Mapping and modelling COVID-19 dynamics using mobility data
Applied research and implementation group

30+ staff based at University of Southampton

Mapping small area demographics and health/development metrics for low and middle income countries

Open data, open peer-reviewed statistical methods, user engagement, capacity strengthening

Multiple partnerships with National Statistical Agencies, Ministries of Health, UN agencies
To discuss:

• Pandemics and human mobility
• Measuring mobility
• COVID-19 spread within and beyond China
• Modelling non-pharmaceutical interventions
• Regional connectivity and intervention coordination
• What next…?
History of Pandemics

Throughout history, as humans spread across the world, infectious diseases have been a constant companion. Even in this modern era, outbreaks are nearly constant.

Here are some of history’s most deadly pandemics, from the Antonine Plague to COVID-19.
Outbreak H1N1 Flu (Swine Flu)

The influenza virus is relatively unique in its ability to change its H and N to attend
the. For example, the swine flu of 1918 was H1N1 and 
found to have changed its hemagglutinin and 
serotypes. Scientists believe that these two factors were involved with an abrupt change 
in the way influenza spreads and is transmitted. 

Concentrations of population BC

before March 31
April 1 - April 15
April 16 - April 30
May 1 - May 15

Influenza
“Second Wave”:
Autumn, 1918
1 = August
2 = September
3 = October
4 = November
But 'Why?'
Human mobility across generations

Great-grandfather

Bradley (1989) Trav Med
Human mobility across generations

Grandfather

Bradley (1989) Trav Med
Human mobility across generations

Bradley (1989) Trav Med
Human mobility across generations

Author: Bradley (1989) Trav Med
Global air network: 1933

Tatem (2014) Int Health
Global air network: Today

Tatem (2014) Int Health
How can we measure and map this mobility?
Data for measuring population movements

Traditional

- Census data
- Cross-border and traffic surveys
- Household travel history surveys

Migration
- Long-term
- Seasonal
- Periodic
- Daily

Neighbourhood
- Intra-urban
- Regional
- Intra-national
- International

Tatem, *Int Health*, 2014; Ruktanonchai et al, *IJHG*, 2018

Prothero, JIAI 1957; Bull WHO 1961
Data for measuring population movements

Traditional
- Household travel history surveys
- Cross-border and traffic surveys
- Census data

Novel
- Personal GPS
- Anonymous mobile phone call detail records
- Satellite nightlights
- Smartphone/app location history
- Air and shipping statistics

Sources:
Tatem, *Int Health*, 2014; Ruktanonchai et al, *IJHG*, 2018
Data for measuring population movements

Traditional
- Census data
- Cross-border and traffic surveys

Novel
- Smartphone/app location history
- Satellite nightlights
- Anonymized mobile phone call detail records
- Personal GPS
- Air and shipping statistics

Tatem, *Int Health*, 2014; Ruktanonchai et al, *IJHG*, 2018
Mobile phone call detail records
Smartphone/app location histories

Ruktanonchai et al (2018) IJHG
Smartphone/app location histories
How can we use these data for estimating disease movements and designing control measures?
How has COVID-19 spread within and beyond China?

Preliminary risk analysis of 2019 novel coronavirus spread within and beyond China

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See our new study on the effect of COVID-19's non-pharmaceutical interventions

Updated version on MedArxiv
Updated on February 5th, 2020

Download a PDF version in English
Download a PDF version in Chinese

Destinations of airline travellers from 18 high-risk cities in mainland China by continent or region
Domestic destinations of 5 million travellers from Wuhan during Lunar New Year Holiday

Historical patterns of daily human movement by county in Wuhan City and Hubei Province before COVID-19
Green/Red colour: 2 weeks before/since LNY's Day

Risk of cities in mainland China receiving travellers with COVID-19 infections from Wuhan during the LNY migration based on the population movement data
The beginnings....
International destinations of travellers from China

Top 50 ranked cities receiving airline travellers from 18 cities in mainland China over a period of three months, representing 15 days before LNY’s Day and 2 and half months following LNY’s Day.

Based on air travel data from February to April 2018, obtained from the International Air Travel Association.
Multi-patch epidemiological model

- Subpopulation: Susceptible, Exposed, Infectious, Recovered

  ![Subpopulation Diagram]

- If each city/country is a patch, we can:
  - Model spread between areas
  - Simulate disease control measures (e.g. lockdowns) in certain areas but not others
  - Account for differences between areas (e.g. disease prevalence, demographics, movement/contact rate reductions)

- Our mobility data helps define rates of movement within and between patches

Lai et al. Nature 2020
Two phases of early intercontinental COVID-19 spread

A

<table>
<thead>
<tr>
<th>No. of exported cases</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
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</thead>
</table>

- **Wuhan lockdown** (China, Jan 23)
- **PHEIC declared** (WHO, Jan 30)
- **Pandemic declared** (WHO, Mar 11)

Yang et al. Journal of Travel Medicine, taaa200
Non-pharmaceutical interventions (NPIs)

- Travel restrictions
- Early detection and isolation of cases
- Contact reduction
Estimated epidemic curves of the COVID-19 outbreak under various scenarios with or without NPIs in China
Successful NPI implementation in China – what about elsewhere?

Mobile Location History (Google + Baidu)
Modeling regional lockdown strategies

- Costs/benefits of international coordination?
- SEIR model to explore hypothetical scenarios across Europe
  - Scenarios tested:
    - Synchronized cycles vs asynchronous (e.g., starting lockdowns)
      - What happens if countries implement lockdowns at the same time versus different times?
    - Coordinated vs uncoordinated lifting (e.g., ending lockdowns)
      - What happens if one country lifts their lockdown before others?
- Initially in Europe due to data availability, but will expand
European strategies? Model ingredients

Cases

Transmission

Lockdown effectiveness

Movement

Ruktanonchai et al (2020) Science
Lockdown effectiveness

- Relative compared to Jan-Feb 2020
  - Smartphone data
Synchronization of starting

• Significant difference when interventions are synchronized:
  • 90% of simulations go to zero local cases if synchronized
  • 5% if asynchronized
Coordination of lifting

• If one country ends lockdowns early, resurgence across the continent occurs up to 5 weeks early
  • Valuable time that could be used to expand test/treat, develop treatments and vaccines

• Significant variance in the earlier second wave, and the country “left out”

Ruktanonchai et al (2020) Science
A return to normality...?
European Whack-a-mole

- Substantial spatial and temporal variations in connectivity, transmission, interventions
- International coordination and synchronization are important in delaying and preventing resurgence
  - Predictions = reality!
- Coordination across all countries infeasible, but potential for highly-connected sub-communities (‘travel corridors’)?

Sub-communities across Europe. Regions in the same color are more strongly connected than those in different colors

Ruktanonchai et al (2020) Science
Domestic mobility across regions and time

Taking Jan 5 – Feb 15, 2020 as a baseline; mainland China taking Jan 5 – 22 as a baseline.

Lai S et al. MedRxiv 2020
Seasonal movements/factors + NPIs + Vaccines

Vulnerable populations...
Summary

• Disease outbreaks are becoming pandemics more rapidly and often than ever before
• The growing reach and volume of human mobility is a key driver
• New forms of data from mobile phones are aiding our abilities to map, model and respond to outbreaks
• Data integration and accounting for geography and demographics is important