of case study as agreed with lead researcher involved.

4.0 Review and Approval Log

This process is reviewed in accordance with the Self-Assessment Process and any updates are included in the next revision.

Rev No.	Date	Revised By:	List of Revisions	Approved Sign & Date
0	25/02/2015	H Lenihan, Chair Research Impact Working Group	Origination of document	Research Impact Working Group
1	20/08/2019	H Lenihan, Chair, Research Impact Committee C Brennan	Updated to embed international best practice	Research Impact Committee
2	14/01/2021	C Brennan	Simplification of template	Research Impact Committee and OVPR QMT

For further information www.ul.ie/researchimpact