Fjelltopp

Harmonising Health Data

COVID-19 Modelling and Data in Bangladesh

A Review With Recommendations

UKaid

from the British people

info@fjelltopp.org www.fjelltopp.org

Fjelltopp Ltd is a UK social enterprise, company limited by shares No. 11961922
Registered Office: 40 Blackburn Road, Padiham, Lancashire, BB12 8JZ

Disclaimer

This report has been commissioned by South Asia Research Hub, Foreign, Commonwealth and Development Office (FCDO), Government of UK. However, the views expressed in the report do not necessarily reflect the UK Government's official policies.

Acknowledgements

The primary authors of this report are Prof Katie Hampson, Dr Jessica Clark and Dr Jonathan Berry. The authors would like to acknowledge the support of Prof Jason Matthiopoulos and the LMIC epi modelling team at the University of Glasgow, as well as Jyri Soppela, Mikolaj Kundegorski and the wider consultancy team at Fjelltopp.

Table of Contents

Disclaimer......2
Acknowledgements......2
Abbreviations......4
Executive Summary......4
Context......6
Existing Modelling Efforts......7
Existing Data Collection and Management Efforts......8
Modelling Recommendations......11
Data Management Recommendations......13
Modelling Implementation plan......17
Data Management Implementation Plan......19
Bibliography......20
ANNEXE 1: Existing Modelling Efforts
ANNEXE 2: Stakeholder Interviews
ANNEXE 3: Existing Data

Abbreviations

a2i	Access to Information
BBS	Bangladesh Bureau of Statistics
CST	Community Support Teams
DGHS	Directorate of General Health Services
icddr,b	International Centre for Diarrhoeal Disease Research, Bangladesh
ICL	Imperial College London
IEDCR	Institute of Epidemiology, Disease Control and Research
JPGSPH	James P Grant School of Public Health
LMICs	Low and Middle Income Countries
MOHFW	Ministry of Health and Family Welfare
PVF	Potential Virus Fighter (CST classification of possible COVID case)
SQL	Standard Query Language
UoG	University of Glasgow
VPN	Virtual Private Network
VVF	Verified Virus Fighter (CST classification of a suspect COVID case)

Executive Summary

We assessed models of COVID-19 mortality and prevalence in Bangladesh, along with data sources used for modelling, specifically undertaking:

- A systematic literature review of modelling pre-prints and publications (Annexe 1).
- Interviews with stakeholders in the Bangladesh COVID-19 response concerning ongoing and unpublished modelling and data collection (Annexe 2).
- Identification of data sources with accompanying notes (Annexe 3).

The following key observations were identified through our work:

- Very little modelling was found to influence public health policy during the pandemic. Three models were confirmed to have been used: 1) projections from Dhaka University used by DGHS between April-July 2020; 2) a statistical model using telemedicine data to predict focal areas at high risk (from a collaboration between University California Berkeley, a2i and others), and 3) an interactive modelling interface for exploring policy options with UN and government officials (from collaborations between FAO, University of Glasgow and others). We are aware that modelling efforts from the James P Grant School of Public Health were discussed with the government, but these were not shared during our interviews.
- Early modelling projections (internal and international efforts) were rejected by the government, as their high predicted mortality impacts were considered alarming, leading to distrust amongst policymakers.
- There is minimal modelling capacity within Bangladesh. Multiple stakeholders expressed a desire to improve this, including IEDCR, DGHS, icddr,b and Vital Strategies.
- The government has not incorporated modelling from international institutions into policymaking because of a lack of ownership and trust. To resolve this the government needs to: better understand the decisions taken during model development, appreciate the reliability and limitations of their data, and see a consensus across multiple modelling efforts.
- Data generation in Bangladesh needs coordination and integration across many agencies. For this to work, stakeholders must collaborate and communicate to facilitate data sharing between institutions and government departments.

Based on our findings we propose the following key recommendations (with further information and an implementation plan given towards the end of this report):

Modelling

1. Establish a DGHS-coordinated consortium of modellers comprising in-country and international partners to improve the understanding and use of data and models, while also building in-country modelling capacity.
2. Improve scientific communication from modellers to policymakers and policymakers to the public, to build a

better understanding of how modelling can be useful and what its limitations are.

Data Management

3. Conduct a political, economic and legal analysis of the public health sector in relation to modelling and data management.
4. Establish national policy and guidelines for data management and digital innovation in public health.
5. Build upon the a2i COVID-19 data warehouse project to establish a DGHS-owned health data and research catalogue using existing open-source solutions to provide features for organising metadata, browsing metadata, referencing data, secure data sharing and health information system (HIS) interoperability in specific use cases.
6. Improve the quality, timeliness and completeness of health surveillance data in Bangladesh, specifically by improving DHIS2 system performance, implementing DHIS2 based laboratory data management, and removing paper based data collection.

Context

The first case of COVID-19 in Bangladesh was identified on March 8th, with the first death following later that same month. Throughout the COVID-19 pandemic the Bangladesh government has been working alongside a far-reaching and complex network of institutions to reduce infection, control the spread of the virus, and manage its impact across the country.

For many countries, an essential tool in making effective public health policy has been the application of epidemiological models. These models use public health surveillance and other covariate data to estimate disease spread and impacts over space and time. For example, for estimating deaths over a set period, cases in a specific area, or the availability of resources like hospital beds. Estimates may be representative for the present moment, the past, or provide projections into the future. The field of infectious disease modelling is a large branch of research with international activity that has received considerable public attention during the pandemic.

The quality of modelled estimates is determined by many factors including, the appropriate mathematical reasoning, the choice of data inputs including consideration of covariates impacting the disease, the availability of large-sample research to calibrate and assess the model, the intended purpose and use of the model outputs, and the availability, reliability and completeness of each input data source. The interpretation of epidemiological modelling is therefore intimately related to the quality of the health system infrastructure and the availability of research expertise that understands the health system's complexity. For this reason many low-and-middle-income-countries (LMICs) struggle to leverage the power of epidemiological modelling effectively whilst forming public health policy.

Moreover, the impacts of COVID-19 in LMICs, while extremely concerning, have generally proven to be less extreme than early models predicted. For example, concerns about rampant spread and devastating consequences in refugee camps, such as the Kutupalong-Balukhali Expansion Site in the district of Cox's Bazaar, have not unfolded as expected (1,2). A number of explanations have been proposed, including younger demographics in LMICs suffering from less severe disease and a few serological studies suggest high exposure in some LMIC settings consistent with this. But on the whole the reasons for discrepancies between predictions and observed impacts in LMICs remain largely unexplained and are unlikely to be resolved quickly. Another important acknowledgement is that behavioural responses to the pandemic have curbed the spread (in both HICs and LMICs), such that worst case scenarios have been avoided. Effective science communication is required to explain how models serve multiple purposes, including forecasts under different scenarios/ interventions and post-hoc evaluations. Failure to recognize these purposes and unrealistic expectations about model accuracy have also contributed to mistrust and misunderstanding.

FCDO has commissioned a review and assessment of existing models of COVID-19 mortality and prevalence in Bangladesh, along with the data sources that those models are built upon. They have requested that findings be synthesised with other literature and expertise in order to make recommendations for further work that will improve the quality of data, models and interpretation of results in Bangladesh. To this end, we have conducted a systematic literature review of published, pre-print and open access models and literature related to COVID-19 modelling in Bangladesh, as well as a number of qualitative interviews to map out key stakeholders and known data sources. In this report we summarise our findings and provide key recommendations. The literature review, and detailed outputs from the interviews are annexed to this report for further information.

Existing Modelling Efforts

We conducted a systematic literature review (Annexe 1) and a series of interviews (Annexe 2) with stakeholders, to identify instances where modelling has influenced COVID-19 policy and practice in Bangladesh and to understand which modelling frameworks have been adopted. Through this work it is clear that though data acquisition has been undertaken by many stakeholders, modelling and robust quantitative analysis has not regularly been carried out and has played a relatively minor role in policy decisions from within the Bangladesh government and across most stakeholders.

We identified five models acknowledged at the policy level; the initial, widely publicised Imperial College London (ICL) model aimed at UK and US scenarios, the James P. Grant School of Public Health (JPGSPH) model, a United Nations (UN) report from relatively early in the pandemic, a model from Dhaka University and collaborative work led by FAO and the University of Glasgow (UoG). The ICL model is given in Annexe 1 (ref 75). The James P. Grant School of Public Health model was not made available to us for evaluation and was not brought up in our interview with JPGSPH representatives as it is considered an internal document between JPGSPH and the government of Bangladesh. The UN model was an internal report. The models by Dhaka University were used by DGHS between April 2020 and July 2020 (Annexe 1). The ICL, JPGSPH and UN models were all poorly received by policymakers, as they estimated very large case numbers and high mortality, and were consequently rejected as being too pessimistic. This limited the uptake of both in-country and international work of relevance identified through the literature review. The FAO/UoG model is described in Annexe 1 and was developed as an interactive tool for examining scenarios in policy discussions.

We make a series of observations regarding the modelling landscape in Bangladesh below, and then expand upon them in our recommendations.

As it stands, there is very little modelling capacity within the Bangladesh government. Modelling can align the many complexities of populations and pathogen transmission to provide evidence-based guidance and its use in policy has been gaining traction globally, receiving particular attention during the pandemic. It is therefore concerning that policy has not benefited from this evidence base, although a lot of data has been generated that could further inform policy. Unfortunately there have been barriers to the wide sharing of these data and parties have struggled to work across silos. From a capacity point of view it also means that there is little understanding of what modelling can and cannot do, nor appreciation of the caveats and assumptions that may invalidate or explain anomalies in any presented results - hence the distrust derived from the initial modelling reports presented for Bangladesh.

Furthermore, there is limited appreciation that available data from different sources of surveillance e.g. laboratory testing, syndromic data, telemedicine use, wastewater analysis, seroprevalence surveys, excess mortality surveys etc, provide only imperfect insight into the true/ underlying ongoing processes. As a consequence, if models do not match directly observed quantities, they have often been rejected on the grounds of being incorrect. Generally, the degree to which surveillance data may underestimate prevalence was widely misconstrued early in the pandemic when the evidence on asymptomatic and pre-symptomatic transmission was unclear, and many countries poorly communicated these issues. In Bangladesh there appeared to be limited communications between policymakers and scientists responsible for surveillance data. Many groups were lobbying the government and there was little opportunity for nuanced explanations about aspects of surveillance that are essential for their interpretation. Indeed there was also little communication between groups collecting data resulting in multiple overlapping sources of the same data types (covered in more detail elsewhere in this report). We further detail in the Recommendations section how positive change can be made on this point, involving both policy makers and modellers.

The state of data sharing in Bangladesh is a limiting factor in the development of models and in building modelling capacity. From our interviews and from the literature review, it is evident that there are many groups working on similar methods and ideas (i.e., data collection) with little/no communication amongst them. Moreover, where data exists, the availability of that data for use by others (even within different departments of government, UN entities, academic institutions etc) is limited. This hinders the development of both national and international collaboration that would facilitate capacity development through skill sharing. It also means that whilst some groups use data that is less than optimal, resulting in modelling projections that appear fanciful, others have the necessary data to improve such estimates but are not willing or able to share, limiting the role modelling can play in the Bangladesh Covid-19 response.

Finally, it is worth noting that whilst isolated modelling efforts by single institutions can provide general insight, at the policy level the strongest approach is generally to draw on multiple, independently developed models that come with their own set of assumptions. A consensus approach can help to identify “most likely” events when multiple models are in agreement, and likewise can identify important epidemiological and population processes handled differently between models that lead to conflicting results. Such approaches have been used successfully in many countries and are mentioned by stakeholders in Annexe 2.

Existing Data Collection and Management Efforts

Extensive public health data have been collected through surveillance and research efforts conducted by the government of Bangladesh and partner institutions, however comparatively little has been used in models. Annexe 3 details data sources that were identified through the systematic literature review (for more details see Annexe 1; note this includes publicly available data streams used in country-level global analyses) and interviews with stakeholders (for more details see Annexe 2).

Through our work we identified the following data sources that have been used in models of COVID-19 in Bangladesh to date:

- **DGHS/IEDCR laboratory testing data** is the most common source of data identified. This data is made available aggregated to district level in various public dashboards hosted by a2i and the aggregated national data is shared publicly via several national and international institutions, including by the European Centre for Disease Prevention and Control (ECDC) and John Hopkins University (JHU) coronavirus resource centre (3). These data have been used in the modelling conducted by: Dhaka university, University of Glasgow and others (Annexe 1). Whilst the national COVID-19 testing programme is an obvious place to begin, it is important to be aware of the data's limitations: coverage will be far from complete; asymptomatic or mild cases (expected to be a large proportion of all cases in Bangladesh given the relatively young demographic) will be under ascertained; testing will include false negatives/positives and be limited by testing capacity (varying over the course of the pandemic and spatially across the country), and be affected by charges associated with testing individuals, whilst data management procedures may also introduce human error.
- **Telecommunications data** has been used to identify high-risk individuals for further testing and focal high prevalence areas. This data has been collected through national "hotlines" set up by the government for individuals with concerns regarding COVID-19. The automated tele-menu system allows for the collection of a large amount of self-reported, structured syndromic data on relevant clinical signs as well as associated metadata on demography and locations. These data are available in the a2i *corona_info* data warehouse.
- **Syndromic data collected by Community Support Teams (CST) in Dhaka** has also been used to identify high-risk individuals for laboratory testing. The work has been coordinated by a consortium of UN agencies, BRAC and a number of NGOs on behalf of DGHS (early work includes data collected by CMED - see Annexe 2) . These data are collected through community-based programmes involving both house visits and individuals self-presenting at health facilities and includes telemedicine follow up. Syndromic data are entered into an electronic questionnaire on a mobile device and submitted to central servers where they are made available through the *corona_info* data warehouse.
- **Population and demographic data** is generally drawn from international sources, and not directly from government sources e.g. Bangladesh Bureau of Statistics (BBS). The sources of this data include WorldPop (4), the World Bank (5), and Landscan (6). This may be because the census data co-ordinated by BBS is dated 2011 and therefore not up to date or lacking in resolution, whereas data such as that available from WorldPop provides a higher resolution estimate by combining multiple data sources.

- **Bangladesh meteorological office** provided co-variate data used in one modelling effort to investigate climatic impacts upon COVID-19 transmission.
- Where models give estimates at a subnational level, the work generally uses or aligns with **the geographic hierarchy curated by *Groupmappers*** (made available through the *corona_info* data warehouse). At the highest administrative levels - the division and district levels - there is broad agreement across the many different sources of geographic boundaries and data that are available. However, below this, consistency and coherency in the geographic boundaries breaks down and ongoing work is required to standardise and improve the quality of the data. Specifically, a government decision in 1999 to change the urban administrative hierarchy from using *thanas* (direct equivalent of rural upazilas) to *city corporations* and *wards* remains a source of confusion over 20 years later. Thanas were on average larger than wards, leading to a problematic belief that they still exist in the hierarchy. Furthermore, various legacy systems are sustained by BBS despite there being no agreed logical mapping between the old and new hierarchy. Integration can only be resolved by aggregation of data on higher administrative levels or by approximation of overlapping areas if up-to-date shape files were available. Infectious disease modelling at a subnational level can provide valuable policy insight for governments, but this requires addressing data quality issues for every subnational region of interest.

There are extensive amounts of research data and co-variate data that could be incorporated into the modelling efforts:

1. The **icddr,b maintain a large data and research repository** that covers a wide ranging programme of research including sero-prevalence surveys and testing data, as well as covariate data including research addressing mental health impacts of the pandemic and antenatal care (ANC) data. The icddr,b appear to be well positioned to support collaboration with data sharing agreements and protocols already in place. Despite this, we have not found any reference to their data being used in existing modelling efforts.
2. The **JPGSPH maintains a data and research repository**. Qualitative research undertaken by the institution may inform and give confidence in some of the assumptions made through the modelling process. It was unclear from our interview what sort of relevant quantitative data was collected by the institution.
3. **UNICEF** conducts a programme of research into social behaviour and the effectiveness of COVID-19 risk communication. The work may be a source of covariate data for more advanced modelling, including observational studies concerning mask wearing behaviour, the effectiveness of COVID-19 media campaigns, community-based incident reports and more.
4. **BRAC NGO** have a lot of community surveillance data and structured syndromic data from internal monitoring of their staff health. There is also some potentially interesting covariate information concerning COVID-19 and vaccination rumours across Bangladesh.
5. **Whole genome sequencing (WGS)** data from Bangladesh is increasingly becoming available and has mostly been generated through IEDCR and deposited on GISAID. These data have begun to provide useful insights when combined with analyses of movement data (7). Global mechanisms to encourage sharing of WGS with repositories such as GISAID (8) and genbank (9) as well as platforms for interactive visualizations like

Nextstrain (10,11) and Microreact (12) appear to be serving their purpose well. However, considerable expertise is needed for the analysis and interpretation of genomic data and so most of our recommendations that apply to effective development and communication of epidemiological models, equally apply to phylogenetic inference.

It is important to note that incorporating covariate data sources is not a recommended next step for improving the quality and use of modelling in Bangladesh. It is important to first address: the quality of the national surveillance and testing data, the government's access to modelling expertise that understands the complexity of the Bangladesh health system, and the government's capacity to understand, assess and trust modelling efforts.

A common theme raised through our interviews was that data has been collected in silos with each organisation understanding very little regarding the data collected under each other organisation. On this matter it is worth commenting:

- FAO and a2i have especially given time and effort to increasing the amount of collaboration and data sharing that is taking place across Bangladesh. JPGSPH and icddr,b have also commented on the importance and value of collaborative projects.
- a2i's work to build a cross-institutional COVID-19 data warehouse is a significant move in the right direction but there remains significant questions concerning the project's efficacy as no metadata exists, access protocols are unclear, and accessing the database requires specific technical/engineering knowledge. For this reason we recommend further work below to upgrade the COVID-19 data warehouse from an SQL database to a feature-rich data cataloguing solution such as CKAN (13).
- icddr,b's clear data sharing agreement and protocol is an excellent approach that could be replicated by the government and other research institutions.
- No public data or research cataloguing efforts were found beyond that which is provided by international peer reviewed journals. Despite this, JPGSPH, icddr,b and BRAC all reported maintaining and working on internal data repository projects. In order to pursue collaboration, some tool to catalogue metadata around data collection and research efforts may prove invaluable.

Modelling Recommendations

1. **Establish a DGHS coordinated consortium of modellers comprising in-country and international partners to improve the understanding and use of data and models, while also building in-country modelling capacity.**
2. **Improve communication between modellers and policy makers and policy makers to the public, to build a better understanding of how modelling can be useful and what its limitations are.**

Evidence: Prof Richard Maude, founder of Groupmappers and Head of epidemiology at the Mahidol Oxford Tropical Medicine Research Unit, reported that other countries, including Thailand, successfully utilise consortia to provide modelling expertise to the government. Consortia of this nature build on a broad base of expertise, and have a track record of evidence synthesis to inform policy.

During our interviews stakeholders reported that the initial ICL model (Annexe 1, ref 75), which was widely publicised, and a UN report, "went too far against the grain in their messaging" (stakeholder quote). The high projected mortality was alarming to policy makers, and their reaction was to reject these results outright. This suggested there was a breakdown in communication between those presenting the model results (modellers) to policy makers, and then from policy makers to the public.

Understanding what models can and cannot do is vital, but also an enduring challenge when using modelling for public health purposes, exacerbated in a crisis. The adverse response to initial modelling work during the pandemic further suggested the need for improved communication between scientists and policy makers and for trust to be built.

Implementation: For modelling to be appreciated and accepted by policy makers in Bangladesh, trust in modelling must be built. This involves placing the ownership of models in the hands of users e.g. government policy advisors. Developing a modelling consortium is a powerful way to do this and establishes a national resource that can be engaged when outbreaks occur. Modelling consortia bring together in-country modelling expertise, and where appropriate international partners, to work closely with policymakers to develop a series of models that are location appropriate and can provide evidence on how best to develop intervention strategies and outbreak response. As teams develop unique models with their own assumptions and caveats, assessing them alongside one another will reveal "most likely" outcomes, and in their differences, will highlight important biological and population processes that have large effects on epidemiological trajectories.

A leading purpose of the consortium is to build trust, then the relevant models will be developed alongside policymakers through continuous conversations where policymakers raise policy relevant questions and modellers can explain whether they can provide those answers, why or why not, how they reach conclusions and importantly the caveats of those conclusions. Public health scientists responsible for surveillance operations are integral to this process. This means all interested parties are involved from the beginning of the modelling process, guided by appropriate questions. This also assists in managing expectations. Public health officials generally want quantitative unambiguous answers, but more often than not models cannot provide this. The assumptions that the model is built on and the data the model is fit to always means there are caveats and therefore expectations need to be managed. A close working relationship between modellers and policy makers can manage expectations, will aid the model development process and ensure appropriate policy questions are addressed.

Training in science communication and policy engagement is an important component of a modelling consortium and should be mandatory. It is not uncommon for modellers to provide information to the media and therefore the public. Training for each avenue of communication is vital to build trust in each level of the modelling process. In building a strong working relationship between modellers and policy makers this training could be shared to assist policy makers in their messaging to the public.

Infectious diseases remain a major cause of morbidity, mortality and economic losses in Bangladesh. Many stakeholders are involved in large-scale surveillance operations that are generating data that should already inform policy and practice, but our work suggests that the channels through which data are shared and inform policy are limited. Developing analytical capacity and policy engagement experience through modelling these infectious diseases could be used to establish working relationships between scientists and policymakers, facilitating understanding and trust through regular exchange. Such an approach would also capitalize on improved data management (see below), specifically if surveillance data was accessible and used as a basis for training in modelling and science communication.

Appetite/Impact: A modelling consortium is a long-term objective given the currently limited in-country capacity in infectious disease modelling. However, several steps can be taken in the short-term to build capacity and experience that would pave the way for this whilst also making better use of existing surveillance data (see implementation plan below). These steps have potential to be mutually beneficial and reinforcing. Initially, the development of such a group could involve a variety of stakeholders including academics, NGOs and international organizations. Groups like the Neglected Tropical Disease Modelling Consortium provide a model for such an approach, funded by the Bill & Melinda Gates Foundation, working closely with the WHO and made up of academic groups, providing ongoing policy insight.

From our interviews it is clear that modelling efforts will be better received at the policy level if led from within Bangladesh. From our systematic literature review, it is also evident that there are academic teams with the mathematical skill to carry out acceptable modelling work in Bangladesh, but not necessarily the experience in public health or infectious disease, to choose the appropriate models for the context and appropriately interpret the epidemiological data (particularly its limitations). Institutions such as JPGSPH and icddr,b explicitly explained that they do not have the skill-set in-house to carry out robust modelling or extensive quantitative analysis, though they expressed an interest in developing this capacity. Moreover, there is an ongoing problem surrounding collaboration, and data/ intellectual property sharing that could be overcome by the implementation of a consortium framework,where multiple teams are working together on shared data. Such collaborative efforts could instigate a change in culture towards data "ownership".

Training in policy engagement and science communication is offered in academic institutions globally and is recognized to be valuable in academic circles. During stakeholder interviews it was also reported that it was difficult to effectively convey scientific insights to the government and that communications on health policy were difficult to voice given other strong lobbying groups with direct access to high level government. It is therefore even more important that scientists can effectively communicate evidence (including models) to policymakers, even when delivering messages that are not what policymakers want to hear.

It is important that relationships be strengthened and capacity built during the post-COVID-19 recovery, to be better prepared for future pandemics and emerging diseases. An ongoing working relationship would improve communication and provide the means by which scientists could help policymakers understand what models can or cannot do, and appreciate limitations - for example that surveillance data will only provide a relative and often biased reflection of disease incidence (see Implementation Plan below). The development of a modelling consortium could build many of these skills whilst providing an environment that facilitates learning and the exchange of knowledge.

As an addendum to these two recommendations we suggest a review to understand why models mostly overestimated observed impacts of the pandemic in Bangladesh. The initial poor reception of projections from the ICL and JPGSPH models, and the internal report from the UN resulted in considerable mistrust in modelling at the policy level affecting the uptake of modelling derived guidance. We expect that recommendations 1 and 2 naturally lend themselves to such a review and subsequent discussion with policymakers. Indeed this could be an objective of a newly formed consortium and would feed into the learning processes described above. This recommendation was repeatedly suggested by individuals in academia and from NGOs and we assume that stakeholders interested and set to benefit from recommendations 1 & 2 will do so with this recommendation also.

Data Management Recommendations

3. **Conduct a political, economic and legal analysis of the public health sector in relation to modelling and data management.**

Evidence: Several stakeholders commented on the political challenges of coordinating efforts across the many agencies that work in Bangladesh. One stakeholder explicitly recognised the conflict of interest faced by funding bodies driving their own portfolio of work within the sector, whilst also trying to coordinate efforts to increase collaboration with other funding bodies. Furthermore, there appears to be confusion concerning the legality of international institutions supporting management and analysis of Bangladesh government data. There was confusion over the legal viability of copying government owned data to computers outside Bangladesh for analysis purposes.

Implementation: A specialist team should be employed to review the political, economic and legal factors relating to public health and epidemiology in Bangladesh. It is important that the review is undertaken by a team with a solid technical understanding of the public health and epidemiology domain, as well as experience in political, economic and legal analysis. The review should seek to identify: the enduring political and economic structures that change slowly in Bangladesh; the context-specific conventions and traditions that determine behaviour of individuals and organisations; the actors that operate within the sector, including their interests, motivations and interactions; the legal constraints that the actors are required to operate in; the economic challenges faced by the government and other key actors; and common patterns in the domain dynamics and decision making. For example, there is a mass migration to cloud infrastructure across the public and private sector in high income countries yet many LMICs (who would benefit the most from outsourcing their infrastructure) face legal and political problems when attempting to harness its extensive power for public health. The precise details of this matter have the potential to make or break the sustainability of digital interventions in LMICs. A detailed assessment of what is legally and politically possible could have a far reaching impact on the success of the technical projects given in below recommendations.

Appetite/Impact: Development is only possible when the proposed solution is sound from a technical, economic, legal and political standpoint. Political analysis can be sensitive and so parts of the review may need to be held internally, but a redacted form of the work could be shared across the sector.

4. **Establish national policy and guidelines for data management and digital innovation in public health.**

Evidence: Several interviewees stated that there should be more leadership from DGHS concerning the collaborative analysis of health data. None of the stakeholders interviewed could identify a clear protocol for working with Government owned data, and there appeared to be some confusion over what was and wasn't allowed or expected when working with government data. The only stakeholder who did present clear data sharing protocols and a template data sharing agreement was icddr,b.

Implementation: A specialist team should be contracted to partner with DGHS and support them in creating national policy for data management and digital innovation in the Bangladesh public health sector. As part of this work, a data sharing protocol and agreement for working with Government-owned data should be drawn up, similar to that made available by icddr,b. There should also be clear guidance on security matters, such as the treatment of patient identifiable data, and the importance of secure password management and data encryption. The policy should explain what metadata should be kept by the Government and partners working with Government owned data, as well as why it is important to keep metadata. There should also be a clear procedure in place for archiving data, metadata, and analysis under DGHS. The policy could also be used to identify standard terminology for data collection efforts in the health sector, especially with respect to demography, geography and indicator definitions. Digital interventions may then help to support the implementation of such policy and guidelines (one such example is given in recommendation 5 below).

DGHS might also consider advocating for a similar set of guidelines for digital innovation (e.g. digitalprinciples.org supported by the UN) in order to bring transparency to the process of procuring digital interventions. Doing so would introduce a clear framework by which the government intends to assess the quality of its digital interventions.

Appetite/Impact: Many stakeholders expressed a desire to reduce friction between national and international institutions working in Bangladesh. IEDCR wants to make more use of the large amount of data that they own, and they recognised that this would involve increasing capacity for collaboration. Addressing this problem will have a far reaching impact into the Bangladesh health system.

5. **Build upon the a2i COVID-19 data warehouse project to establish a DGHS-owned health data and research catalogue using existing open-source solutions to provide features for: organising metadata, browsing metadata, referencing data, secure data sharing and health information system (HIS) interoperability in specific use cases.**

Evidence: FCDO have commissioned a report to review the COVID-19 data and modelling landscape in Bangladesh. This has been necessary because there are no centralised public sources of this information. Many stakeholders commented on the huge amount of data that has been collected, but expressed frustrations with the lack of capacity for analysis. A health data catalogue may open up opportunities for collaborative analysis.

The a2i COVID-19 warehouse has had significant political success in securing access to a wide range of datasets related to the Bangladesh COVID-19 response. As far as we are aware the data has been consolidated in a simple SQL database and access is made available using a shared account to an SQL endpoint via a VPN. We haven't been able to identify any publicly available metadata, any user-friendly interface for non-technical individuals, or an easy way of securely administering data access. As such very few people actually know what is in the data warehouse, whether it is useful to them, and how to pursue collaboration if it is useful to them.

Implementation: The warehouse could be upgraded using a tried and tested open source data cataloguing tool such as CKAN (13), used to build high-profile public data catalogues such as data.gov and data.gov.uk. We would envisage The catalogue should provide tools for requesting, storing and organising metadata, versioning data, as well as granting and administering data access and licensing, and an API for system interoperability. The catalogue should be implemented with specific use cases in mind, including: creating a more flexible technical platform for the a2i COVID-19 data warehouse, facilitating data sharing between IEDCR and DGHS, and data sourcing for the policy making dashboard. As priorities move away from COVID-19 in the mid to long term, such a system would provide a sound framework upon which to build further health data consolidation efforts and to efficiently distribute all health data/research/reports to the wide network of interested partners.

We would imagine that the catalogue would be administered by a2i, and be initially seen as an upgrade to the COVID-19 data warehouse. Success would probably depend on a funding institution pairing an experienced international technical partner (for initial technical design and implementation) with an in-country technical partner such as a2i (for long-term system maintenance). The international technical partner can provide a second line of support and offer training and guidance as desired on a part-time or ad-hoc basis to the in-country partner. We would envisage the initial development phase to take a matter of months on a budget no more than the cost of commissioning this report (14).

Appetite/Impact: Cataloguing data and research in an easily accessible space does not seem to have been considered by any of the stakeholders that we pressed on the issue. Yet it may solve much of the problems we are seeing related to user-friendly data access, secure but flexible access management, management of metadata, and centralisation of knowledge.

6. **Improve the quality, timeliness and completeness of health surveillance data in Bangladesh, specifically by increasing the performance and use of DHIS2.**

Evidence: Multiple stakeholders have commented on the slow performance of DHIS2. As the data stored in DHIS2 instances have grown, we have seen an increasing and unaddressed need for improving DHIS2 maintenance capacity in many LMICs. Further to this, IEDCR and DGHS have reported a rapid expansion in laboratory testing capacity across the country, though evidence from IEDCR and FAO suggest that the laboratory data management is still conducted through Excel. a2i reported that there are still paper-based data collection processes in place in Bangladesh resulting in poor timeliness of data in the COVID-19 dashboards

Implementation: Bangladesh has a DHIS2 instance to co-ordinate electronic public health surveillance. Funding could pay for upgrading the server infrastructure, as well as pairing the Bangladesh DHIS2 maintenance team with international technical expertise (probably one of the many international private companies with experience supporting LMIC DHIS2 instances) on a part time basis to build in-country capacity and ensure the performance upgrade is delivered. When you improve the quality of a country's public health surveillance you improve the quality of the country's modelling efforts.

Three specific areas for improvement have been found during this study. Firstly, system infrastructure should be reviewed and upgraded to improve performance and stability; the country must trust that DHIS2 provides a stable and reliable service if they are to invest in it. Secondly, to implement an electronic laboratory data management platform using DHIS2. The current system is reportedly based on excel. Whilst excel is a powerful tool for agile data management, at a national level it can be indicative of an under-developed and rapidly-assembled data management process that is not consistent with the national public health surveillance strategy. In our experience, Excel based systems in LMICs are less likely to address: timeliness of data dissemination, security of data in transit and at rest, automation of processes such as data aggregation and sms/email alerts, validation of data at input, monitoring of data quality, consistency of data definitions with other public health surveillance data, scalability of system coverage, and safe versioned backup of all data at all points in the workflow. Finally, we recommend using DHIS2 electronic data collection tools to phase out paper based collection techniques in order to improve the quality, completeness and timeliness of data. Electronic forms will reduce human error, manual workload, and data delay.

Appetite/Impact: An effective and scalable electronic data management system for laboratory data will have a direct impact on the quality and real time access to surveillance data in Bangladesh used by modellers as well as for assessing the impacts of interventions. It would also improve the transparency of the data quality, meaning modellers have more flexibility to factor data uncertainty and lags (incompleteness due to timeliness of recording/submissions) into their model. The efficacy of a country's HIS depends upon reliable performance. An unstable system will have a far reaching negative impact upon many aspects of the Bangladesh health system and COVID-19 response.

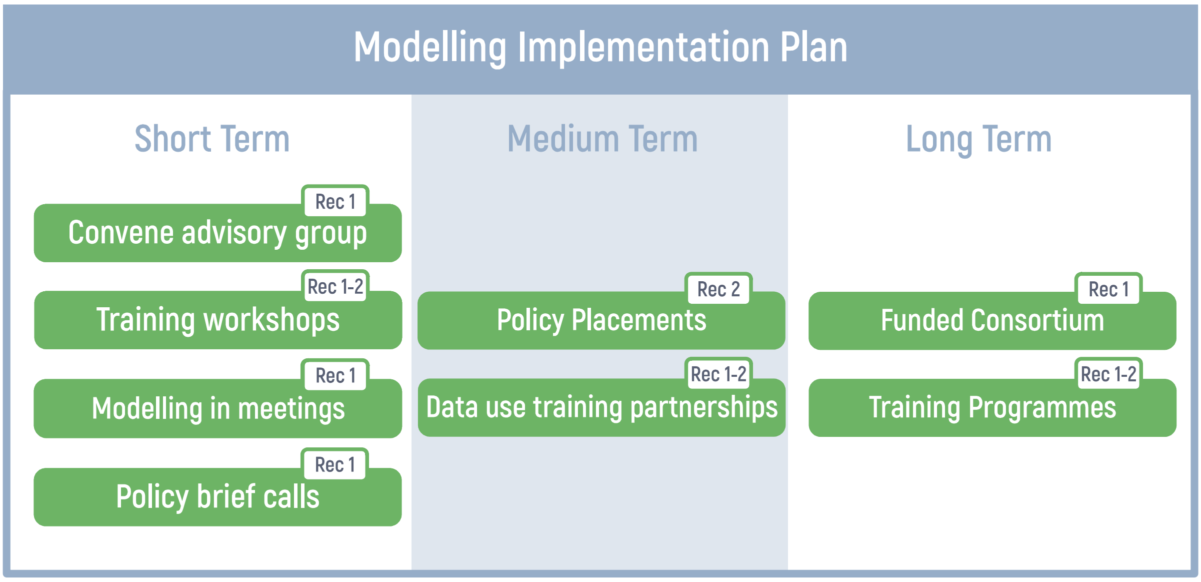

Figure 1: Showing the implementation plan over the short term (requiring either modest funds or periods of time less than 6 months), medium term (can be completed within a year) and long term (should be considered multi-year projects/ programmes). Each step is labelled with the corresponding recommendation from the recommendations section above.

Modelling Implementation plan

Figure 1 visualises the implementation plan laid out below.

Short term tasks requiring either modest funds or short periods of time (less than 6 months):

1. Convene an infectious disease policy advisory group bringing in specific modelling expertise. The advisory group remit could focus on development of a pandemic preparedness plan, and identification of national priorities for infectious disease modelling work.

2. Training workshops for representatives from key institutions with the aim of building proficiency in understanding the value of models and interpreting modelling work (not in developing models as this would be a longer term objective). Similar workshops could be held focusing on policy engagement.

3. Support modelling sessions during national infectious disease and public health meetings and fora, to build engagement between local researchers and modelling experts (ideally these would be incorporated into regular events which might take place over multiple years).

4. Solicit policy briefs from Bangladesh institutions on priority topics (identified under task 1) for review and coaching by the policy advisory group. Those of high enough quality could be offered a policy engagement audience (and invited to be consortium members - see longer term recommendations).

Medium term tasks that can be completed within a year:

5. Policy placements whereby Bangladesh modellers (as part of PhD training) are embedded within international organizations and DGHS departments for the purposes of identifying and addressing key research questions

6. Support bilateral training partnerships between Bangladesh institutions and modelling experts focusing on use of routine surveillance data to address key policy questions (1)

Long term tasks that should be considered multi-year projects/ programmes:

7. Fund a DGHS-led consortium comprising modelling, health systems, data management and policy expertise, with regular meetings with policymakers and funding available to undertake identified modelling priorities (see short-term task 1).

8. Support training programmes for Bangladesh scientists to become proficient infectious disease modellers. This may be most efficiently achieved through attendance on established training programmes outside of Bangladesh, but must require deliverable policy briefs following extended work with Bangladesh stakeholders to address specific pressing policy questions. As needed modelling mentorship should be provided (where local capacity is lacking). An alternative model might be to fund parallel capacity to support existing infectious disease projects in Bangladesh.

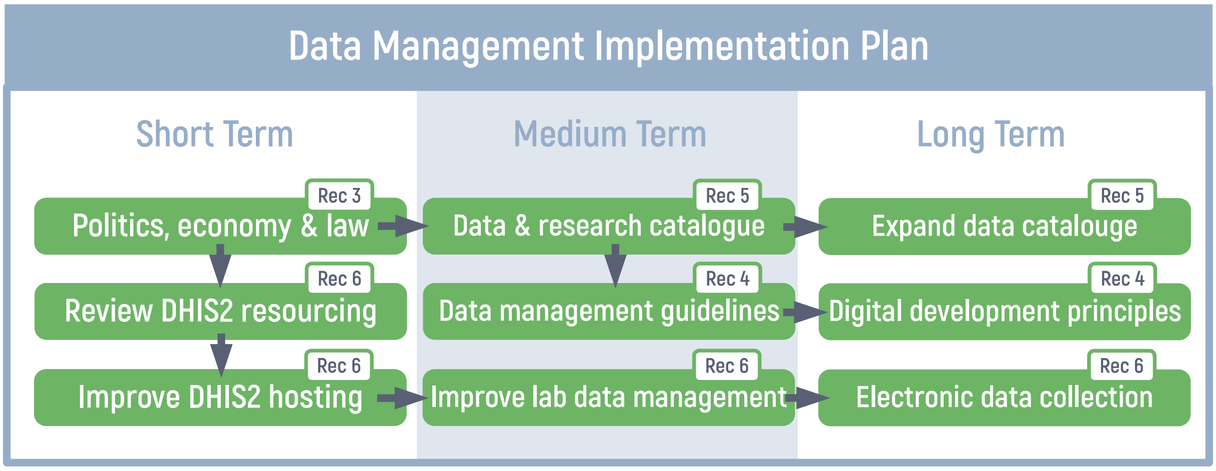

Figure 2: Showing the implementation plan over the short term (achievable by 1-2 people over a matter of weeks to months), medium term (a small team or collaboration over several months) and long term goals (not recommended until short and medium term goals are achieved). Each step is labelled with the corresponding recommendation and the suggested order of implementation is shown by the arrows.

Data Management Implementation Plan

Figure 2 visualises the implementation plan laid out below.

Short term tasks requiring 1 or 2 individuals over a matter of weeks to months:

1. Conduct an analysis of the political, economic and legal landscape. The work would be suitable for two people or a small team. Expertise is required in public health and data management across LMICs, as well as law and political analysis. The review could seek a deeper understanding of the political, economic and legal feasibility of the recommendations laid out in this document.
2. Employ a technical specialist to review the efficacy of the DHIS2 instance, and confirm second-hand reports that the system is under-resourced, offering poor/slow performance, and still using paper based data collection. Also, review the existing laboratory data management process and identify any areas for improvement.
3. If necessary, improve the stability of the DHIS2 system by funding an experienced technical partner to support the DHIS2 maintenance team part-time to build in-country technical-capacity and implement a scalable and robust infrastructure solution.

Medium term tasks requiring a small team and/or collaboration over several months:

4. Implement a DGHS-owned health data and research catalogue for securely disseminating data and reports amongst partners. The catalogue could be implemented in a few months by a small team using the open source software CKAN that is also powering data.gov.uk and humdex.org. A specific scope and clear use-cases should direct the project.

5. Depending on the outcome of task 3, hire technical and public health specialists to support implementation of a DHIS2-based laboratory data management system, and a strategy to transition away from the current system to the new system.

6. Fund a data management expert to work with DGHS on developing best practises and principles for Health Data Management in Bangladesh. This should include template data licenses and sharing agreements, security concerns for different types of data, metadata management

Longer term tasks, not necessarily requiring more time and resources, but deemed to be of lower priority and dependant upon completion of previous tasks:

7. If the data catalogue is well received in Bangladesh, there may be calls to expand the scope and use cases for the catalogue. For instance automated interoperability with DHIS2 to securely share surveillance data with approved modellers, or expansion of the catalogue to list data and research from third-party organisations such as icddr,b.

8. As a lower priority, it would be good to work with DGHS to identify and advocate for some digital development principles, such as those supported by FCDO, Fjelltopp and the UN, and available from digitalprinciples.org. This would provide greater transparency in the sector and a metric by which to assess future interventions.

9. Employ an experienced team to phase out all paper based data collection, ensuring that all health surveillance data is consistently and automatically stored in DHIS2. This may or may not be done with DHIS2. Fjelltopp have had real success in multiple LMICs using Open Data Kit (ODK) to conduct secure and reliable electronic data collection for DHIS2.

Bibliography

1. Truelove S, Abrahim O, Altare C, Lauer SA, Grantz KH, Azman AS, et al. The potential impact of COVID-19 in refugee camps in Bangladesh and beyond: A modelling study [Internet]. Vol. 17, Plos Medicine. 2020. Available from: <Go to ISI>://WOS:000542757500001

2. Cruickshank S. Edge of emergency [Internet]. The Hub - John Hopkins University. 2020 [cited 2021 Mar 24]. Available from: https://hub.jhu.edu/2020/09/22/coronavirus-transmission-model-averts-rohingya-humanitarian-crisis/

3. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. Lancet Infect Dis. 2020 May;20(5):533–4.

4. WorldPop [Internet]. [cited 2021 Mar 15]. Available from: https://www.worldpop.org/

5. World Bank Open Data [Internet]. [cited 2021 Mar 16]. Available from: https://data.worldbank.org/

6. LandScan [Internet]. [cited 2021 Mar 15]. Available from: https://landscan.ornl.gov/

7. Cowley LA, Afrad MH, Rahman SIA, Mahfuz-Al-Mamun Md, Chin T, Mahmud A, et al. Genomic and mobility data reveal mass population movement as a driver of SARS-CoV-2 dissemination and diversity in Bangladesh [Internet]. Public and Global Health; 2021 Jan [cited 2021 Mar 15]. Available from: http://medrxiv.org/lookup/doi/10.1101/2021.01.05.21249196

8. GISAID - Initiative [Internet]. [cited 2021 Mar 15]. Available from: https://www.gisaid.org/

9. GenBank Overview [Internet]. [cited 2021 Mar 15]. Available from: https://www.ncbi.nlm.nih.gov/genbank/

10. Nextstrain [Internet]. [cited 2021 Mar 15]. Available from: https://nextstrain.org/sars-cov-2/

11. Hadfield J, Megill C, Bell SM, Huddleston J, Potter B, Callender C, et al. Nextstrain: real-time tracking of pathogen evolution. Kelso J, editor. Bioinformatics. 2018 Dec 1;34(23):4121–3.

12. London IC. Microreact COVID-19 [Internet]. Microreact. [cited 2021 Mar 15]. Available from: https://microreact.org/project/COVID-19

13. CKAN Data Catalog/Portal System [Internet]. ckan. [cited 2021 Mar 17]. Available from: https://ckan.org/

14. Data Hubs For Health [Internet]. Fjelltopp. [cited 2021 Mar 24]. Available from: https://datahubs.fjelltopp.org

Fjelltopp
Harmonising Health Data

Annexe 1
Existing Modelling Efforts
COVID-19 in Bangladesh

We identify a body of modelling work relevant to Bangladesh. These are either open access models that can be applied to Bangladesh data, or work from or relevant to Bangladesh as identified through a systematic literature review. The results of this work will be presented in three parts: First we will provide an overview of the generic frameworks that have been or are suitable for use in policy. Second, we will summarize the modelling literature identified through our systematic review. Finally, we will highlight specific model frameworks that address recurring themes, with direct policy application.

Table of Contents

Generic Frameworks....2
Literature Review....2
- Work led by individuals/ academic groups in Bangladesh:....5
- Bangladesh-specific work &/or with detailed epidemiological data....6
- Low-and-middle-income country (LMIC) and/ or with potential relevance....7
- Generic frameworks including Bangladesh as an example country....8

Unpublished, ongoing modelling work specifically for Bangladesh....10
Bibliography....13

info@fjelltopp.org www.fjelltopp.org

Fjelltopp Ltd is a UK social enterprise, company limited by shares No. 11961922
Registered Office: 40 Blackburn Road, Padiham, Lancashire, BB12 8JZ

Generic Frameworks

The following models (summarised in Table 1) represent a variety of frameworks with online interfaces, or packages accessible for users to run models using the open access software R. All of these models have been used by policymakers around the world and provide country-level outputs. They vary in complexity, but can all be applied at the global level using publicly available data (see Annex 3). The ICL packages can be fit to more local data. Only the COVID-SIM model contains a spatial process that allows for more localised estimation of epidemiological parameters. The IHME model has come under severe scrutiny, despite being used for some national level policy decisions (mainly in the US). It is likely that the estimates produced from this model continue to be unreliable as the underlying statistical framework does not include epidemiological mechanisms or processes and cannot recapitulate observed dynamics, therefore this model is not recommended for policy decisions or even general insight.

Literature Review

The process of the systematic literature review is shown in figure 1. Prior to the allocation of papers, the grading rubric identified in Figure 1 was agreed upon by all reviewers, based on a set of four randomly chosen papers reviewed by all eight reviewers.

The selection process resulted in 79 papers. Table 2 details the scores assigned to each paper. Six papers were assessed by two people anonymously and independently to assure consistency. One discrepancy was discussed whilst the others were in agreement. Four papers were not scored because they were either not modelling, not relevant to Bangladesh or were incomplete manuscripts resulting in 75 papers listed here. One paper (Shimul, Hussain et al. 2020) was reported to have been used in policy. This was confirmed through our interviews, as it is this model framework that was used by the DGHS from April to July 2020 (more detail available from sites.google.com/site/shafiunihe/recent-work-on-covid-19). Joint work from UoG and FAO also informed government policy and international organizations as indicated below.

We present further details on papers that were scored 5 below. This score indicates our confidence in the use of this modelling work for policy purposes. With regards to the applicability of this work to Bangladesh, we present the details in four sections: 1. Work published from academic research groups in Bangladesh; 2. Detailed epidemiological data from Bangladesh collected specifically for the study; 3. Models focused on low– and middle-income countries with relevance to Bangladesh; 4. Generic frameworks of which Bangladesh is one example presented. Additionally, we identified six recurring policy relevant themes that these models were used for: 1. Inferring past events; 2. Projections; 3. Impacts of non-pharmaceutical interventions (NPIs); 4. Parameter estimation; 5. Spatio-temporal frameworks; and 6. Applications to refugee camps. An indication of these use cases will accompany each description.

Institute	Name	Interface	Citations	Framework	Inputs	Outputs
ICL	SQUIRE	R package	[9,74]	Stochastic, age structured SEIR	All inputs can be found here: mrc-ide.github.io/squire/reference/run_explicit_SEEIR_model.html	Number of infections and deaths, hospital occupancy, ICU occupancy, hospital and ICU demand
ICL	SIRCOVID	SIRCOVID package in (R)	UK reports	Stochastic, discrete-time, age-structured, SEIR, with hospital compartments and care homes. Can include daily vaccine doses to be applied. Fit with Bayesian methods initially published as a state-space model.	Available from the model Github page: mrc-ide.github.io/sircovid/	Forecasting numbers of infections and deaths. Estimating R0/ Rt and for inferring past events. Outputs can be age-structured.
ICL	COVID-SIM	nimue (R)	UK reports	Spatial model, built upon the SIRCOVID and SQUIRE models	SQUIRE inputs plus vaccination relevant parameters (efficacy, availability etc).	Compartmental quantities (S, I, R etc), incidence, incidence of false positives, treatment rate, impact of vaccinations, spatial spread information from seed case, R0 in houses and places, shape and peak of epidemiological curves.
IHME	IHME	covid19.healthdata.org/bangladesh	-	Statistical framework, no epidemiological mechanism and assumptions not transparent.	Not manually adjustable via the interface.	Infections, deaths, hospital resource use, testing, mask use, social distancing.
LSTMH	Epi-forecast	epiforecasts.io/covid/posts/national/bangladesh/ and epinow2 (R)	[76]	Statistical framework with capability to account for imperfect data	Not manually adjustable via the interface.	Confirmed cases, expected change in daily cases, effective reproduction number R, growth rates, doubling/ halving times
Oxford/ Cornell	CoMo	comomodel.net	-	Age structured SEIR model	Probability of infection given, % of all asymptomatic infections reported, country specific values, various interventions that can happen concurrently, virus characteristics, hospital characteristics.	Infection numbers, hospital demand and ICU beds, test/PPE/medical resources required, costs

Table 1. Summary table detailing the frameworks and R packages used for country-level modelling of SARS-CoV-2

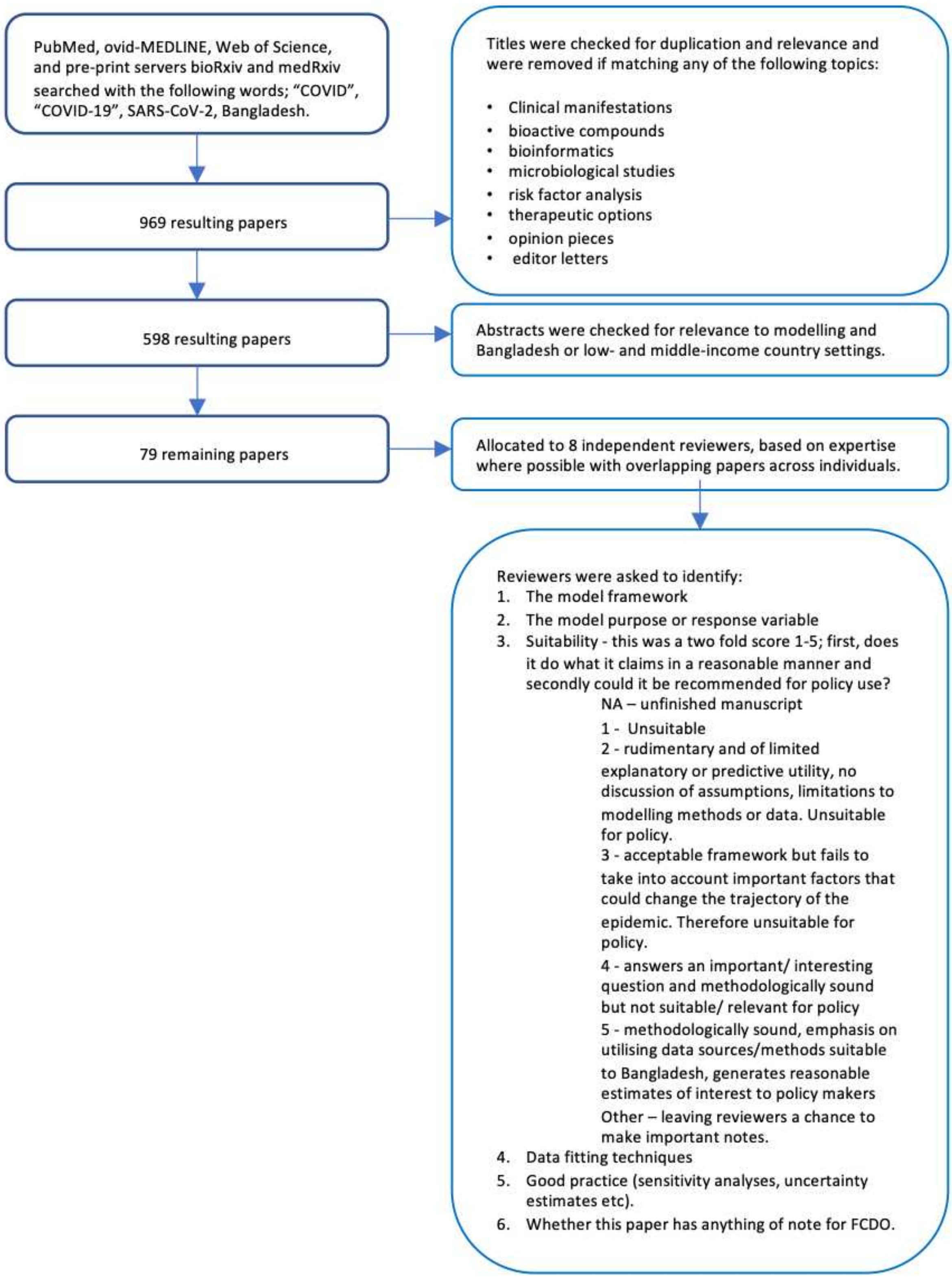

Figure 1. Flowchart of the systematic literature review indicating the number of papers included at each step and reviewed.

Score	Citation
1 (unsuitable)	(Bairagi, Masud et al. 2020, Fu 2020, Gupta and Pal 2020, Hassan, Dosar et al. 2020, Li, Zhang et al. 2020, Neve, Patel et al. 2020, Noh and Danuser 2020, Rahaman Khan and Hossain 2020)
2	(Ahamad, Aktar et al. 2020, Ahmad, Ahmed et al. 2020, Bagal, Rath et al. 2020, Bautista Balbás, Gil Conesa et al. 2020, Chauhan, Kumar et al. 2020, Dey, Rahman et al. 2020, Hridoy, Naim et al. 2020, Islam, Hoque et al. 2020, Kriston 2020, Kundu, Ferdous et al. 2020, Levitt, Scaiewicz et al. 2020, Liu, Liu et al. 2020, Macías-Ordóñez and Villaseñor-Amador 2020, Mahmud and Patwari 2020, Notari 2020, Pal, Ghosh et al. 2020, Rahman, Ahmed et al. 2020, Shimul, Hussain et al. 2020, Hassan, Bhuiyan et al. 2021, Siam, Arifuzzaman et al. 2021, Uddin, Akter et al. 2021)
3	(Amo-Boateng 2020, Ayoub, Chemaitelly et al. 2020, Bertacchini, Bilotta et al. 2020, Chaubal, Kannan et al. 2020, Fargana, Arifutzzaman et al. 2020, Hoque 2020, Huang, Liu et al. 2020, Islam, Hasanuzzaman et al. 2020, Karimuzzaman, Afroz et al. 2020, Khatua, Guha et al. 2020, Mazumder, Bharadiya et al. 2020, Nabi 2020, Nabi, Kumar et al. 2020, Paul, Chatterjee et al. 2020, Shahidul Islam, Irana Ira et al. 2020, Tembine 2020, Kannoth, Kandula et al. 2021)
4	(Acharya, Khanal et al. 2020, Belloir and Blanquart 2020, Chow, Chang et al. 2020, Li 2020, Ohi, Mridha et al. 2020, Thomas and Marks 2020, Vilar and Saiz 2020, Cowley, Afrad et al. 2021, Roy, Saha et al. 2021)
5 (sound, directly relevant)	(Babačić, Lehtiö et al. 2020, Basu, Salvatore et al. 2020, Chowdhury, Heng et al. 2020, Ćmiel and Ćmiel 2020, Džiugys, Bieliūnas et al. 2020, Gilman, Mahroof-Shaffi et al. 2020, Hernandez-Suarez, Verme et al. 2020, Hoque, Islam et al. 2020, Hridoy, Naim et al. 2020, Islam, Hasanuzzaman et al. 2020, Li, Bedi et al. 2020, Louca 2020, Mahmud, Chowdhury et al. 2020, Masrur, Yu et al. 2020, Russell, Golding et al. 2020, Sánchez-Romero, Lego et al. 2020, Truelove, Abrahim et al. 2020, Walker, Whittaker et al. 2020, Barnett-Howell, Watson et al. 2021, Salvatore et al. 2020)

Table 2. Citations of each paper selected from for review and their assigned scores. Only papers scoring a 5 are detailed in the text below. Grading rubric given in figure 1.

Work led by individuals/ academic groups in Bangladesh:

Title: **Adjusted Dynamics of COVID-19 Pandemic due to Herd Immunity in Bangladesh [31]**
Data: IEDCR, Socioeconomic Data and Application Center, JHU

This deterministic SIRD model with age group cluster analysis and fixed parameter values from available literature is used for **forecasting, parameter estimation, inferring past events and studying the impact of interventions**. This model adheres to best practices by providing uncertainty estimates and **acknowledges the noisy and incomplete nature of the data**. Pages 10-11 also provides an insightful section on observations from their analysis, and policy recommendations.

Title: **Effect of meteorological factors on COVID-19 cases in Bangladesh [36]**
Data: Bangladesh Meteorological Department, IEDCR, www.timeanddate.com

A deterministic, statistical Distributed Log Non-Linear (DLNM) model using the wavelet transform coherence method is used for temporal analysis, specifically **parameter estimation and inferring the dynamics of past events**. This statistical framework ignores human behaviour and therefore is not as suitable as more mechanistic frameworks accounting for explicit epidemiological processes. Fixed parameters are taken from the literature, data fitting is conducted using residual minimisation, curve fitting, and the LOESS method of local smoothing and methods are validated by comparison with other methods.

Title: **Estimation of Effective Reproduction Number for COVID-19 in Bangladesh and its districts [33]**
Data: IEDCR, DGHS.

This statistical spatiotemporal model is used with machine learning techniques for **parameter estimation, including estimating the real-time reproduction number Rt, and associated metrics (e.g., growth rate), and contains a spatiotemporal component.** This framework is complementary to work being conducted at the University of Glasgow; the methods will require further comparison. The model is fitted to data using Bayesian methods, providing an indication of best fit and uncertainty estimates through visual investigation, and maximum likelihood.

Bangladesh-specific work &/or with detailed epidemiological data

Title: **Participatory syndromic surveillance as a tool for tracking COVID-19 in Bangladesh [51]**
Data: worldpop, DGHS, IEDCR, Grameenphone, Banglalink, Robi, Teletalk, the Bangladesh Telecommunication Regulatory Commission, and the National Telecommunications Monitoring Centre, BRAC, CMED.

This paper presents a statistical framework that uses regression analysis to analyse multiple streams of syndromic data (telemedicine calls on respiratory signs and other clinical data indicative of COVID-19) across **space** and **time** to estimate **SARS-CoV-2 prevalence and spatiotemporal trends**. The framework is implemented with the open access software R using the merTools package. This work is particularly valuable because it uses syndromic data which for a number of reasons may be more reliable than laboratory case confirmed data or deaths during the early stages of the epidemic, and the uncertainties and challenges of working with such data are discussed clearly.

Title: **Space-Time Patterns, Change, and Propagation of COVID-19 Risk Relative to the Intervention Scenarios in Bangladesh [53]**
Data: LandScan™ Population dataset, IEDCR

The model presented here is a statistical framework that encompasses a spatiotemporal element. Despite being underpowered the methodology is directly relevant to Bangladesh and could be utilised. The framework is used to **infer past events and investigate the impact of interventions**. The outputs are the timing of clustered outbreaks at district-level and changes in relative risk of infection over time.

Title: **The potential impact of COVID-19 in refugee camps in Bangladesh and beyond: A modelling study [74]**
Data: values from the literature, no data fitting.

This stochastic, mechanistic compartmental model is used to **forecast** the impact of a covid-19 outbreak in the Kutupalong-Balukhali Expansion Site. The model was appropriate and sensitivity analyses were presented, but in retrospect, the predicted health impacts were overestimated, possibly due to mortality rate estimates that did not fully account for the younger populations within the refugee camps. This model produced estimates of the **probability of large outbreaks, hospital burdens and the days into the outbreak that this could occur**.

Low-and-middle-income country (LMIC) and/ or with potential relevance

Title: **The impact of COVID-19 and strategies for mitigation and suppression in low- and middle-income countries [76]**
Data: WHO, ACAPS, Covid response tracker. All data used is reportedly available for public download from the cited sources and the code is available as an R package from Zenodo and a Github repository for the SQUIRE framework.

This model uses the SQUIRE model framework described above (Table 1), from ICL. It is used for **forecasting, parameter estimation, and to project the impact of interventions.** This model follows best practice in that they conduct sensitivity analyses, provide uncertainty estimates and a thorough overview of the training process for the model as well as making all code for the model available online. The model produces estimates of the final proportion of the population infected, infections per 100,000, hospital burden, infection fatality ratio, and daily mortality.

Title: **The benefits and costs of social distancing in high- and low-income countries [10]**
Data: SQUIRE default variables (Table 1)

The model uses the SQUIRE framework (see Table 1) to **forecast** the epidemic trajectory and **estimate the cost of mitigations** in comparison to leaving SARS-CoV-2 unmanaged. This is a good example of the flexibility of the more general frameworks.

Title: **COVID-19 prevalence in 161 countries and over time [49]**
Data: Seroprevalence data – not from Bangladesh.

This stochastic, statistical, age-specific mortality model is used to **infer past events** using mortality data compared with seroprevalence data to provide an estimate of true prevalence. This model highlights the important difference between the number of cases confirmed through testing, and the likely number of cases accounting for under-detection and under-reporting.

Title: **Modelling interventions to control COVID-19 outbreaks in a refugee camp [26]**
Data: Values from literature (not Bangladesh).

This is an individual-based spatio-temporal model designed to **explore the impact of interventions** in refugee camps. Agent-based models are valuable tools for forecasting the spread of disease in spatially structured and heterogeneous populations and are used extensively to build an evidence base in public health, but the individual and spatial detail may be unnecessary. Most other models assume populations in refugee camps are well-mixed i.e. infection will spread rapidly throughout. The authors state that this model can be adapted for use for other settings and epidemics. Their outputs are the **proportion infected** and **epidemics averted** under a series of scenarios.

Title: **Dynamic interventions to control COVID-19 pandemic: a multivariate prediction modelling study comparing 16 worldwide countries [18]**
Data: Worldbank data - available hospital beds, financial information. Other parameters from literature.

This age structured compartmental SEIR model **estimates the impact of dynamic NPIs** on numbers of COVID-19 patients needing to be **hospitalized**, **requiring intensive care**, and **deaths**. They explore different scenarios of NPI use, accounting for the economic impact of NPI's which may be better received, than models considering only total lockdown and/or deaths from COVID-19.

Title: **Comprehensive public health evaluation of lockdown as a non-pharmaceutical intervention on COVID-19 spread in India: national trends masking state-level variations [67]**
Data: Weekly case counts, fatalities, recoveries and test positivity by state in India. These data are publicly available from covid19india.org.

Using publicly available data from India, analyses were performed to measure a number of important epidemiological quantities including **case fatality rates, epidemic doubling times, growth rates and reproduction numbers and assessment of testing capacity** (including test positivity rates). The study is useful and interesting in terms of comparatively assessing the differences between states that relate to the spread of the pandemic and the degree to which NPIs were effectively implemented. The paper acknowledges a number of limitations including that of the data which although comprehensive and spatially disaggregated certainly underascertain COVID-19 cases. The paper also acknowledges that it's focus is retrospective evaluation rather than prospective forecasting, but makes recommendations as to how such approaches could be used. Code is provided for all analyses, and the methods used could be broadly and usefully applied to district-level data in Bangladesh. It is also expected that COVID-19 dynamics in Bangladesh are likely to be more similar to India (that to HICs) given their relative proximity and similar demographics.

Generic frameworks including Bangladesh as an example country

Title: **Reconstructing the early global dynamics of under-ascertained COVID-19 cases and infections [66]**
Data: ECDC

This age-adjusted stochastic statistical model is fit with a Bayesian framework tp reported data on COVID-19 cases and fatalities globally, and is **used to infer past events** – that is the proportion of all cases that are symptomatic and reported. This model, though fine enough as a standalone model, could be used as an observation component in a state-space approach. It would be more likely to prove useful in the short-term as a source of error-corrected time series of case counts, for the start of the outbreak. Such corrections are likely to prove influential for parameter estimation, especially given that this paper has argued that Bangladesh is an extreme case in the spectrum of countries analysed.

Title: **Simplified model of Covid-19 epidemic prognosis under quarantine and estimation of quarantine effectiveness [22]**
Data: ECDC, humdata.org

This deterministic, mechanistic compartmental model is used for **parameter estimation** and to **explore the impact of interventions**. The model is fit to data via curve fitting methods, various best practice methods are applied, model outputs are given for numerous countries including daily case estimates, infection rate (i.e., the transmission parameter estimated as the number of new registered cases of infection to number of active cases ratio) and daily growth rates.

Title: **A new, simple method of describing the COVID-19 trajectory and dynamics in any country based on Johnson Cumulative Distribution Function fitting [19]**
Data: Our world in data.

This statistical, parametric curve fitting exercise, so suspect by default, has other redeeming features: mainly taking a multi-country and multi-wave view. It is used for **forecasting, parameter estimation, and inferring past events**. This is one of the only papers to consider multiple waves within a country. However a model with epidemiological mechanisms may be more applicable.

Title: **Evaluating Short-term Forecast among Different Epidemiological Models under a Bayesian Framework [46]**
Data: JHU

A number of stochastic growth and compartmental models are unified under a Bayesian framework. These frameworks are used for forecasting and parameter estimation. There are two large caveats to this model; first the software is only available in the USA. Secondly, the model comparisons fail to find a single "best" model across all locations, however rather than this being a failing this shows the complexity of producing suitable models by locality. Additionally, there is extensive detail on which model frameworks worked best and where which may be of use. They also consider the use of an ensemble model which we found no other mention of across our review. Ensemble models are a useful method for bringing together multiple model streams and could be beneficial. Furthermore, the processes of best practice including goodness-of-fit, visual and cross-model validation in this paper make a good example of quality work applicable to policy. The outputs of this model are new daily confirmed cases.

Title: **Global between-countries variance in SARS-CoV-2 mortality is driven by reported prevalence, age distribution, and case detection rate [7]**
Data: Worldometer, ECDC, UN

This deterministic statistical model is used for **parameter estimation and inferring past events**. This is a between-country comparison, so the methods are not suitable for a within-country study, although the findings are interesting. In particular, it was found that Bangladesh is one of 5 outliers in having more deaths than predicted by the model. Unfortunately, there was no discussion as to why this was. This is one of the few models that explicitly models the number of deaths.

Title: **How many lives can be saved? A global view on the impact of testing, herd immunity and demographics on COVID-19 fatality rates [68]**
Data: Population data

This compartmental mechanistic model is used **for parameter estimation and to investigate the impact of interventions** and asymptomatic individuals on fatality rates – thus explicitly models mortality. They also estimate an incubation period, the proportion of cases that are asymptomatic and $R_{0.}$ They project forward to investigate the landscape of covid globally after 1 year, investigating different scenarios including the impact of testing, herd immunity and additional demographic factors. This also provides a "number of lives saved" metric.

Title: **Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand [24]**
Data: Unclear, the report is based on the UK scenario at the time and just states census data/ population density data. This framework has apparently been taken and used by advisors to the DGHS, as identified via communication with stakeholders and examination of citation [69], however, the methods of that report do not align with Ferguson [24].

This is a stochastic, spatially structured individual-based simulation. Community transmission depends explicitly on distance, as it is intended to represent random contacts associated with movements and travel.

Unpublished, ongoing modelling work specifically for Bangladesh

Title: **Developing cost-effective non-pharmaceutical interventions to reduce the impact of COVID-19 in Bangladesh**
Lead author & institution: Elaine Ferguson, Rachel Steenson, Mikolaj Kundergorski, Katie Hampson - University of Glasgow; Ayesha Mahmud - University of California, Berkeley, USA; Anir Chowdhury - a2i, Nabila Purno - UNFPA, Eric Brum, FAO, Bangladesh

Background: With limited treatment options, many countries turned to non-pharmaceutical interventions (NPIs) to limit transmission during the COVID-19 pandemic. However, some of these measures may be difficult to maintain or less effective in low- and middle- income countries (LMICs). A national lockdown was quickly implemented following detection of cases in Bangladesh, but rapidly exacerbated poverty, and so could only be a short-term measure, preceding more context-appropriate interventions. We aimed to explore the outcomes and costs of different post-lockdown NPIs, incorporating suggestions from policymakers on NPIs under consideration.

Methods: We developed an SEIR model, parameterised using a combination of literature values and calibration to death data from Bangladesh, to forecast the COVID-19 epidemic in Dhaka District, Bangladesh. We modelled NPI scenarios involving combinations of lockdown and post-lockdown measures considered feasible, specifically symptoms-based household quarantining and compulsory mask-wearing. Deaths, hospitalisations relative to capacity, working days lost, and cost-effectiveness were compared between scenarios. We also designed an interactive app for policymakers to directly explore different scenarios and parameterisations, including levels of compliance and testing capacity (https://rabies.shinyapps.io/Dhaka_covid19/).

Results: Lockdowns alone were predicted to be unable to prevent overwhelming of the health service in Dhaka District and were costly in working days lost. Symptoms-based household quarantining post-lockdown was similarly unable to prevent hospitalisations exceeding capacity whereas compulsory mask-wearing, both protected health services from being overwhelmed and was cost-effective when masks had high filtration efficiency. When combined with household quarantining, masks prevented excess hospitalisations under a range of assumptions about mask quality.

Conclusions: Masks and symptoms-based household quarantining act synergistically to prevent transmission, and are feasible and cost-effective to implement in LMICs. This combination of measures likely averted a public health disaster in Bangladesh as predicted under an unmitigated epidemic. Our interactive app was effective in supporting decision-making in Bangladesh.

Title: **Spatial and temporal patterns in COVID-19 cases across the megacity of Dhaka, Bangladesh**
Lead author & institution: Yacob Haddou, Janine Illian, Jason Matthiopoulos and contributions from University of Glasgow COVID-19 LMICs Research Group, and partners from the CST programme.

The capital of Bangladesh, Dhaka recorded over 150,000 cases of COVID-19 in 2020, which when combined with limited control measures and lack of consistent access to testing, resulted in the ongoing health crisis. Here we explore the spatial and temporal patterns in COVID-19 cases across the municipalities of Dhaka in relation to demographic, socio-economic and environmental variables.

Case data aggregated, weekly, at the ward (n=126) and municipality (n=20) level was modelled from June 2020, together with spatially and temporally varying covariates including: healthcare access, the percentage of urban and rural land cover, mean Wealth and USD income per household, road density, slums coverage, mobility changes, air pollution, temperature and rainfall. The Integrated Nested Laplace Approximation (INLA) framework, which allows for quick and computationally inexpensive Bayesian inference on large datasets and spatially, temporally and spatio-temporally structured random effects, was used to explain patterns in case data. We further addressed inconsistent sampling efforts across space (distribution of testing points) and time (numbers of tests), by accounting during the model fitting for offsets. So far, we have found that structured temporal and spatial effects are not consistently detectable, either as the result of very high levels of population mixing or inconsistencies in data collection. We observed that more recorded cases were associated with higher urban development and easier access to essential services whilst accounting for population density. Our results have potential to inform the pandemic response including testing efforts. Our aim is to support implementing partners with useful inference in detecting areas of the city where the relative risk of COVID-19 is higher than expected and focused containment measures should be applied. We are using this approach to tease out the effects of CST visits on case detection. This work also provides a pathway to analyze how the spatial and temporal processes underpinning case distribution vary between macro and micro scales.

Title: **Understanding the spatiotemporal dynamics of COVID-19 across the 64 Bangladesh districts**
Lead author & institution: Craig Wilkie, Yacob Haddou, Mahi Siddika, Luca Nelli, Ben Swallow, Janine Illian. University of Glasgow

Daily COVID-19 case numbers have been recorded across Bangladesh since the beginning of 2020. After an initial case early in 2020, confirmed cases exceeded 400,000 by the end of the year.

Understanding the drivers of spatio-temporal dynamics of infection is vital for planning for appropriate distribution of healthcare resources across the country. We therefore propose a spatio-temporal conditional autoregressive (CAR) modelling approach that accounts for the spatial and temporal correlation structures, while enabling the assessment of covariate effects. Specifically, we fit a Besag-York-Mollié (BYM) model of case counts by district over time, with covariates and structured and unstructured area- and time-specific effects and interactions. The model is fitted through the widely-used, flexible and computationally efficient integrated nested laplace approximation (INLA) framework, with reproducible code written in R. Analyses were performed on the raw case counts and on the case counts with an offset for numbers of tests carried out. This provides the flexibility to identify the main spatial and temporal structures in the data, while allowing for local variation. This allows specific districts of concern to be identified at specific timepoints, for example, where unusually high case numbers are identified and ensures a more robust understanding of the effects of covariates. More complex models accounting for space-time interactions performed much better than those without, suggesting that the underlying patterns in case counts cannot be adequately explained by a single pattern for the whole country, with temporal dynamics of the outbreak differing across the districts. For the model with the most flexible interaction, log(walking time to healthcare) was estimated to relate negatively to case counts, while log(mean poverty score) was estimated to relate positively to increased case counts. No covariates were found to have non-zero relationships with case counts after accounting for testing numbers using an offset term. We will consider appropriate methods of modelling testing numbers directly in future work.

Title: **Combining Rapid Antigen Testing with Symptomatic Data to Predict COVID-19 Cases**
Lead author & institution: Fergus Chadwick, contributions from University of Glasgow COVID-19 LMICs Research Group, and partners from the CST programme.

The COVID-19 pandemic has spread quickly in low and middle income countries, where resources are limited for gold-standard RT-PCR testing of COVID-19. Rapid antigen tests (RATs) are inexpensive, fast, less physically invasive and can be conducted discreetly in the patient's home by teams embedded in the community without the need to travel to a designated site. However, RATs are less sensitive than RT-PCR. Community support teams (CST) have been trained to undertake syndromic surveillance for COVID-19 in Dhaka and provide support to potentially infected and/or vulnerable individuals and will pilot the use of RATs in communities. To improve COVID-19 detection, we are evaluating RAT, syndromic and patient context data to create a predictive model of COVID-19 status, validated against RT-PCR testing.

We have developed the model to address the lack of independence between self-reported symptoms and their non-specificity for COVID-19 disease. Specifically we have trained a multivariate probit model with 14 response dimensions (COVID-19 test status, and 13 self reported symptoms) and 5 predictor variables (gender, age, duration of symptoms, VVF ratio of recording, and temperature), to syndromic data collected by CST, fit in the Stan programming language. To date model fits have been tested using posterior retrodictive checks and found to have useful predictive power when used on a relatively small set of syndromic data collected by CST following refresher training (N =153). In summary, these analyses provide a proof of principle for the statistical approach and suggest potential for improved diagnostic accuracy with increasing data availability. We are in the process of applying the approach for assessing the optimal syndromic case definition in combination with individual and household-level RAT. Specifically we are comparing 1) swab types in terms of sensitivity under RAT versus PCR-testing performed by medical technicians at IEDCR, and 2) individual versus household-level RAT undertaken by CST in communities in comparison to duplicate samples tested by RT-PCR.

Bibliography

1. Abbott S, Hellewell J, Thompson RN *et al.* (2020) 'Estimating the time-varying reproduction number of SARS-CoV-2 using national and subnational case counts" [version 1; peer review: awaiting peer review] Wellcome Open Research, **5**:112 https://doi.org/10.12688/wellcomeopenres.16006.1
2. Acharya, B. K., L. Khanal, A. S. M. Mahyoub, Z. Ruan, Y. Yang, S. K. Adhikari, S. Pandit, B. K. Neupane, B. K. Paudel and H. Lin (2020). "Execution of intervention matters more than strategy: A lesson from the spatiotemporal assessment of COVID-19 clusters in Nepal." medRxiv: 2020.2011.2007.20227520.
3. Ahamad, M. M., S. Aktar, M. Rashed-Al-Mahfuz, S. Uddin, P. Liò, H. Xu, M. A. Summers, J. M. W. Quinn and M. A. Moni (2020). "A machine learning model to identify early stage symptoms of SARS-Cov-2 infected patients." Expert Systems Applications 160: 113661.
4. Ahmad, G., F. Ahmed, S. Rizwan, J. Muhammad, H. Fatima, A. Ikram and H. Zeeb (2020). "Evaluating Data-Driven Forecasting Methods for Predicting SARS-CoV2 Cases: Evidence From 173 Countries." medRxiv: 2020.2008.2003.20167189.
5. Amo-Boateng, M. (2020). "Tracking and Classifying Global COVID-19 Cases by using 1D Deep Convolution Neural Networks." medRxiv: 2020.2006.2009.20126565.
6. Ayoub, H. H., H. Chemaitelly, S. Seedat, G. R. Mumtaz, M. Makhoul and L. J. Abu-Raddad (2020). "Age could be driving variable SARS-CoV-2 epidemic trajectories worldwide." medRxiv: 2020.2004.2013.20059253.
7. Babačić, H., J. Lehtiö and M. Pernemalm (2020). "Global between-countries variance in SARS-CoV-2 mortality is driven by reported prevalence, age distribution, and case detection rate." medRxiv: 2020.2005.2028.20114934.
8. Bagal, D. K., A. Rath, A. Barua and D. Patnaik (2020). "Estimating the parameters of SIR model of COVID-19 cases in India during lock down periods." medRxiv: 2020.2006.2003.20120899.
9. Bairagi, A. K., M. Masud, D. H. Kim, M. S. Munir, A. Al Nahid, S. F. Abedin, K. M. Alam, S. Biswas, S. S. Alshamrani, Z. Han and C. S. Hong (2020). "A Noncooperative Game Analysis for Controlling COVID-19 Outbreak." medRxiv: 2020.2005.2022.20110783.
10. Barnett-Howell, Z., O. J. Watson and A. M. Mobarak (2021). "The benefits and costs of social distancing in high- and low-income countries." Trans R Soc Trop Med Hyg.
11. Basu, D., M. Salvatore, D. Ray, M. Kleinsasser, S. Purkayastha, R. Bhattacharyya and B. Mukherjee (2020). "A Comprehensive Public Health Evaluation of Lockdown as a Non-pharmaceutical Intervention on COVID-19 Spread in India: National Trends Masking State Level Variations." medRxiv: 2020.2005.2025.20113043.
12. Bautista Balbás, L. A., M. Gil Conesa, G. Rodríguez Caravaca and B. Bautista Balbás (2020). "COVID-19 effective reproductive ratio determination: An application, and analysis of issues and influential factors." medRxiv: 2020.2007.2015.20154039.
13. Belloir, A. and F. Blanquart (2020). "Estimating the global reduction in transmission and rise in detection capacity of the novel coronavirus SARS-CoV-2 in early 2020." medRxiv: 2020.2009.2010.20192120.
14. Bertacchini, F., E. Bilotta and P. S. Pantano (2020). "On the temporal spreading of the SARS-CoV-2." medRxiv: 2020.2008.2001.20166447.
15. Chaubal, R., S. Kannan, N. Khattry and S. Gupta (2020). "WORLDWIDE CASE FATALITY RATIO OF COVID-19 OVER TIME." medRxiv: 2020.2010.2004.20206599.
16. Chauhan, P., A. Kumar and P. Jamdagni (2020). "Regression Analysis of COVID-19 Spread in India and its Different States." medRxiv: 2020.2005.2029.20117069.
17. Chow, C. C., J. C. Chang, R. C. Gerkin and S. Vattikuti (2020). "Global prediction of unreported SARS-CoV2 infection from observed COVID-19 cases." medRxiv: 2020.2004.2029.20083485.
18. Chowdhury, R., K. Heng, M. S. R. Shawon, G. Goh, D. Okonofua, C. Ochoa-Rosales, V. Gonzalez-Jaramillo, A. Bhuiya, D. Reidpath, S. Prathapan, S. Shahzad, C. L. Althaus, N. Gonzalez-Jaramillo and O. H. Franco (2020). "Dynamic interventions to control COVID-19 pandemic: a multivariate prediction modelling study comparing 16 worldwide countries." European Journal of Epidemiology**35**(5): 389-399.
19. Ćmiel, A. M. and B. Ćmiel (2020). "A new, simple method of describing the COVID-19 trajectory and dynamics in any country based on Johnson Cumulative Distribution Function fitting." medRxiv: 2020.2012.2005.20244178.
20. Cowley, L. A., M. H. Afrad, S. I. A. Rahman, M. Mahfuz-Al-Mamun, T. Chin, A. Mahmud, M. Z. Rahman, M. M. Billah, M. H. Khan, S. Sultana, T. Khondaker, S. Baker, N. Banik, A. N. Alam, K. Mannor, S. Banu, A. Chowdhury, M. S. Flora, N. R. Thomson, C. O. Buckee, F. Qadri and T. Shirin (2021). "Genomic and mobility data reveal mass population movement as a driver of SARS-CoV-2 dissemination and diversity in Bangladesh." medRxiv: 2021.2001.2005.21249196.

21. Dey, S. K., M. M. Rahman, K. H. Shibly, U. R. Siddiqi and A. Howlader (2020). "Epidemic Trend Analysis of SARS-CoV-2 in SAARC Countries Using Modified SIR (M-SIR) Predictive Model." medRxiv: 2020.2006.2029.20142513.
22. Džiugys, A., M. Bieliūnas, G. Skarbalius, E. Misiulis and R. Navakas (2020). "Simplified model of Covid-19 epidemic prognosis under quarantine and estimation of quarantine effectiveness." medRxiv: 2020.2004.2028.20083428.
23. Fargana, A., A. Arifutzzaman and A. A. Rakhimov (2020). "Spreading Analysis of COVID-19 Epidemic in Bangladesh by Dynamical Mathematical Modelling." medRxiv: 2020.2006.2012.20130047.
24. Ferguson, Neil M., Daniel Laydon, Gemma Nedjati-Gilani et al. Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. Imperial College London (16-03-2020), doi: https://doi.org/10.25561/77482.
25. Fu, X. (2020). "Global analysis of daily new COVID-19 cases reveals many static-phase countries including US and UK potentially with unstoppable epidemics." medRxiv: 2020.2005.2008.20095356.
26. Gilman, R. T., S. Mahroof-Shaffi, C. Harkensee and A. T. Chamberlain (2020). "Modelling interventions to control COVID-19 outbreaks in a refugee camp." medRxiv: 2020.2007.2007.20140996.
27. Gupta, R. and S. K. Pal (2020). "Trend Analysis and Forecasting of COVID-19 outbreak in India." medRxiv: 2020.2003.2026.20044511.
28. Hassan, M. S., M. A. H. Bhuiyan, F. Tareq, M. Bodrud-Doza, S. M. Tanu and K. A. Rabbani (2021). "Relationship between COVID-19 infection rates and air pollution, geo-meteorological, and social parameters." Environmental Monitoring & Assessment**193**(1): 29.
29. Hassan, R., A. S. Dosar, J. K. Mondol, T. H. Khan, A. A. Noman, M. S. Sayem, M. Hasan and N. S. Juyena (2020). "Prediction of Epidemics Trend of COVID-19 in Bangladesh." Frontiers in Public Health**8**: 559437.
30. Hernandez-Suarez, C., P. Verme, S. Radyakin and Efren-Murillo (2020). "COVID-19 Outbreaks in Refugee Camps." medRxiv: 2020.2010.2002.20204818.
31. Hoque, E., M. S. Islam, M. R. Amin, S. K. Das and D. K. Mitra (2020). "Adjusted Dynamics of COVID-19 Pandemic due to Herd Immunity in Bangladesh." medRxiv: 2020.2009.2003.20186957.
32. Hoque, M. E. (2020). "An early estimation of the number of affected people in South Asia due to Covid-19 pandemic using susceptible, infected and recover model." International Journal of Modern Physics C**31**(10).
33. Hridoy, A.-E. E., M. Naim, E. Alam, N. U. Emon, I. H. Tipo, S. M. S. H. Tusher, S. Alam and M. S. Islam (2020). "Estimation of Effective Reproduction Number for COVID-19 in Bangladesh and its districts." medRxiv: 2020.2008.2004.20168351.
34. Hridoy, A.-E. E., M. Naim, N. U. Emon, I. H. Tipo, S. Alam, A. Al Mamun and M. S. Islam (2020). "Forecasting COVID-19 Dynamics and Endpoint in Bangladesh: A Data-driven Approach." medRxiv: 2020.2006.2026.20140905.
35. Huang, J., X. Liu, L. Zhang, K. Yang, Y. Chen, Z. Huang, C. Liu, X. Lian and D. Wang (2020). "The amplified second outbreaks of global COVID-19 pandemic." medRxiv: 2020.2007.2015.20154161.
36. Islam, A. R. M. T., M. Hasanuzzaman, M. A. K. Azad, R. Salam, F. Z. Toshi, M. S. I. Khan, G. M. M. Alam and S. M. Ibrahim (2020). "Effect of meteorological factors on COVID-19 cases in Bangladesh." Environment Development and Sustainability.
37. Islam, A. R. M. T., M. Hasanuzzaman, M. Shammi, R. Salam, M. Bodrud-Doza, M. M. Rahman, M. A. Mannan and S. Huq (2020). "Are meteorological factors enhancing COVID-19 transmission in Bangladesh? Novel findings from a compound Poisson generalized linear modeling approach." Environmental Science and Pollution Research.
38. Islam, M. S., M. E. Hoque and M. R. Amin (2020). "Integration of Kalman filter in the epidemiological model: a robust approach to predict COVID-19 outbreak in Bangladesh." medRxiv: 2020.2010.2014.20212878.
39. Kannoth, S., S. Kandula and J. Shaman (2021). "The Association between Early Country-level Testing Capacity and Later COVID-19 Mortality Outcomes." medRxiv: 2021.2001.2018.21249998.
40. Karimuzzaman, M., S. Afroz, M. M. Hossain and A. Rahman (2020). "Forecasting the COVID-19 Pandemic with Climate Variables for Top Five Burdening and Three South Asian Countries." medRxiv: 2020.2005.2012.20099044.
41. Khatua, D., D. Guha, S. Kar, A. De and E. Samanta (2020). "Analysis of SIR-Network Model on COVID-19 with respect to its impact on West Bengal in India." medRxiv: 2020.2008.2005.20169037.
42. Kriston, L. (2020). "Predictive Accuracy of a Hierarchical Logistic Model of Cumulative SARS-CoV-2 Case Growth." medRxiv: 2020.2006.2015.20130989.
43. Kundu, L. R., M. Z. Ferdous, U. S. Islam and M. Sultana (2020). "Forecasting the spread of COVID-19 pandemic in Bangladesh using ARIMA model." medRxiv: 2020.2010.2022.20217414.
44. Levitt, M., A. Scaiewicz and F. Zonta (2020). "Predicting the Trajectory of Any COVID19 Epidemic From the Best Straight Line." medRxiv: 2020.2006.2026.20140814.

45. Li, M., Z. Zhang, S. Jiang, Q. Liu, C. Chen, Y. Zhang and X. Wang (2020). "Predicting the epidemic trend of COVID-19 in China and across the world using the machine learning approach." medRxiv: 2020.2003.2018.20038117.
46. Li, Q., T. Bedi, G. Xiao and Y. Xie (2020). "Evaluating Short-term Forecast among Different Epidemiological Models under a Bayesian Framework."medRxiv: 2020.2010.2011.20210971.
47. Li, S. (2020). "The Relationship between Weekly Periodicity and COVID-19 Progression." medRxiv: 2020.2011.2024.20238295.
48. Liu, Q., Z. Liu, J. Zhu, Y. Zhu, D. Li, Z. Gao, L. Zhou, Y. Tang, X. Zhang, J. Yang and Q. Wang (2020). "Assessing the Global Tendency of COVID-19 Outbreak." medRxiv: 2020.2003.2018.20038224.
49. Louca, S. (2020). "COVID-19 prevalence in 161 countries and over time." medRxiv: 2020.2012.2001.20241539.
50. Macías-Ordóñez, R. and D. Villaseñor-Amador (2020). "The misleading illusion of COVID-19 confirmed case data: alternative estimates and a monitoring tool." medRxiv: 2020.2005.2020.20107516.
51. Mahmud, A. S., S. Chowdhury, K. H. Sojib, A. Chowdhury, M. T. Quader, S. Paul, M. S. Saidy, R. Uddin, K. Engo-Monsen and C. O. Buckee (2020). "Participatory syndromic surveillance as a tool for tracking COVID-19 in Bangladesh." medRxiv: 2020.2008.2028.20183905.
52. Mahmud, R. and H. M. A. F. Patwari (2020). "Estimation of the Basic Reproduction Number of SARS-CoV-2 in Bangladesh Using Exponential Growth Method." medRxiv: 2020.2009.2029.20203885.
53. Masrur, A., M. Yu, W. Luo and A. Dewan (2020). "Space-Time Patterns, Change, and Propagation of COVID-19 Risk Relative to the Intervention Scenarios in Bangladesh." International Journal of Environmental Research & Public Health **17**(16): 14.
54. Mazumder, A., V. Bharadiya, P. Berry, M. Arora, M. Agarwal, M. Gupta, G. G. Parameswaran and P. Behera (2020). "Study of Epidemiological Characteristics and In-silico Analysis of the Effect of Interventions in the SARS-CoV-2 Epidemic in India." medRxiv: 2020.2004.2005.20053884.
55. Nabi, K. N. (2020). "FORECASTING COVID-19 PANDEMIC: A DATA-DRIVEN ANALYSIS." medRxiv: 2020.2005.2012.20099192.
56. Nabi, K. N., P. Kumar and V. S. Erturk (2020). "Projections and fractional dynamics of COVID-19 with optimal control analysis." medRxiv: 2020.2011.2017.20233031.
57. Neve, D., H. Patel and H. S. Dhiman (2020). "On Modeling of COVID-19 for the Indian Subcontinent using Polynomial and Supervised Learning Regression." medRxiv: 2020.2010.2014.20212563.
58. Noh, J. and G. Danuser (2020). "Estimation of the fraction of COVID-19 infected people in U.S. states and countries worldwide." medRxiv: 2020.2009.2026.20202382.
59. Notari, A. (2020). "Temperature dependence of COVID-19 transmission." medRxiv: 2020.2003.2026.20044529.
60. Ohi, A. Q., M. F. Mridha, M. M. Monowar and M. A. Hamid (2020). "Exploring optimal control of epidemic spread using reinforcement learning." Sci Rep**10**(1): 22106.
61. Pal, D., D. Ghosh, P. K. Santra and G. S. Mahapatra (2020). "Mathematical Analysis of a COVID-19 Epidemic Model by using Data Driven Epidemiological Parameters of Diseases Spread in India." medRxiv: 2020.2004.2025.20079111.
62. Paul, A., S. Chatterjee and N. Bairagi (2020). "Prediction on Covid-19 epidemic for different countries: Focusing on South Asia under various precautionary measures." medRxiv: 2020.2004.2008.20055095.
63. Rahaman Khan, M. H. and A. Hossain (2020). "Countries are Clustered but Number of Tests is not Vital to Predict Global COVID-19 Confirmed Cases: A Machine Learning Approach." medRxiv: 2020.2004.2024.20078238.
64. Rahman, M. M., A. Ahmed, K. M. Hossain, T. Haque and A. Hussain (2020). "Impact of control strategies on COVID-19 pandemic and the SIR model based forecasting in Bangladesh." medRxiv: 2020.2004.2019.20071415.
65. Roy, S., M. Saha, B. Dhar, P. Santa and R. Nasrin (2021). "Geospatial analysis of COVID-19 lockdown effects on air quality in the South and Southeast Asian region." Science and the Total Environment**756**.
66. Russell, T. W., N. Golding, J. Hellewell, S. Abbott, L. Wright, C. A. B. Pearson, K. van Zandvoort, C. I. Jarvis, H. Gibbs, Y. Liu, R. M. Eggo, W. J. Edmunds, A. J. Kucharski and C. C.-W. Grp (2020). "Reconstructing the early global dynamics of under-ascertained COVID-19 cases and infections."Bmc Medicine**18**(1).
67. Salvatore M, Basu D, Ray D, *et al* (2020). 'Comprehensive public health evaluation of lockdown as a non-pharmaceutical intervention on COVID-19 spread in India: national trends masking state-level variations" BMJ Open;10:e041778. doi: 10.1136/bmjopen-2020-041778
68. Sánchez-Romero, M., V. d. Lego, A. Prskawetz and B. L. Queiroz (2020). "How many lives can be saved? A global view on the impact of testing, herd immunity and demographics on COVID-19 fatality rates." medRxiv: 2020.2004.2029.20084400.
69. Shahidul Islam, M., J. Irana Ira, K. M. Ariful Kabir and M. Kamrujjaman (2020). "COVID-19 Epidemic Compartments model and Bangladesh." Preprints.

70. Shimul, S. N., M. Hussain, A. J. Faisel and S. A. Hamid (2020). "Impact of lock down relaxation on the COVID-19 epidemic trajectory in Bangladesh." medRxiv: 2020.2007.2020.20158527.
71. Siam, Z. S., M. Arifuzzaman, M. S. Ahmed, F. A. Khan, M. H. Rashid and M. S. Islam (2021). "Dynamics of COVID-19 transmission in Dhaka and Chittagong: Two business hubs of Bangladesh." Clinical Epidemiology and Global Health **10**: 100684.
72. Tembine, H. (2020). "COVID-19: A Data-Driven Mean-Field-Type Game Perspective." medRxiv: 2020.2007.2023.20160853.
73. Thomas, B. S. and N. A. Marks (2020). "Estimating the Case Fatality Ratio for COVID-19 using a Time-Shifted Distribution Analysis." medRxiv: 2020.2010.2025.20216671.
74. Truelove, S., O. Abrahim, C. Altare, S. A. Lauer, K. H. Grantz, A. S. Azman and P. Spiegel (2020). "The potential impact of COVID-19 in refugee camps in Bangladesh and beyond: A modeling study." Plos Medicine **17**(6).
75. Uddin, M. M., A. Akter, A. B. M. Khaleduzzaman, M. N. Sultana and T. Hemme (2021). "Application of the Farm Simulation Model approach on economic loss estimation due to Coronavirus (COVID-19) in Bangladesh dairy farms-strategies, options, and way forward." Tropical Animal Health and Production **53**(1).
76. Vilar, J. M. G. and L. Saiz (2020). "The evolving worldwide dynamic state of the COVID-19 outbreak." medRxiv: 2020.2011.2026.20239434.
77. Walker, P. G. T., C. Whittaker, O. J. Watson, M. Baguelin, P. Winskill, A. Hamlet, B. A. Djafaara, Z. Cucunubá, D. O. Mesa, W. Green, H. Thompson, S. Nagyagam, K. E. C. Ainslie, S. Bhatia, S. Bhatt, A. Boonyasiri, O. Boyd, N. F. Brazeau, L. Cattarino, G. Cuomo-Dannenburg, A. Dighe, C. A. Donnelly, I. Dorigatti, S. L. van Elsland, R. FitzJohn, H. Fu, K. Gaythorpe, L. Geidelberg, N. Grassly, D. Haw, S. Hayes, W. Hinsley, N. Imai, D. Jorgensen, E. Knock, D. Laydon, S. Mishra, G. Nedjati-Gilani, L. C. Okell, H. J. Unwin, R. Verity, M. Vollmer, C. E. Walters, H. Wang, Y. Wang, X. Xi, D. G. Lalloo, N. M. Ferguson and A. C. Ghani (2020).. "The impact of COVID-19 and strategies for mitigation and suppression in low- and middle-income countries." Science **369**: 413-422.

Fjelltopp
Harmonising Health Data

Annexe 2:

Stakeholder Interviews

COVID-19 in Bangladesh

Table of Contents

Aim......3
Method......3
Summary of Stakeholder Interviews......3
Access to Information (a2i)......5
Introduction......5
COVID-19 Hotline Data......5
COVID-19 Data Warehouse......5
COVID-19 Policy Making Dashboard......6
COVID-19 Public Dashboard......6
Telemedicine Platform......6
Reflections......7
Bill and Melinda Gates Foundation......7
Introduction......7
Funding Operations......8
Reflections......8
BRAC NGO, Health Section......8
Introduction......8
Monitoring staff health......8
COVID-19 Data Tree......9
Rumour Maps......9
Reflections......9
BRAC NGO, Technology for Development (T4D)......10
Introduction......10
BRAC Health Data Repository......10
Reflections......11

info@fjelltopp.org www.fjelltopp.org

Fjelltopp Ltd is a UK social enterprise, company limited by shares No. 11961922
Registered Office: 40 Blackburn Road, Padiham, Lancashire, BB12 8JZ

CMED....11
Introduction....11
Early Urban CST Surveillance Framework....11
Reflections....12
Directorate of General Health Services (DGHS) - Retired Member....12
Introduction....12
DGHS and Dhaka University COVID-19 Modelling....12
Reflections....13
Groupmappers....13
Introduction....13
Geospatial data....13
Reflections....14
Institute of Epidemiology, Disease Control and Research (IEDCR)....14
Introduction....14
Laboratory Data....15
Contact Tracing Data....15
Reflections....15
International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)....16
Introduction....16
Sero-prevalence surveys....16
Health and demographic surveillance datasets (HDS)....17
icddr,b data repository....17
Reflections....17
James P Grant School of Public Health, Brac University (JPGSPH)....18
Introduction....18
Arise: Health and Wellbeing in Slum Settlements....18
Reflections....18
United Nations Food and Agricultural Organisation (FAO)....19
Introduction....19
The UN Inter-agency Support Team (IST)....19
Urban Community Support Teams (CST) Work....20
Reflections....20
United Nations Children's Fund (UNICEF), Communications Section....21
Introduction....21
RCCE 4W Dashboard....21
uReport....21
Community Feedback Centres....22
Reflections....22
Vital Strategies....22
Introduction....22
Excess Mortality Analysis....23
Reflections....23

Aim

To accompany our review of related pre-print and published literature, we conducted a series of semi-structured interviews with a variety of stakeholders in the Bangladesh COVID-19 response. The aim of these interviews was to identify significant COVID-19 data collection, analysis and modelling efforts undertaken for the country. In particular this work differed from the literature review by identifying:

- Work that is unpublished or not widely available in pre-print form
- Recent progress to known projects
- Priority challenges being faced at this moment in time
- Political and human challenges to field

Method

Given the restrictive nature of the project's timeline and the intended use of the project's outputs, a formal qualitative study design was not implemented. Instead we put together a semi structured interview design which was reviewed by internal and external partners prior to starting the interviews. This helped us to structure our findings and form some parity of purpose to our many interviews, whilst also giving us a degree of flexibility to pursue interesting issues.

All interviews were conducted using video conferencing platforms (either Zoom, Microsoft Teams or Google Meet). Recordings were kept for internal note taking purposes only. Varying internet connections significantly impacted upon the fidelity of communication. Those in attendance at each interview were:

- Project lead Jonathan Berry
- Modelling lead Jessica Clark
- Between one and three individuals from the stakeholder's organisation
- Occasionally modelling advisor Prof Katie Hampson (University of Glasgow)
- Occasionally data management advisor Mikolaj Kundegorski (Fjelltopp)

The lead interviewers were new to working in Bangladesh, though they did have prior experience working in the public health sector for a number of other low and middle income countries.

Summary of Stakeholder Interviews

The table 1 below shows the list of stakeholders approached as part of the study. We then give a summary of what was learnt during each interview. For each stakeholder interviewed we provide: a brief introduction to the stakeholder; details concerning any data management, modelling or research efforts reported in the call; and some reflections concerning how the work of the stakeholder fits into the wider picture of the national COVID-19 response.

Stakeholder Interviews	
Roles of Individuals	**Organisation**
Policy Assistant	Access to Information (a2i)
Program Officers	Bill and Melinda Gates Foundation
Senior Director Associate Director (Health, Nutrition, Population) Head of Strategic Partnerships	BRAC Non Governmental Organisation
Head of Technology for Development (T4D)	BRAC University
Chairman and Founder	CMED
Retired Director General	Directorate of General Health Services (DGHS)
Founders	Groupmappers, founded from the Mahidol Oxford Tropical Medicine Research Unit
Principal Scientific Officer (PSO) and colleagues	Institute of Epidemiology, Disease Control and Research (IEDCR)
Senior Director of Maternal and Child Health	International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)
Senior Scientist	International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)
Professors	James P Grant School of Public Health (JPGSPH) Brac University
UN Interagency Support Team (IST) Lead	UN Food and Agricultural Organisation (FAO)
Member of Communications Section	United Nations Childrens Fund (UNICEF)
Deputy Director, Technical Implementation Advisor Bloomberg Data For Health Initiative Regional Deputy Director (Asia and Pacific)	Vital Strategies
Stakeholders Identified but not interviewed	
Stakeholder	**Connection**
UNICEF Social Policy Evaluation and Research (SPEAR)	Undertaking various population based research projects. SPEAR contacted us by email, but no interview took place.
Bangladesh Bureau of Statistics	Responsible for national geospatial data, the census and other population based research efforts.
Bangladesh Health Watch (BRAC University)	Publishes annual report on the state of health in Bangladesh
CDC Bangladesh	Reportedly funding sero-surveys in six metropolitan areas.
Child health research foundation (CHRF)	Dhakka research group collecting data on pediatrics

Table 1: Showing the stakeholders identified during the project

Access to Information (a2i)

Introduction

- a2i sits under the Prime Minister's Office and is tasked with "introducing citizen-centric public service innovation" as part of the government's Digital Bangladesh agenda.
- Anir Chowdhury leads the agency, but was unfortunately unable to attend our call; we met with a Policy Economist instead.

- The agency incorporates engineers, public health experts, epidemiologists, policy makers and economists, and has provided DGHS with direct technological support during the COVID-19 pandemic. It has played a key role in connecting the dots and repurposing existing solutions and services for COVID-19 management.

COVID-19 Hotline Data

- At the start of the pandemic two telephone hotlines (telephone numbers 333 and 16263) were introduced, providing advice to Bangladeshi citizens with concerns regarding COVID-19.
- The hotlines were very popular, seeing approximately 200000 calls a day early on in the pandemic. Interest has since dropped to 5000-6000 calls a day.
- The data collected through the hotlines include structured symptomatic data drawn from the telephone menu system used. Callers who suspect they have COVID are passed through a series of automated screening questions and their responses are recorded as part of the data set.
- The structured symptomatic data was used in a statistical model that helps to determine which of the callers received a COVID-19 test, as testing capacity was limited.

COVID-19 Data Warehouse

- A relational SQL database has been set up by a2i to store COVID-19 data from various different sources in one place.
- There are a large number of inputs reportedly sourced for the data warehouse including: DHIS2, Press Releases, IEDCR data, hotline data (see above), Urban and Rural Community Support Team (CST) data, laboratory data, contact tracing data, telemedicine data, vaccine data.
- Data is stored in the warehouse as a flat list of independent tables. The interviewee identified a need for more database maintenance capacity and data management capacity in curating the warehouse. No success concerning the integration of the different data sources could be reported.
- The data warehouse is reportedly used by a closed group of researchers and epidemiologists, named the "National Data Analytics Task Force" by the interviewee. Despite multiple follow ups, a2i has not identified who the members of this task force are.
- Access is made available to partners via a VPN and SQL prompt, therefore requiring some technical expertise to view the data. There is no documentation or metadata available, and the regulations around accessing the data do not appear to be transparent.

COVID-19 Policy Making Dashboard

- The agency has designed and maintains an interactive dashboard that visualises COVID data for the purposes of policy and decision making within the government. Approximately 220 policy makers reportedly have access to the dashboard, including the prime minister.

- The interviewee believed that the dashboard's simple design had been a key factor in its success with policy makers who lack expertise in data analysis and interpretation. The dashboard is described as being professionally presented in the local language with a large number of (albeit simple) visualisations of the data e.g. the daily case distribution.
- A slightly more complex method for calculating risk level and progress metrics at the district level was included. It was unclear how well this had been received by policy makers.
- Data for the dashboard was sourced through the COVID-19 warehouse from DHIS2, IEDCR and press releases.
- The dashboard is not real time, and it generally takes 7 days to get the final picture in the dashboard due to paper based data entry processes.

COVID-19 Public Dashboard

- In addition to the policy making dashboard a2i host a public facing dashboard providing visualisations of a select few key indicators.
- This dashboard can be viewed at corona.gov.bd.
- The data is also sourced through the COVID-19 warehouse described above and is also subject to a seven day data timeliness lag (this is not clearly indicated in the dashboard).

Telemedicine Platform

- A telemedicine platform developed by a2i was briefly discussed during the interview.
- A public call was made for doctors to download and register through an app, and then to provide limited consultations to patients via the app. It was described by the interviewee as an "Uber-style" platform for doctors.
- The app collects symptomatic data through the consultations it facilitates, which is pushed into the COVID-19 data warehouse.
- It was reported that 4000 doctors had registered with the platform. The screening process for selecting doctors based on their experience was not discussed.
- It was not made clear whether the symptomatic data was used for any purpose outside of the consultation.

Reflections

- a2i are leading an exciting programme of flagship digital innovation for the Bangladesh government. We applaud their efforts and believe more support could be given to help focus their work and yield more mature sustainable solutions.
- The interviewee identified the need for more data management, analysis, and modelling expertise to support their efforts, whilst also remarking that policy makers lacked the capacity to understand and trust advanced data analysis tools and modelling.
- We recognise the political success a2i have had in manually consolidating multiple data sources into a single SQL database. However, the project is clearly lacking: documentation and metadata, transparent and approved access protocols, versioning and audit trails for the data. A simple SQL database struggles to fulfil these needs for non-technical and technical users alike.
- We found out later, from the Bill and Melinda Gates Foundation, that a2i carries responsibility for data management to support the vaccination roll out. This includes a vaccination registration app developed by a2i, and a digital certification system. The agency is adapting work here by DIVOC (divoc.health)

Bill and Melinda Gates Foundation

Introduction

- The Bill and Melinda Gates Foundation (gatesfoundation.org) are a significant funding partner in development operations around the globe. Although not directly responsible for data collection efforts, they work with operational partners in-country on a variety of COVID-19 related projects.
- We spoke to a programme officer and a senior programme officer both working on public health programmes across South Asia.

Funding Operations

- a2i was their first engagement in the region (for more information see above). They funded work to understand where there are emerging areas of COVID-19 from the hotline data, and as that evolved, the design of the policy-making and public data dashboards. They also reported that a2i had been given charge of the vaccine roll out data management systems, and had developed a vaccine registration app incorporating digital certification. a2i are reportedly partnering with DIVOC (divoc.health) and adapting their work for this.
- Icddr,b were given funds for a few different epidemiological studies to understand: the impact of population density on COVID-19 transmission in Dhaka; mortality site (graveyard) surveillance; and wastewater surveillance in collaboration with University of Virgina and Imperial College London; sero-surveys in sex metropolitan areas in collaboration with CDC Bangladesh.

- FAO and BRAC are collaborating on the Community Support Teams (CST) programme: patients are screened for COVID-19 by community support teams and signposted to appropriate further testing and care.

Reflections

- This call raised a few studies that we were otherwise unaware of, including a2i's vaccination roll out responsibilities, and the sero-surveys supported by CDC, and the transmission with icddr,b.
- The interviewees flagged that early modelled projections for Bangladesh were rejected by the government, after which much of the COVID-19 modelling efforts were shut down. Upon questioning other stakeholders regarding this narrative, it seems that these projections were generated using a model from Imperial College London. Several stakeholders (FAO, and JPGSPH) have remarked that these early projections significantly overstated the impact of COVID-19 and have suggested further investigation into understanding why is necessary.

BRAC NGO, Health Section

Introduction

- BRAC is an international development organisation that was founded in Bangladesh in 1972. The organisation has since grown to have a presence in 13 different countries and over 90,000 employees.
- The organisation conducts a programme of research into public health across Bangladesh. Specifically during the COVID-19 pandemic there have been research efforts addressing the economic, social and public health impact of COVID-19 in Bangladesh.

Monitoring staff health

- BRAC has a large number of employees and has released some technology explicitly to monitor the health of their staff.
- A mobile app was released to their employees that collects data about the users symptoms and determines whether they are at risk of having contracted COVID-19. The app is another source of structured syndromic data.
- The app saw a lot of traffic during the first 3 months of the pandemic, but since then use has dropped significantly as people have become familiar with the symptoms.
- BRAC has also developed a telemedicine platform for internal use. The Mobile platform connects employees with BRAC's internal doctors and provides electronic tools for remote consultations to take place.
- At present the data from both apps are only used internally.

COVID-19 Data Tree

- The COVID-19 tree is a decision making business intelligence tool used by BRAC to showcase the work BRAC is doing across Bangladesh related to COVID-19. It is primarily used for fundraising purposes at present.
- It includes extensive syndromic data collected by BRAC health workers grouped to the smallest administrative area in Bangladesh. It also includes other data from all 17 programmes run by BRAC.
- The tool isn't public, but the interviewee offered access to the tool, suggesting it is easy easy to be given access if there is a clear purpose in place.

Rumour Maps

- The interviewee discussed a project funded by USAID and called the *COVID-19 Rumour Map*.
- Quantitative questions are filled in through face-to-face interviews in order to collect data that identifies what people are saying and believing about COVID-19 in Bangladesh.
- The project is mostly used by the communications section to develop BRAC's communication campaigns.
- Further to the COVID-19 rumour map, they have also launched a Vaccine Rumour map to identify what people believe about the vaccine. Example questions include: have you heard of corona vaccine? If so, do you think that the corona vaccine will reduce risk?
- Between 15 and 20 samples are collected from every district of Bangladesh every week.
- The data from the vaccine rumour map is presented in a dashboard that is publicly available at vaccine.brac.net.

Reflections

- Those interviewed could not identify any infectious disease modelling efforts taking place under BRAC NGO, but they expressed deep interest in pursuing collaboration to achieve this. They offered BRAC's service to collect data, if there was a clear proposal for a model put together.
- The use of CMED's app to conduct community surveillance was briefly discussed. For more information see the account of our interview with CMED below.
- The interviewees commented that whilst the government had collected a lot of data, they did not appear to have the time or resources to analyse the data.
- They are also concerned about external institutions using government published data without understanding the limitations of how it is collected. For instance they noted that testing in Bangladesh is only performed on those reporting symptoms. They noted that icddr,b's study to measure the transmission and mortality rate of COVID-19 in Bangladesh does not match the government published data. They also believe that the relief packages offered by the Government to those infected mean there are people who are actively trying to get infected and then tested. It is important that modellers and analysts have a nuanced understanding of the data and its limitations.

BRAC NGO, Technology for Development (T4D)

Introduction

- BRAC conducts a wide-ranging programme of research across the health sector in Bangladesh. The data from this research is reportedly not consolidated in one place at present.
- We met with the head of T4D at BRAC who has been tasked with the implementation of a central data repository to store all of BRAC's health data.

BRAC Health Data Repository

- The aim of the data repository is to provide a Business Intelligence tool that can visualise all of BRAC health's data. The interviewee recognised that much of BRAC's work is collected and analysed in silos, causing inefficiencies and replication of work.
- The repository will be focused on COVID-19 data during the pandemic, beginning with the CST programme data from Dhakaand Chittagong, other data will be brought in after March, including CST rural data.
- The primary use case would be for internal decision making within BRAC, though it is also envisaged the repository would help with collaboration and possibly export data to the government's DHIS2 instance.
- The repository is funded by a Microsoft Grant and will be implemented using Microsoft Technologies, including Power BI, Azure Cloud Infrastructure, and Microsoft SQL Server.

Reflections

- We have seen many data consolidation projects that are driven by a desire for "business intelligence" that, when scrutinised, perhaps seems a little unclear. We recognise the importance of clear use cases in a successful data consolidation effort. This project is in it's very early stages and such use cases may transpire.
- Through the brief interview we could not identify clear plans for catalogue and metadata management, flexible access management, system interoperability, and data audit trails, all of which will be important if the repository is to help facilitate internal and external collaboration.
- The interviewee recognised that Bangladesh had significantly improved it's work in digital health with a digital health strategy now in place, and that COVID-19 had made the sector more open to collaboration which he hoped would continue after the pandemic.

CMED

Introduction

- CMED is a private limited company in Bangladesh working on technology solutions for preventative healthcare.
- The company was founded by Dr. Khondaker A. Mamun and Dr. Farhana Sarker, and has now grown to a team of 65 people.
- CMED's mission is "to accurately assess the vitals of people's health over time, in the environments where they live, work and play so they can reduce health risk, live more healthy & productive lives. Consequently, CMED [minimizes] peoples suffering & the overall mortality rate from non-communicable diseases."

Early Urban CST Surveillance Framework

- Early in the Pandemic CMED launched a mobile based screening and contact tracing system to approximately 14000 community clinics. The CMED system has been used to identify suspected COVID-19 cases and then signpost them to appropriate further testing and care at a regional health facility. This system has been reportedly used as the Community Support Team surveillance framework for urban people.
- The system's primary aim is to screen patients for COVID-19 and signpost them to further health care. The system incorporates a mobile device app providing a questionnaire to guide consultations with patients who self report to clinics and also patients identified by Government workers on household visits.
- The app implements a screening protocol developed with reference to international guidelines during a consultative workshop co-ordinated by CMED in April 2020, and attended by many doctors and scientists.
- The symptomatic data collected from the screening process is then also reported back to DGHS in a dashboard. There are reportedly approximately two million records of data. The dashboard reports aggregated numbers, but does not provide more complex analysis of the information.
- The system has been developed in Java for Android devices and deployed on AWS infrastructure. It is entirely proprietary, meaning that only CMED staff can review and develop the inner workings of the system.

Reflections

- The interviewee identified "political and financial" constraints that were limiting the system and meant it could not be deployed with complete coverage across Bangladesh.
- CMED's framework appears to have been used in early CST efforts in an urban setting. However, FAO colleagues reported that CMED developed and rolled out the system without a contract. According to FAO (see section below), their work is now no longer used by the urban CST project moving forwards. FAO colleagues reported that CMED had developed and rolled out the system without contract in the hope of the Government being forced into adoption, but this simply didn't happen.
- Proprietary software solutions create vendor lock-in for important governmental programmes, leading to costs potentially spiralling out of control as the system is cemented at a national level. Proprietary software also

lacks the transparency and accountability that is so important in the public health sector where there are many stakeholders but only one "paying customer".

Directorate of General Health Services (DGHS) - Retired Member

Introduction

- DGHS is a governmental department and part of the Ministry of Health and Family Welfare. It is responsible for the provision of the nation's public health services.
- We spoke to a recently retired member of DGHS who gave insight into the operations of DGHS during the early part of the pandemic.
- Early in the pandemic DGHS looked at the WHO modelling portal that provides an online tool to create COVID-19 projections. They also received projections drawn from the Imperial model, but these projections were huge and the senior leadership of DGHS were "afraid". These projections appear to have been overstated and did not tally with the projections from the WHO portal and Dhaka University as discussed below.

DGHS and Dhaka University COVID-19 Modelling

- DGHS created a public health advisory group made up of public health experts - one for each of the 8 geographical divisions of Bangladesh. This public health advisory group worked with Dhaka University's Health Economics Unit, and some other international experts on modelling and projections.
- These projections of morbidity and mortality were reportedly communicated to the Prime Minister and contributed to policy decisions and implementation of health interventions by the government. They apparently especially helped to communicate the danger of international travel to the policy makers.
- The projections were provided on a voluntary basis by the University, which was identified as a limitation of the work.
- The projections were derived from two models; an SIR (susceptible, infected, recovered) model and a Gompertz curve fitting model. Both were fit to laboratory testing data from IEDCR. The SIR model framework appears to be based on the initial ICL model (i.e., citation 24 in Annexe 1, based on the authors personal site https://sites.google.com/site/shafiunihe/recent-work-on-covid-19), however, as there was little methodology provided alongside the reports that detail the model results, it is hard to tell exactly how the model was accessed or calibrated as the code was not publicly available at this point in time. The Gompertz model is a curve fitting exercise that predicted the peak of the outbreak would be later than the SIR model predicted. The report itself is quite reflective in the narrative, discussing issues around compliance through public holidays and the impact of a second wave.

Reflections

- This interview revealed that COVID-19 modelling efforts were referenced by policy makers at the top of the government. We were otherwise unaware of these particular modelling efforts. In general we have found very little modelling used in national policy making, which is why this interview was so significant.
- The interviewee recognised the importance of increasing modelling capacity in Bangladesh, not only for the purposes of COVID-19 response, but also for responding to outbreaks of other diseases such as Dengue.

Groupmappers

Introduction

- GroupMappers are a consortium of volunteers who collect and integrate geospatial data for communicable disease control in Bangladesh.
- GroupMappers is co-ordinated by the Mahidol-Oxford Tropical Medicine Research Unit (MORU) and comprises volunteer members with expertise in Geographic Information Systems (GIS) from various institutions across Bangladesh including the Department of Disease Control DGHS in Bangladesh.
- The idea was born from a project to provide modelling and analytics for Malaria across Bangladesh. MORU were worried that the quality of the modelling was poor because the quality of the geospatial data was poor.

Geospatial data

- The basic geospatial data is published by the Bangladesh Bureau of Statistics (BBS) with each census. The census only takes place once every 10 years, and in between each census geospatial data can become significantly out of date.
- Groupmappers have been working since 2017 to update the geospatial data through volunteer activities and crowd-funded programmes. The next census is due to take place this year 2021 but may be delayed due to COVID-19.
- Every city corporation keeps a record of their own data. This information is not available from some central source and must be manually requested as a hard copy map from every individual city corporation.
- This hard copy map was requested from each city corporation, annotated, digitised and and integrated with the BBS data. This was a large manual effort and the project's success lies in the distributed support received from a large number of volunteers.
- The resulting SHP file storing the data has not gone through the necessary procedures to be published as an official government approved data source. For this reason the data is not currently in the public domain, even though the intention is to make it open access.

- GroupMappers are working with a2i and the outputs are used by the government of Bangladesh.

Reflections

- This appears to be an effective and exciting approach to solving an important problem that will impact any subnational infectious disease modelling effort in Bangladesh. We wonder whether this crowd-resourcing approach could be used to improve the quality of other data streams as well. Geospatial data is particularly suited to this approach since it is not generally deemed to be sensitive in nature, unlike health data.
- It is a shame that the work is not in the public domain, however it has been made available to collaborators working with a2i on modelling. Our FAO colleagues have seen and reviewed the geodata, and further details are available in the accompanying annex listing known data sources.
- The interviewee noted the challenges faced by governments who lack internal modelling capacity. He reported that in Thailand a consortium of local and international academic institutions collaborated with the government to deliver modelled projections. Where there was consensus between the institutions, the government was able to trust the outputs and allow them to influence policy making.

Institute of Epidemiology, Disease Control and Research (IEDCR)

Introduction

- IEDCR is a governmental organisation that sits under DGHS and has government granted authority to coordinate disease surveillance and outbreak response.
- It was established in 1976 through a bill approved in the Parliament which called for the establishment of an institute for epidemiological and communicable disease research as well as functioning of disease control programs mainly in the form of parasitic and entomological containment of vector borne diseases through application of epidemiological principles.
- During the COVID-19 pandemic they provided daily press briefings and, for the period of March-June 2020, they were directly responsible for the national data reporting. It is understood that later in the pandemic DGHS took over responsibility for this.
- IEDCR manages the government's laboratories and is responsible for the government's contact tracing programme. They have also coordinated the quarantining of 312 Bangladeshi citizens after travelling back from Wuhan.

Laboratory Data

- IEDCR has an electronic system to facilitate efficient testing for COVID-19 and dissemination of test results. Unfortunately we did not discuss in detail the nature of this system.
- IEDCR has concerns about data completeness and timeliness. They reported that there is a 4-5 day delay in getting laboratory results through the system.

- They were happy with the way they managed to repurpose existing laboratory testing expertise to COVID-19.

Contact Tracing Data

- IEDCR has staff at the district level to support contact tracing. There is also a collaboration with other ministries and with a mobile phone based contact tracing framework.
- Contact tracing takes place by telephone. Information is gathered in excel spreadsheets by the district level staff and emailed to a central contact point who manually aggregates the data.
- The only currently identified used for the contact tracing data is to identify at-risk individuals.
- IEDCR's efforts are limited to points of contact within households and does not have full coverage (as would be expected). An actual estimation of coverage was not given.
- Outbreak investigation officers are also supporting the contact tracing efforts.

Reflections

- IEDCR reported that they are sitting on a lot of data right now, but lack the capacity to undertake effective analysis of that data. They want to begin modelling with the data and have worked with some Universities on this (including BRAC) but there has not been much progress. They have a key desire to build modelling capacity within Bangladesh institutions.
- The challenge was that isolated modelling work by partner institutions could not guide government policy decisions. The government needed to have a sense of ownership over the modelling process, understanding the data that goes in and how the various parameters of the models had been configured. This explains why the a2i policy making dashboard is comparatively so simple in analytical approach.
- They also want to provide training on the "data to policy process" for policy makers in Bangladesh. They believe that because policy makers have limited capacity in data analysis, they are not getting the most from their data during decision making processes.
- IEDCR believe they had some real success influencing policy during the COVID response. They reported that the prime minister's office and the government ministries have really listened to and responded to IEDCRs suggestions during the pandemic.
- FAO colleagues have commented during their interview that the IEDCR laboratory test results management system needs further investment and currently involves a lot of manual work.
- This interview suggests there is a lack of modelling being used by the government to guide the national response to COVID-19.

International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)

Introduction

- icddr,b is a research institute based in Dhakka that is not affiliated with the government. It aims to solve public health problems faced by low-and-middle-income countries through scientific research – including laboratory-based, clinical, epidemiological and health systems research.
- We met with multiple staff over multiple interviews. They have a wide ranging research programme that we only touch upon here. We hope we have identified the work most relevant to COVID-19 and modelling.

Sero-prevalence surveys

- Details were given concerning a large study looking at COVID-19 sero-prevelance in Dhaka and Chittagong, within and without slum districts, for children aged 10+ and adults.
- The 3000 participants provided samples of blood and hair, and a questionnaire was used to collect other data, including: underlying health conditions, BMI, symptomatic data, vaccination data, indicators of impact upon mental health, and more.
- The survey teams performed household visits to gather participation consent and to schedule a separate visit for data and sample collection. There were no difficulties in getting blood samples and questionnaire data, but hair samples were much harder due to the association of hair with local superstitious practises.
- The blood samples were tested for COVID-19 as well as nutritional markers and other common viral pathogens. The hair samples were tested in order to assess stress levels.
- The data collection has completed and the laboratory assays are underway. It is hoped that somewhere between 4-8 papers will be written up from the work. Once the work is published, icddr,b will be happy to share the data more widely.
- It was hypothesised by the interviewee that COVID-19 mortality in slum areas is low because of the distribution of ages. Slums reportedly have very low numbers of elderly people and young children.

Health and demographic surveillance datasets (HDS)

- icddr,b curate two large health and demographic surveillance datasets; one for urban Dhaka and another for rural Matlab. The urban HDS covers approximately 125000 people, whilst the rural HDS covers approximately 220000 people.
- A team of approximately 20 individuals are responsible for collecting the demographic and non-communicable disease data from the regions. The regions under surveillance are mapped in detail.
- The HDS is a tool for use in research, providing a cloud-hosted interface for the dataset. Anyone is welcome to collaborate with icddr,b and make use of the dataset. For example, the data was used in the Dhaka part of the sero-prevalence survey discussed above. This meant that undertaking the work in Dhaka was quicker than undertaking the work in Chittagong, as geospatial and preliminary population data was already available.

icddr,b data repository

- For a summary list of research efforts related to COVID-19 see the accompanying Annexe 3 listing known data sources and data collection efforts.
- As research projects are finished in icddr,b data is submitted to a central data repository for reference and long term storage.
- This repository takes the form of a share drive where any excel files, SPSS files or other data/analysis files relating to research are organised under a simple folder structure.
- There are clear data sharing agreements and protocols in place, to be signed if you wish to access the data repository.
- No public cataloguing of the data or research exists and you must first sign the agreement before it is possible to see the scope of research and data that icddr,s can make available.

Reflections

- The breadth, scope and quality of the work conducted by icddr,b was impressive. We were surprised that their work did not appear when reviewing literature related to Bangladesh COVID-19 modelling. We believe icddr,b could be an excellent and largely unused source of data for further modelling efforts.

- A detailed list of COVID-19 research efforts conducted by icddr,b is available in the accompanying Annexe 3 on data sources.

- Staff at icddr,b reflected that it would be good to see more modelling capacity available within the country, especially within the government, in order to draw more value from the wealth of data that is being collected by IEDCR. There was even a direct suggestion from an interviewee to pursue a collaboration between UK universities and icddr,b in this regard.

- It was excellent that they could immediately share a data sharing agreement and a protocol to access their data repository. This is a model that could be replicated by other institutions.

James P Grant School of Public Health, Brac University (JPGSPH)

Introduction

- James P Grant School of Public Health was founded by BRAC, icddr,b and BRAC University in 2004 to address the unmet public health challenges of the Developing World.

- The school has conducted a wide ranging programme of research concerning COVID-19 in Bangladesh, including it's impact upon: slum areas, Rohinga refugee camps, adolescents, sex workers, LGBTQ populations and more. Much of their COVID-19 research is documented and reported on their website covid-bracjpgsph.org.

- Much of the work reported by the interviewees appeared to be qualitative, and so not directly useful in modelling. Details were provided during the interview of just one particularly significant example of the school's research.

Arise: Health and Wellbeing in Slum Settlements

- This is a large, ongoing, multi-institution collaborative research project taking place over a period of 5 years. The qualitative study is an in-depth nuanced study of the lives of the most vulnerable Bangladeshi citizens over a long period of time. It offers insight into the fluidity of poverty, and how residents of the slum areas cope with and manage disruption such as COVID-19.
- The study began prior to the pandemic. The questioning therefore changed when the COVID-19 pandemic began, and all interviews are now held online instead of in the field.
- Semi-structured interviews were used to collect the data, with all interviews recorded, transcribed, coded and analysed.
- The data from the project is stored in the school's data management system. This system appears to be locked down and only accessible to members of the school. They could not point us to a catalogue of data stored in the system. The interviewees said that they were open to a meaningful partnership but that any collaboration requiring data access would have to be arranged in conversation with the donors who co-own the data.

Reflections

- The interviewees recognised that the health system has grown a lot in recent years. The development of IT capacity and the work of a2i was applauded.
- They recognised that it is hard to acquire data and collaborate because everyone is operating in silos. Very little research collaboration appears to take place, with the exception of a few very large national-level surveys.
- Like icddr,b they reported having a central data management system but no public facing catalogue or clear protocol for encouraging collaboration and data sharing. As with almost all interviewed stakeholders, there was no sense of engagement with the value of open data in the public domain.
- Multiple other stakeholders indicated during their interviews that JPGSPH had undertaken some modelling efforts, although these efforts weren't raised by JPGSPH during their interview. Upon following up with the interviewees regarding the work we were informed that they aren't able discuss the efforts with us, stating that one *"didn't match the numbers predicted (much lower case fatalities than what was predicted) like most of the predictions done by epidemiologists"* and the other is only shared with *'Govt advisors and remains an internal document'*. Much could be learned by reviewing this work in detail.

United Nations Food and Agricultural Organisation (FAO)

Introduction

- FAO is a specialist agency of the United Nations that leads international efforts to defeat hunger and improve nutrition and food security across the globe.

- The Bangladesh office is based in Dhakka was established in 1978 to support FAO's efforts in a region where some 27 % of the population (according to their website) are under-nourished by FAO's definition.

- FAO have formed an integral part of the UN's COVID-19 response in the country.

The UN Inter-agency Support Team (IST)

- FAO co-ordinates the UN IST which is responsible for leading the UN operational work. The IST has been particularly interested in facilitating collaboration and integration between the many partners operating in Bangladesh. We lay out here some of the challenges IST have faced through their work.

- The interviewee criticised a data "hoarding mentality" across the sector in Bangladesh, whereby partners used data access as political leverage for getting ahead of the competition. It is believed that this has stifled the potential analytical work.

- It was recognised that there was no technical framework or vision for cataloging data sources and research efforts, and also no transparent protocols for facilitating data sharing. Leadership from the government was needed concerning cross-institutional collaboration.

- DGHS and IEDRC reportedly have not integrated their systems very well prior to the pandemic. During the early stages of the pandemic, results were being shared but not the data itself. The interviewee recognised that a2i had helped to somewhat correct this, but there is much more work to be done.

- The interviewee highlighted conflicts of interests between consortium members in terms of their work towards inter-agency collaboration, whilst also wanting to drive the success of their own organizations portfolio of work. Concerns were raised about lack of transparency between partners and lack of coordination between funders, which is critical to the nature of such a complex partnership.

- Historically laboratory testing has been centralised under IEDCR, but COVID-19 put so much pressure upon available testing capacity that there was open disagreement between the director general of DGHS and IEDCR concerning the expansion of testing capacity beyond the centralised facility. This happened, and laboratories were opened across the country, but these laboratories reportedly struggled from a bio-safety perspective. Most of the testing remained in Dhaka and there is a need for a better system for dissemination of test results.

Urban Community Support Teams (CST) Work

- The CST initiative is health intervention co-ordinated by an inter-agency collaboration to strengthen the Bangladesh preparedness and response plan for COVID-19.

- Each CST is made up of health workers and volunteers who conduct household visits in order to identify potential virus fighters (PVFs) and screen them for COVID-19 symptoms. If the individuals are identified as verified virus fighters (VVFs), the team then facilitates further medical help and communicates recommended approaches to community transmission of the virus.

- The project is already active and between June 2020 and January 2021, CSTs visited 1,825,424 households across Dhaka, screening 207,663 PVFs, of which 54,508 were identified as VVFs.
- A dedicated mobile app has been developed to support household screening and vulnerability assessment by the CSTs. The CST-dedicated telemedicine system was set up by a2i in coordination with DGHS with technical support from FAO and UNFPA, and provides toll free numbers, a hotline for supporting VVFs, and a separate hotline for supporting women of reproductive age for any sexual and reproductive health or gender-based violence issues.
- Due to the planned vaccination rollout, a second phase of the programme began in January 2021, with a focus on identifying and protecting vulnerable individuals at higher risk of developing severe disease.
- Data from this project is already used in ongoing modelling efforts discussed in the accompanying literature review annex.

Reflections

- The CST work is divided into multiple projects, with BRAC NGO leading rural CST work and Save the Children also driving another implementation. It is an example of a large inter-agency collaboration.
- The interviewee also told us that Imperial College modelling was rejected early in the pandemic, with modelling from local universities given more attention instead. The Imperial College results have since proven plausible for the UK and the US, specifically as counterfactual scenarios in the absence of lockdowns and NPIs. It is unclear whether the modeling was understood in Bangladesh to reflect worst case scenarios without either NPIs or individual-level behaviour change. Moreover, these estimates applied to Bangladesh would overestimate mortality if case fatality rates were not adjusted for younger demographics. That withstanding the mortality burden of covid-19 in many LMICs (particularly in sub-saharan Africa and Asia) has been lower than model predictions and this remains unexplained. It was suggested that a key research priority should be addressing why severity was lower than originally predicted in Bangladesh. An early seroprevalence study from icddr,b found a very high reproduction rate R of over 3 and subsequent serological surveys also suggest a high case load with low mortality (i.e., >50% positivity). There is consequently a need to reconcile modeling predictions with data, to understand the extent of discrepancies. This process may also help to bring clarity about the purpose of models and their limitations, and likewise limitations of different data streams.
- This interview provided clarity on a number of narratives that were previously unclear to our team, including the reception of Imperial College modelling results, the challenges facing inter-agency collaboration, and the data management challenges faced by the country.

United Nations Children’s Fund (UNICEF), Communications Section

Introduction

- The Bangladesh government and UNICEF are co-leading the Risk Communication and Community Engagement (RCCE) pillar from the Bangladesh Preparedness and Response Plan.

- We spoke with a member of UNICEF communications section, who was able to present various sources of data on efforts concerning the nation's RCCE response.
- The section of UNICEF called SPEAR (Social Policy Evaluation and Research) conducts various population based studies collecting data on social behaviour and policy. Despite multiple attempts to reach out to the team, we were unable to make contact.

RCCE 4W Dashboard

- The term 4W refers to the four questions: who, what, where and when? It is a common principle in business intelligence and data dashboard design. This project aims to report these four pieces of information for all known RCCE efforts in Bangladesh.
- There are separate dashboards for national level efforts and subnational efforts.
- Each new record in the dataset reflects a different RCCE effort. The information is aggregated and analysed in a quantitative manner through the dashboard.
- The simple dashboard is used by RCCE staff prior to forming new projects. It helps them identify gaps in existing RCCE work and avoid overlap and duplication of efforts. This should create synergy and coherence across RCCE operations.
- Data is sourced through the submission of a google form. They have had challenges with data completeness as partners do not understand the efficacy of the project and can be reluctant to submit the forms.

uReport

- uReport engages with young people across Bangladesh on a variety of social issues. It provides feedback from the community on a variety of RCCE matters, enabling them to create accountability to the affected population.
- uReport provides a mobile app which is downloaded by young people across Bangladesh. The app provides forms to collect data on social opinion and practise e.g. Do you wear a mask and why?
- There are over 4000 young people engaged with uReport across Bangladesh. The large user base was already engaged prior to the pandemic and has proved a valuable means of acquiring feedback on RCCE matters.
- It's important to recognise that the tool is limited by its sample of participants, which is made up exclusively of self selecting, self reporting, young people.

Community Feedback Centres

- Prior to the pandemic, UNICEF was involved in setting up community feedback centres to collect reports of health, violence, water, sanitation and hygiene related issues from key areas in person.

- One such centre has been set up in Rohingya Refugee camp at Cox's Bazar, and a detailed case study is available from the UNICEF Bangladesh office.
- The centres have provided further insight into the impact of COVID-19 on their communities.
- The staff of these centres fill in quantitative questionnaires on mobile tablet computers. This quantitative data concerning the reported issues are submitted to central servers where the data is aggregated, stored and disseminated.

Reflections

- It seems that UNICEF holds quite a bit of data that might be considered co-variate information, however the incorporation of such data into modelling is probably not feasible at this stage for Bangladesh.
- This was our first interview and provided valuable feedback for the way in which our interviews were conducted.

Vital Strategies

Introduction

- Vital Strategies are an international NGO helping governments strengthen their public health systems to contend with important and difficult health challenges, especially concerning non-communicable diseases.
- The NGO builds scalable solutions to help facilitate data flow between the Ministry of Health and other government departments responsible for civil registration and national statistics.
- A key pillar of their work is "government ownership and leadership", as such they do not undertake data collection themselves, they are not the owners of any relevant data and they cannot share the data themselves. To access any data for their projects we should speak with DGHS.
- Their work in Bangladesh is funded by the Bloomberg Foundation.

Excess Mortality Analysis

- Vital strategies provide an excel tool that the country can use to compare their mortality data over time. The tool uses mortality datasets for each year and provides some averages with confidence intervals and an assessment of statistical significance in differences occurring over time. The tool can thereby give some indication of excess mortality during the cOVID-19 pandemic.
- Simplicity of the tool is its strength - the solution is replicable across many countries and comprehensible by government staff.

- Death registration completeness in Bangladesh is very low. The interviewee gave an estimate of 10%. Even so, this is a large sample of people, which means you can usefully compare trends in mortality data over time providing that you account for any significant changes in policy or practise. This is a known limitation of the work.
- Mortality data is sourced from health facility data, HDS sites (see section on icddr,b above), the civil registrar and cemetery data.
- The inputs, outputs and excel tool are owned by DGHS and shared with a2i, though it has not been found in the a2i COVID-19 data warehouse. It is also shared with the cabinet division and the office of the registrar (which operates at a local government level independently of BBS).
- The interviewee did not identify any specific use-cases for the work.

Reflections

- It should be noted that a2i did not mention this effort when we met with them, nor have we found any evidence of the effort in their data warehouse. We only know about their work because it was reported during our interview with the Bill and Melinda Gates foundation. We are conscious that excess mortality analysis will be politically sensitive data.
- The excess mortality data could be used to calibrate modeling efforts. Specifically these data could be referred to in attempting to reconcile overestimates of covid-19 mortality. Seroprevalence data would provide an indicator of exposure and excess mortality estimates would provide an indicator of mortality. Together these could be used to estimate case fatality rates for a given locality. This would be valuable given the currently limited understanding of why impacts have not, as yet, been as severe as predicted.
- Whilst we recognise that simplicity can be valuable when working with LMICs, the limitations of this simplistic approach must be clearly communicated to the government and data users.

Fjelltopp

Harmonising Health Data

Annexe 3:

Existing Data

COVID-19 in Bangladesh

Table of Contents

List of COVID-19 related data sources identified through our work......3
Data sources used in modelling literature......6
Notes......8
Bibliography......14

info@fjelltopp.org www.fjelltopp.org

Fjelltopp Ltd is a UK social enterprise, company limited by shares No. 11961922
Registered Office: 40 Blackburn Road, Padiham, Lancashire, BB12 8JZ

List of COVID-19 related data sources identified through our work

Data source title	Data source description	Used in citation	Source	Notes
a2i corona_info data warehouse	Data warehouse hosting data from various sources		Privately held by a2i	1, 5
DGHS COVID-19 patient and lab data	Directorate of Health has a DHIS2 public health data warehouse that stores patient and laboratory data for COVID-19 test results		DHIS2, privately held by DGHS	2
Community symptom-based surveillance	The CST community surveillance program tracks symptoms and quarantine status of patients. Hosted by DGHS.		Privately held by a2i and DGHS	2
Mobility data	Telecom-based data about population mobility		Privately held by a2i	2
Compiled COVID-19 screening data	Screening data from several sources, from UNDP hotline, CMED self-screening app, CST program, other community programs		Privately held by a2i	
BBS Geodata	BBS (Bangladesh government statistics institute) provided geodata		[1]	3
Geomappers Geodata	Region and district geographic data with associated geometry, stored as shapefiles. These shapefiles have been curated by the crowd-resourced team called GroupMappers. It seems to be considered the most up-to-date source of geographic information at present in Bangladesh.		Privately held by a2i and government	2
COVID-19 hotline phone data	Symptoms data based on calls from the COVID-19 hotlines 333, 16263 and USSD. Data collected from telecommunications operators: Grameenphone, Banglalink, Robi, Teletalk, the Bangladesh Telecommunication Regulator.	[2]	Privately held by a2i	2
Facility register	DGHS maintained register of health facilities in Bangladesh		[3]	

The MOHFW Supply Chain Management Portal (SCMP)	Medical stock data maintained by Bangladesh Ministry of Health and Welfare		(4)	5
RT-PCR cross-sectional survey	Transmission Dynamics of COVID-19 in Dhaka. Survey by IEDCR and Icddr,b. Funded by BMGF and USAID		Privately held by IEDCR	
Mask wearing survey	UNICEF mask wearing survey		Privately held by UNICEF	
Icddr,b data repository	Sharepoint containing excel data files SPSS files and other analysis files		Privately held by icddr,b	4
GISAID genomic data	Date-stamped SARS-CoV-2 genome sequences and associated metadata (usually very little resolution beyond country)		(5)	
John-Hopkins University COVID-19 Dashboard Database	Global Johns Hopkins University (JHU) Center for Systems Science and Engineering (CSSE) COVID-19 dashboard, provides e.g. death data on national level	(6,7)	(8)	
Contact matrices	Social contact matrix analysis. Does not include Bangladesh specific data.		(9)	
ECDC	European Centre for Disease Prevention and Control provides e.g. country-level death figures	(10–12)	(13)	
RCCE 4W Dashboard	UNICEF hosted dashboard reporting on risk communications and community engagement efforts in Bangladesh		Privately held by UNICEF	
IECDR	Bangladesh Institute of Epidemiology, Disease Control and Research are responsible for laboratory testing and contact tracing in Bangladesh. They publish the number of laboratory confirmed COVID-19 cases through a public dashboard. This is the most commonly used data for COVID-19 modelling in Bangladesh.	(2,6,14–16)	(17)	
Socioeconomic Data and Application Center	Focusing on human interactions in the environment, SEDAC has as its mission to develop and operate applications that support the integration of socioeconomic and earth science data and to serve as an "Information Gateway" between earth sciences and social sciences.	(6)	(18)	

Bangladesh Meteorological Department	Bangladesh Meteorological Department (BMD) is the national meteorological organization of Bangladesh, working under the Ministry of Defense of the Government of Bangladesh.They make various data sources available through their website.	(14)	(19)	
timeanddate.com	Time information repository maintained by Time and Date AS, a Norwegian private enterprise	(14)	(20)	
LandScan™ Population dataset	Oak Ridge National Laboratory data for global population distribution data	(16)	(21)	
WHO COVID-19 Dashboard	The World Health Organization has published a dashboard reporting COVID-19 data.	(22)	(23)	
ACAPS COVID19 Government Measures Dataset	ACAPS is a non-profit information provider and a consortium of Norwegian Refugee Council, Save the Children and Mercy Corps. The COVID-19 Government Measures Dataset puts together all the measures implemented by governments worldwide in response to the Coronavirus pandemic. Data collection includes secondary data review.	(22)	(24)	
Oxford COVID-19 Government Response Tracker	The Oxford COVID-19 Government Response Tracker (OxCGRT) systematically collects information on several different common policy responses that governments have taken to respond to the pandemic on 18 indicators such as school closures and travel restrictions. It now has data from more than 180 countries.	(22)	(25)	
SQUIRE values and data used by the SQUIRE team	SQUIRE modeling team age-structured SEIR model data	(26)	(27)	
Worldpop	Open access spatial demographic datasets built using transparent approaches.	(2)	(28)	
Worldbank	The World Bank's open data project provides access to their global development data.	(29)	(30)	
Worldometers	Open access live world statistics on population, government and economics, society and media, environment, food, water, energy and health.	(12)	(31)	
HumData	Humanitarian Data Exchange: Various data types related to humanitarian and international development efforts.	(11)	(32)	
Our world in data	Data repository maintained by the Global Change Data Lab, a UK based charity.	(33)	(34)	
UNICEF SPEAR data sets	Ongoing and completed Social Policy Evaluation and Research from UNICEF		Privately held by UNICEF	6

Data sources used in modelling literature

Title	Authors	Reference	Data
Adjusted Dynamics of COVID-19 Pandemic due to Herd Immunity in Bangladesh	Hoque, E., M. S. Islam et al. (2020)	(6)	IEDCR, Socioeconomic Data and Application Center, John-Hopkins University Database
Effect of meteorological factors on COVID-19 cases in Bangladesh	Islam, A. R. M. T. et al. (2020)	(14)	Bangladesh Meteorological Department, IEDCR, www.timeanddate.com
Estimation of Effective Reproduction Number for COVID-19 in Bangladesh and its districts	Hridoy, A.-E. E. et al. (2020)	(15)	IEDCR, DGHS.
Participatory syndromic surveillance as a tool for tracking COVID-19 in Bangladesh	Mahmud, A. S. et al. (2020)	(2)	worldpop, DGHS, IEDCR, COVID-19 hotline phone data
Space-Time Patterns, Change, and Propagation of COVID-19 Risk Relative to the Intervention Scenarios in Bangladesh	Masrur, A. et al. (2020)	(16)	LandScan™ Population dataset, IEDCR
The impact of COVID-19 and strategies for mitigation and suppression in low- and middle-income countries	Walker, P. G. T. et al. (2020)	(22)	WHO COVID-19 Dashboard, ACAPS COVID19 Government Measures Dataset, Oxford COVID-19 Government Response Tracker
COVID-19 prevalence in 161 countries and over time	Louca, S. (2020)	(35)	Seroprevalence data not from Bangladesh
Modelling interventions to control COVID-19 outbreaks in a refugee camp	Gilman, R. T. et al.(2020)	(36)	Data not from Bangladesh
The benefits and costs of social distancing in high- and low-income countries	Barnett-Howell, Z. et al. (2021)	(26)	SQUIRE values and data used by the SQUIRE team

Dynamic interventions to control COVID-19 pandemic: a multivariate prediction modelling study comparing 16 worldwide countries	Chowdhury, R. et al. (2020)	(29)	Worldbank
Reconstructing the early global dynamics of under-ascertained COVID-19 cases and infections	Russell, T. W. et al. (2020)	(10)	European Centre for Disease Prevention and Control
Simplified model of Covid-19 epidemic prognosis under quarantine and estimation of quarantine effectiveness	Džiugys, A. et al. (2020)	(11)	European Centre for Disease Prevention and Control, HumData
A new, simple method of describing the COVID-19 trajectory and dynamics in any country based on Johnson Cumulative Distribution Function fitting	Ćmiel, A. M. and B. Ćmiel (2020)	(33)	Our world in data
Evaluating Short-term Forecast among Different Epidemiological Models under a Bayesian Framework	Li, Q., T. Bedi, G. Xiao and Y. Xie (2020)	(7)	Johns Hopkins University Center for Systems Science and Engineering COVID-19 Data Repository
Global between-countries variance in SARS-CoV-2 mortality is driven by reported prevalence, age distribution, and case detection rate	Babačić, H. et al. (2020)	(12)	Worldometers, European Centre for Disease Prevention and Control, United Nations
How many lives can be saved? A global view on the impact of testing, herd immunity and demographics on COVID-19 fatality rates	Sánchez-Romero, M. et al. (2020)	(37)	UN Department of Economic and Social Affairs, Population Dynamics, World Population Prospects 2019.

Notes

1 Data warehouse hosting providing access to several other data sources

2 Available in a2i corona_infodata warehouse: Joint UN and Bangladeshi government initiative Access to information (a2i) is maintaining a data warehouse that is regularly updated using data from external data sources. The warehouse stores COVID-19 related data, some of which has already been used for analysis for academic and modeling purposes. It is also used as a data source for the National Data Analytics Task Force for policy making dashboards.

3 Bangladesh does not currently have a unified administrative district structure that is used by all institutions. Different data sets may use different administrative district breakdowns, and separate mapping tables are required to match regional data in several cases. The nation is divided into divisions, which are further divided into districts. The administrative levels below districts, however depend on the context. The legacy system of dividing districts into thanas is still sometimes used, and urban areas are divided into city corporations. Rural areas adhering to the reformed administrative district are divided into upazilas. Groupmappers has created unified data sets for Bangladesh geodata. This data also includes shape files.

4 Icddr,b have provided the list below of COVID-19 related research in their data repository

Sl. #	Project Title	PI	Division
1	Novel Corona virus disease 2019 (COVID-19) among patients admitted with severe acute respiratory infection to the selected hospitals in Bangladesh	Fahmida Chowdhury	IDD
2	Multicenter study on nosocomial transmission of SARS-CoV-2 virus	Sayera Banu	IDD
3	Ivermectin and doxycycline in combination or Ivermectin alone for the treatment of adult Bangladeshi patients hospitalized for COVID-19: a randomised, double-blind, placebo-controlled trial	Wasif Ali Khan	IDD
4	Detection of nCoronavirus, role of COVID-19 specific antibodies and determination of protection against infection	Firdausi Qadri	IDD

5	Clinical evaluation of a point-of-need diagnostic system for detection of COVID-19 towards its deployment at peripheral health care settings	Prakash Ghosh	NCSD
6	Optimising the treatment of COVID-19 adults with severe pneumonia and/or ARDS in Bangladesh using an adaptive version of locally made Bubble CPAP	Mohammod Jobayer Chisti	NCSD
7	Reconnaissance for COVID-19 and other emerging infectious diseases through a cell phone-based platform, Bangladesh	Abu Muhammad Zubair Akhtar	IDD
8	Effect of Influenza and SARS-COV-2 infection on recurrent cardiovascular disease in Bangladesh during COVID-19 pandemic	Abu Muhammad Zubair Akhtar	IDD
9	Mental health condition of doctors working frontline with COVID-19 patients in Bangladesh	Aminur Rahman Shaheen	HSPSD
10	Understanding Social and Health System Circumstances of COVID-19 Death Cases in Cities, Bangladesh Using Mixed Methods Approach	Aminur Rahman Shaheen	HSPSD
11	Evaluation of saliva as an alternate specimen for diagnosis of SARS-CoV-2	Mohammad Khaja Mafij Uddin	IDD
12	Status of SARS-CoV-2 Titres in Wastewater as Forecaster of the prevalence of SARS-CoV-2 infection before clinical diagnosis	Md. Mahbubur Rahman	IDD
13	Transmission Dynamics of COVID-19 in Bangladesh	Arifa Nazneen	IDD
14	Antigen study	Md. Ziaur Rahman	IDD
15	Post COVID Follow up study	Farzana Afroze	IDD
16	COVID testing at Mirpur TBSTC by Gene Xpert		IDD
17	Detection of airborne SARS-CoV-2 in Bangladeshi hospitals	Mohammed Badrul Amin	LSSD
18	Optimising the treatment of COVID-19 adults with severe pneumonia and/or ARDS in Bangladesh using an adaptive version of locally made Bubble CPAP	Mohammod Jobayer Chisti	NCSD

19	A study to assess the extent of food insecurity in urban and rural households of Bangladesh who are suffering from financial constraint during the COVID-19 pandemic and to develop a basic food package for ensuring food security at household level	Subhasish Das	NCSD
20	Serosurveillance of COVID-19 among slum and non-slum dwellers in Dhaka and Chattogram Cities and the impact of pandemic on mental health status	Rubhana Raqib	IDD
21	Rapid assessment of the readiness of public hospitals regarding COVID-19 management	Ahmed Ehsanur Rahman	MCHD
22	Tracking clinically suspect COVID-19 cases using existing national teleconsultation services in Bangladesh	Fatema Khatun	HSPSD
23	Investigating the inflammatory cytokines and Cytokine Storm among Bangladeshi patients with COVID-19: a prospective, observational study	Monira Sarmin	NCSD
24	COVID-19 prevalence during pregnancy and pregnancy outcomes in 8 low and middle income sites: A Global Network Study	S Masum Billah	MCHD
25	Baseline sero survey for malaria and COVID infection in Alikadam, Bandarban	Wasif Ali Khan	IDD
26	Estimating the excess mortality due to the COVID-19 pandemic in Dhaka (North and South) and Chittagong (Chattogram) City Corporation areas in Bangladesh by rapid mortality survey in graveyards, cemeteries and crematoriums, reporting and record-keeping system in the burial sites	Ahmed Ehsanur Rahman	MCHD
27	Rapid Mortality Household Survey to estimate the additional deaths due to COVID-19 among the population aged 40 years and above in an area of Chittagong district	Ahmed Ehsanur Rahman	MCHD
28	COVID-19: Sewage surveillance for SARS-CoV-2 in selected areas of Bangladesh	M Rashidul Haque	IDD
29	Rapid assessment of the impact of COVID-19 on the food environment and mental health, and feasibility of preventive measure among residents living in urban informal settlement in Dhaka city	Sabrina Rasheed, Daniel D Reidpath	HSPSD

30	Detection and genetic characterization of Coronaviruses among patients with febrile illness and history of drinking raw date palm sap in Bangladesh	Mohammed Ziaur Rahman	IDD
31	Risk factors, clinical characteristics and serological responses for COVID-19 infection among Health Workers, Bangladesh	Pritimoy Das	IDD
32	A multi-center, open-label, randomized parallel controlled evaluation on the efficacy and safety of BDB-001 injection in the treatment of progressive severe COVID-19 in phase II/III	M Rashidul Haque	IDD
33	Indirect effects of the COVID-19 pandemic on utilization of essential maternal newborn and child health services and experiences of communities and services providers	Ahmed Ehsanur Rahman	MCHD
34	Impact of COVID19 pandemic upon routine immunisation and maternal health care services in Bangladesh	Aminur Rahman Shaheen	HSPSD
35	Serosurveillance for SARS-COV-2 infection and health survey among health care workers through establishment of a health care worker cohort in Bangladesh	Mohammad Abdul Aleem	IDD
36	Rapid assessment of health systems impacts of COVID-19 on the urban slum dwellers in selected slums of Dhaka city	Shehrin Shaila Mahmood, Daniel D Reidpath	HSPSD
37	The experience of integrating telemedicine in the women’s maternal healthcare service during the COVID-19 pandemic situation in Bangladesh	Sabrina Jabeen	MCHD
38	Serosurveillance to improve estimates of burden and at-risk populations of cholera and COVID-19	Firdausi Qadri	IDD
39	A Randomized, Double-Blinded, Placebo Controlled Phase III Clinical Trial of SARS-CoV-2 Inactivated (Vero Cell) Vaccine, in Adults Aged 18 Years and Above	Firdausi Qadri	IDD
40	The prevalence and predictors of seropositivity to SARS-CoV-2 infection in a household sample of city corporation residents and an occupational sample of factory workers, with an embedded, concurrent study of the validity of rapid (serology) test	Daniel D Reidpath	HSPSD

41	Rapid antigen tests to diagnose COVID-19 in an urban community of Dhaka	Mohammad Shafiul Alam	IDD
42	A randomized, double-blind placebo-controlled trial to evaluate the safety and efficacy of a SARS-CoV-2 inactivated vaccine COVAXIN (BBV152) among healthcare workers in Bangladesh	M Khalequzzaman	IDD
43	Prediction of disease severity in young children presenting with acute febrile illness in resource-limited settings (Project A) and "Prognostication of Oxygen Requirement In Non-severe SARS-CoV-2 Infection (Project B)	Dinesh Mondal	NCSD
44	Integration of pulse-oximetry in the COVID-19 …	Ahmed Ehsanur Rahman	MCHD
45	COVID-19: Testing and tracing in Bangladesh	Md. Mustafizur Rahman	IDD
46	Estimates of the indirect effects of the coronavirus pandemic on maternal and child mortality and child nutrition in Bangladesh at sub-national level	Tazeen Tahsina	MCHD
47	Survey of sewage and other contaminated surface water sources for the presence of SARS-CoV-2 in and around Dhaka city	Md. Sirajul Islam	LSSD
48	Centralized Laboratory for Measurement of Immune Responses Elicited by SARS-CoV-2 Vaccine Candidates	Rubhana Raqib	IDD
49	COVID-19: Harnessing AMANHI Infrastructure to Assess Direct Impact on MNCH	Rubhana Raqib	IDD
50	Performance evaluation of GR kits with other Emergency Use Authorization (EUA) certified assays for detection of antibody against COVID-19	Rubhana Raqib	IDD
51	Evaluation of the maintenance of under-5 mortality Health System Delivered Evidence-Based Interventions during the COVID-19 pandemic in Bangladesh'	Fauzia Akhter Huda	MCHD

5 Based on stakeholder interviews we have identified that the a2i data warehouse includes but is not limited to the following data sources:

Data type	Description	Source
Geographic data	Administrative region catalogue	
Hotline call data	Data from the COVID-19 hotlines that identified suspected COVID-19 cases	16263, 333 and USSD hotlines
Hospital information	Hospital data with bed occupancy figures	
COVID-19 test data	Aggregated COVID-19 Tests and positive tests	
Population data	Populations by upazila	
Mobility data	Population mobility data based on telecom data	Teleoperators
Dhaka case data	Ward-level data and zoning system data for Dhaka	
Community surveillance data	Data from the CST program	CST program

6 The UNICEF Social Policy Evaluation and Research (SPEAR) section gave the below list of COVID-19 related research efforts below

Sl.	Title	Type of study	Participants	Disaggregation	Survey lead	Survey status
1	Rapid Assessment for Community Feedback on COVID-19 (Round I)	Online survey (self-participate)	Age 10 years or higher (N=21,892)	Sex, Age, Division, Location, Education, Occupation and Income	UNICEF	Completed
2	Rapid Assessment for Community Feedback on COVID-19 (Round II)	Online survey (self-participate)	Age 10 years or higher (N=835)	Sex, Age, Division, Location, Education and Occupation	UNICEF	Completed
3	Effect of coronavirus (COVID-19) on household expenditure, food security and employment	Online survey (self-participate)	Age 14 years or higher (N=529)	Sex, Age, Location, Occupation, HH size and Meal skipping	UNICEF	Completed
4	Effect of coronavirus (COVID-19) on women and children	Online survey (self-participate)	Age 14 years or higher (N=926)	Sex, Age, Division, Location, Education, Occupation,	UNICEF	Completed
5	Feedback collection from Children and Youth for UN Socioeconomic Recovery Programme	Online survey (self-participate)	Age 14 years or higher (N=580)	Sex, Age, Area, Division, Education and Occupation	UNICEF	Completed
6	Assessment of Effectiveness of Covid-19 Related Media Campaign	Observation	Number of places observed (N= 237); Number of people observed (18,772)	Area and Place of observations	UNICEF	Completed
7	Observation Survey: Mask Wearing in Bangladesh	Observation	Number of places observed (N= 7,308); Number of people observed (190,662)	Sex, Area, Division, Place of observation	UNICEF	Completed
8	COVID-19 Rapid Surveys, Round 2	Survey (jointly with world bank and DRI	Telephonic survey was done	Data analysis and report writing will be stared soon	World Bank	On going
9	Regional Survey - Random Digit Dialing Survey on Implications of COVID-19 in Bangladesh	Questionnaire was reviewed from SPEAR section	Survey will start soon.	n/a	UNICEF/World Bank	On going

Bibliography

1. Bangladesh Bureau of Statistics Geodata [Internet]. [cited 2021 Mar 16]. Available from: http://bbs.gov.bd/site/page/c025afd8-1773-484b-a15a-e5a31e5e27c5/-
2. Mahmud AS, Chowdhury S, Sojib KH, Chowdhury A, Quader MdT, Paul S, et al. Participatory syndromic surveillance as a tool for tracking COVID-19 in Bangladesh. medRxiv. 2020. p. 2020.08.28.20183905.
3. Bangladesh MOHFW Facility Registry [Internet]. [cited 2021 Mar 16]. Available from: http://facilityregistry.dghs.gov.bd/
4. SoftWorks. MOHFW Supply Chain Management Portal [Internet]. [cited 2021 Mar 16]. Available from: https://scmpbd.org/index.php/covid-19-dashboard
5. GISAID - Initiative [Internet]. [cited 2021 Mar 15]. Available from: https://www.gisaid.org/
6. Hoque E, Islam MdS, Amin MR, Das SK, Mitra DK. Adjusted Dynamics of COVID-19 Pandemic due to Herd Immunity in Bangladesh. medRxiv. 2020. p. 2020.09.03.20186957.
7. Li Q, Bedi T, Xiao G, Xie Y. Evaluating Short-term Forecast among Different Epidemiological Models under a Bayesian Framework. medRxiv. 2020. p. 2020.10.11.20210971.
8. John Hopkins University COVID-19 Dashboard [Internet]. Johns Hopkins Coronavirus Resource Center. [cited 2021 Mar 16]. Available from: https://coronavirus.jhu.edu/map.html
9. Prem K, van Zandvoort K, Klepac P, Eggo RM, Davies NG, Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, et al. Projecting contact matrices in 177 geographical regions: an update and comparison with empirical data for the COVID-19 era [Internet]. Epidemiology; 2020 Jul [cited 2021 Mar 16]. Available from: http://medrxiv.org/lookup/doi/10.1101/2020.07.22.20159772
10. Russell TW, Golding N, Hellewell J, Abbott S, Wright L, Pearson CAB, et al. Reconstructing the early global dynamics of under-ascertained COVID-19 cases and infections [Internet]. Vol. 18, Bmc Medicine. 2020. Available from: <Go to ISI>://WOS:000585907900001
11. Džiugys A, Bieliūnas M, Skarbalius G, Misiulis E, Navakas R. Simplified model of Covid-19 epidemic prognosis under quarantine and estimation of quarantine effectiveness. medRxiv. 2020. p. 2020.04.28.20083428.
12. Babačić H, Lehtiö J, Pernemalm M. Global between-countries variance in SARS-CoV-2 mortality is driven by reported prevalence, age distribution, and case detection rate. medRxiv. 2020. p. 2020.05.28.20114934.
13. ECDC COVID-19 Data Sources [Internet]. European Centre for Disease Prevention and Control. 2020 [cited 2021 Mar 16]. Available from: https://www.ecdc.europa.eu/en/publications-data/download-todays-data-geographic-distribution-covid-19-cases-worldwide
14. Islam ARMT, Hasanuzzaman M, Azad MAK, Salam R, Toshi FZ, Khan MSI, et al. Effect of meteorological factors on COVID-19 cases in Bangladesh [Internet]. Environment Development and Sustainability. 2020. Available from: <Go to ISI>://WOS:000576395400004
15. Hridoy A-EE, Naim M, Alam E, Emon NU, Tipo IH, Tusher SMdSH, et al. Estimation of Effective Reproduction Number for COVID-19 in Bangladesh and its districts. medRxiv. 2020. p. 2020.08.04.20168351.
16. Masrur A, Yu M, Luo W, Dewan A. Space-Time Patterns, Change, and Propagation of COVID-19 Risk Relative to the Intervention Scenarios in Bangladesh. Vol. 17, International Journal of Environmental Research & Public Health. 2020. p. 14.
17. DGHS and IEDCR COVID-19 Data Portal [Internet]. Bangladesh Directorate of General Health Services (DGHS). [cited 2021 Mar 16]. Available from: https://public.tableau.com/views/COVID-19_15848570974940/Confirmed-DB?:embed=y&:showVizHome=no&:host_url=https%3A%2F%2Fpublic.tableau.com%2F&:embed_code_version=3&:tabs=no&:toolbar=yes&:animate_transition=yes&:display_static_image=no&:display_spinner=no&:display_overlay=yes&:display_count=yes&publish=yes&:loadOrderID=0

18. Socioeconomic Data and Applications Center (SEDAC) [Internet]. [cited 2021 Mar 16]. Available from: https://sedac.ciesin.columbia.edu/
19. Bangladesh Meteorological Department [Internet]. [cited 2021 Mar 16]. Available from: http://live3.bmd.gov.bd/
20. timeanddate.com [Internet]. [cited 2021 Mar 16]. Available from: https://www.timeanddate.com/
21. LandScan [Internet]. [cited 2021 Mar 15]. Available from: https://landscan.ornl.gov/
22. Walker PGT, Whittaker C, Watson OJ, Baguelin M, Winskill P, Hamlet A, et al. The impact of COVID-19 and strategies for mitigation and suppression in low- and middle-income countries. Vol. 369, Science. 2020. p. 413–22.
23. WHO Coronavirus (COVID-19) Dashboard [Internet]. [cited 2021 Mar 16]. Available from: https://covid19.who.int
24. COVID-19 Government Measures Dataset [Internet]. ACAPS. 2020 [cited 2021 Mar 16]. Available from: https://www.acaps.org/covid-19-government-measures-dataset
25. COVID-19 Government Response Tracker [Internet]. University of Oxford. [cited 2021 Mar 16]. Available from: https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker
26. Barnett-Howell Z, Watson OJ, Mobarak AM. The benefits and costs of social distancing in high- and low-income countries [Internet]. Trans R Soc Trop Med Hyg. 2021. Available from: https://www.ncbi.nlm.nih.gov/pubmed/33440007
27. SQUIRE: SEIR transmission model of COVID-19 [Internet]. [cited 2021 Mar 16]. Available from: https://mrc-ide.github.io/squire/index.html
28. WorldPop [Internet]. [cited 2021 Mar 15]. Available from: https://www.worldpop.org/
29. Chowdhury R, Heng K, Shawon MSR, Goh G, Okonofua D, Ochoa-Rosales C, et al. Dynamic interventions to control COVID-19 pandemic: a multivariate prediction modelling study comparing 16 worldwide countries. Vol. 35, European Journal of Epidemiology. 2020. p. 389–99.
30. World Bank Open Data [Internet]. [cited 2021 Mar 16]. Available from: https://data.worldbank.org/
31. Worldometer - real time world statistics [Internet]. [cited 2021 Mar 16]. Available from: https://www.worldometers.info/
32. Humanitarian Data Exchange [Internet]. [cited 2021 Mar 16]. Available from: https://data.humdata.org/
33. Ćmiel AM, Ćmiel B. A new, simple method of describing the COVID-19 trajectory and dynamics in any country based on Johnson Cumulative Distribution Function fitting. medRxiv. 2020. p. 2020.12.05.20244178.
34. Our World in Data [Internet]. Our World in Data. [cited 2021 Mar 16]. Available from: https://ourworldindata.org
35. Louca S. COVID-19 prevalence in 161 countries and over time. medRxiv. 2020. p. 2020.12.01.20241539.
36. Gilman RT, Mahroof-Shaffi S, Harkensee C, Chamberlain AT. Modelling interventions to control COVID-19 outbreaks in a refugee camp. medRxiv. 2020. p. 2020.07.07.20140996.
37. Sánchez-Romero M, Lego V di, Prskawetz A, Queiroz BL. How many lives can be saved? A global view on the impact of testing, herd immunity and demographics on COVID-19 fatality rates. medRxiv. 2020. p. 2020.04.29.20084400.