Epidemics 49 (2024) 100802

Contents lists available at ScienceDirect

Epidemics

journal homepage: www.elsevier.com/locate/epidemics

Building in-house capabilities in health agencies and outsourcing to academia or industry: Considerations for effective infectious disease modelling

ARTICLE INFO

Keywords:
Modelling
In-house
Academia

ABSTRACT

Infectious disease models provide a systematic way to estimate crucial features of epidemic dynamics and explore different transmission and control scenarios. Given the importance of model-based analysis in managing public health crises, there has been an increase in post-pandemic creation of both academia-driven modelling centres, hubs and consortiums and government-driven public health agencies with in-house modelling units or teams. However, in the past, the delineation of roles and responsibilities between government- and academia-led modelling groups has often been unclear. Who should perform which tasks and when? This ambiguity can increase the risk of duplicated work or unaddressed gaps in analysis. It also raises questions about the sustainability of modelling capacity for addressing routine operational analytical needs while also developing new approaches that can be tailored for emergencies. In the sections below, we discuss factors that could inform decisions about where to locate infectious disease modelling activity. Rather than giving a fixed set of rules, we outlined key considerations and trade-offs that could be taken into account to enable academic and government modelling activities to complement each other effectively, which can in turn be refined as new public health crises emerge in future.

1. Operational planning vs scientific research to inform outbreak control

Outbreak control measures can include border controls, case-finding, contact tracing, case isolation, quarantine of close contacts, blanket population-wide non-pharmaceutical interventions (NPIs) and vaccination campaigns. During an outbreak, public health agencies need to define the operational design of such measures. For instance, they may need to specify the duration of contact tracing and quarantine or balance a case-finding strategy between targeted and non-targeted testing. These specifications can be informed by epidemiological parameters, such as the incubation period and serial interval, which can be estimated from case investigation data combined with models of the epidemic process to adjust for common biases (Charniga et al., 2024; Park et al., 2024). The same parameters can also be used to assess the potential effect of future outbreak measures under consideration or evaluate the impact of past ones that have already been introduced. During COVID, this included prospective estimation of the impact of digital contact tracing, rapid testing, broader NPIs and vaccination (Ferretti et al., 2020; Kucharski et al., 2020) as well as retrospective evaluation of these interventions (Ferretti et al., 2024; Kucharski et al., 2023). When deciding whether modelling should be led in-house at public health agencies or externally by academic modelling groups, it can, therefore, be useful to distinguish between analysis that is routinely necessary to inform real-time operational activities and analysis that involves deeper scientific research to guide longer-term control strategies. For example, public data dashboards during COVID-19 were often managed by health agencies (Centers for Disease Control and Prevention, 2020; Ministry of Health, Singapore, 2020; UK Health Security Agency, 2020), while the development of complex multi-variant scenario models to inform control was typically led by academic groups (National Institute for Communicable Diseases, 2020; Scientific Advisory Group for Emergencies, 2022).

2. Frequency and timescale of outbreak-related tasks

Real-time outbreak metrics can help monitor the effectiveness of outbreak control measures and identify changes in transmission dynamics to inform future strategies. For example, the effective reproduction number can be used to quantify the current magnitude of transmission in a given location. Such metrics were reported weekly, or even daily, in situational updates to policymakers during the COVID-19 pandemic (Centers for Disease Control and Prevention, 2024; Department of Health and Aged Care, 2020; Pung et al., 2021; UK Health Security Agency, 2022). In some cases, this created intense pressure on academic teams, pulling limited capacity away from research tasks better suited to their skill sets. Given the high frequency of analysis outputs required, alongside timely communication to policymakers, these tasks can be well-suited for in-house modelling groups, especially if they are able to use methods that are already established and software tools that are stable. In doing so, this reduces bottlenecks in delivering and communicating results internally, as well as freeing up academic modellers to develop new methods to enhance existing outbreak

https://doi.org/10.1016/j.epidem.2024.100802
Received 14 August 2024; Received in revised form 18 October 2024; Accepted 29 October 2024
Available online 9 November 2024

metrics, and provide advisory oversight of real-time reports where relevant. Similarly, when handling the introduction of vaccines against a novel infection like COVID, public health agencies or organisations need to identify and respond swiftly to areas with lower vaccine coverage; the data analysis required to inform such activities could, therefore, be efficiently conducted in-house (CDC, 2024; UK Health Security Agency, 2024). Routine data releases and technical reports from health agencies were a particular success during COVID-19, providing data and situational awareness for a wider audience. In contrast, academic groups could evaluate the impact of vaccine policies over longer timescales with more detailed models that produce less frequently updated outputs, in close collaboration with health agencies (Barnsley et al., 2024; Liu et al., 2023; Wang et al., 2023). Characterising the regularity and urgency of other outbreak analytics tasks (e.g. monitoring the severity of the outbreak, assessing risk factors) in this way could help further determine the key modelling capabilities that are best placed in-house and in academia.

3. Funding timescales and sustainability

In academia, methodological and discovery research is typically supported by research funders and the timescales of funding range between 1–2 years. Even in emergencies, it may take several weeks and months to get funding from rapid funding calls in place. For Zika in 2015–16, local epidemics were over by the time many studies commenced (Koopmans et al., 2019). Furthermore, career progression in academia historically depends on tangible research outputs such as academic papers (Nixon et al., 2022; Sherratt et al., 2024). As such, infectious disease modelling-related research in academia tend to focus on self-contained projects which are not expected to be funded indefinitely. The short-term funding timescales also mean academic researchers are more likely to move between institutions and projects over time. During a pandemic, a considerable amount of analytics and modelling work will involve repeated analysis or require extensive data wrangling often without significant novel findings. As many stakeholders depend on these modelling outputs for resource planning, such forms of routine work need to be sustainable. During COVID-19, this led to critical tasks being conducted by staff who were on contracts with a hard end date, sometimes mid-pandemic. The importance of these modelling tasks to inform outbreak response may not be assessed in a similar fashion in academia (Nixon et al., 2022; Sherratt et al., 2024). As such, if academic metrics and career progression cannot evolve to support activities required for effective routine response, then these non-discovery research functions could be better located in public health agencies.

To achieve quality assurance for in-house modelling and to encourage the development of novel modelling techniques when resources are available, it would be ideal for modelling projects or studies to undergo rigorous academic review. There were some positive examples of rapid independent review initiatives during COVID-19, such as CODECHECK and the Royal Society RAMP Scheme, supported by academic collaborations (Nüst and Eglen, 2021; The Royal Society, 2020). If we expect modelling teams to achieve sufficiently high quality in their work during epidemics, have the ability to translate novel tools from academia to operation, and provide an epidemiological assessment of the outbreak situation, then the incentives structure could be designed to ensure quality control and talent retention. This is an ongoing challenge in many academic and government modelling groups, given alternative career paths available for quantitative researchers, and hence, providing opportunities for impact and valuing contributions will be crucial for a sustainable response.

4. Resource availability and scalability beyond funding

Domain-specific expertise in infectious disease dynamics is a finite resource and is not readily scalable during a pandemic, even when funding is not a constraint. A good researcher in this field requires extensive knowledge of disease epidemiology, data generation, and modelling methodologies coupled with the ability to communicate effectively. These are typically skills acquired over years of experience. Furthermore, certain data sources for model inputs are not available overnight and can require substantial time and resources for design and collection. A potential solution is to engage government or academic personnel with skills that are useful for infectious disease modelling. This includes initiatives to link up research groups working on infectious disease dynamics with other researchers in peripheral research fields or industries (The Royal Society, 2020) or the pivoting of long-standing population survey functions in government organisations to support the collection of infectious disease survey data (Office for National Statistics, 2020). This could provide a possible solution for the rapid scale-up of modelling resources during a pandemic. The ease with which such resources can be tapped into will shape whether such activities are better delivered at scale in government or in academia.

5. More complexity benefits from more perspectives

During the COVID-19 pandemic, policymakers had to decide the extent of stringent NPIs or when to relax these measures while minimising the risk of a large epidemic (Reich et al., 2022; Scientific Advisory Group for Emergencies, 2022). These decisions have a significant socioeconomic impact but the paucity of information on certain epidemiological aspects of an outbreak adds complexity to the decision-making process. To overcome this challenge, ensemble forecasting or scenario modelling aims to capture the variation in different modelling outputs by integrating multiple possibilities. Reliance on one modelling output should be avoided, regardless of in-house or academia, in order to produce robust estimates (Borchering et al., 2023; Medley, 2022; Reich et al., 2022). Thus, aspects of modelling which require diversity of viewpoints should be enhanced within both in-house and academic modelling groups prior to the next pandemic, ideally with methods refined via application to routine seasonal epidemics (Mathis et al., 2024; Moss et al., 2023) rather than just emergencies, with adequate resources to support such efforts, as discussed above.

Alongside complex questions about epidemic dynamics, there are also questions that can be addressed with simpler models. These include quantifying the intrinsic characteristics or risk factors of the infection. Outsourcing such questions to multiple groups could introduce unnecessary inefficiencies. Hence, such works may be better situated in-house and these teams could either rely on well-established modelling techniques or seek to validate their findings via scientific publication or other independent academia-led assessment.

6. Data sensitivities and governance affect the type of modelling studies to outsource

Specific infectious disease data, such as those related to personal details of infected cases, will often be confidential. Despite the availability of anonymous or aggregated data in modelling analysis, extensive data collection on the demographics of these cases could result in re-identification of the individual. Given the sensitivities around individual-level data, there is a need for in-house modelling groups to have the necessary skill set to answer detailed questions that require high-resolution data (e.g. around the incubation period). Initiatives such as OpenSAFELY present a useful example of how complex questions can be asked of sensitive data during emergencies while also preserving patient privacy (Williamson et al., 2020).

To facilitate data sharing between data controllers (e.g. public health agencies, healthcare institutions) and government- or academia-led modelling groups, the administrative data governance processes and the data pipelines need to be built before a health crisis. Data governance teams would need to evaluate the risk of data leakage occurring in both in-house and external modelling groups. Thus, depending on the direction of the data flows and governance of the data sharing, this could determine the extent of data use and the type of modelling work to be done by either group.

7. Refining these considerations in future

The optimal location of infectious disease modelling activity may change over time based on a variety of factors such as the considerations above. It will be an iterative process of prioritisation and deprioritisation in both government- and academia-led modelling groups. While building capacity in public health agencies is important, shifting needs in public health emergencies may require assistance from other governmental sectors, academia or industry sources given the expansion in public health-related questions to address. Overall, the design of holistic outbreak control strategies would require both academia and governments to work together and provide two-way feedback on the modelling outputs derived from upstream operations and downstream research.

Funding

RP acknowledges funding from the Singapore Ministry of Health. AJK acknowledges support from Wellcome Trust (206250/Z/17/Z), data.org (Epiverse-TRACE) and NIHR HPRU in Modelling and Health Economics, a partnership between the UK Health Security Agency, Imperial College London and LSHTM (NIHR200908). The views expressed are those of the authors and not necessarily those of the NIHR, UK Health Security Agency or the Department of Health and Social Care.

CRediT authorship contribution statement

Adam J. Kucharski: Writing – review & editing, Writing – original draft, Conceptualization. **Rachael Pung:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Rachael Pung reports article publishing charges was provided by Government of Singapore Ministry of Health. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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