

<b>Institution:</b> University of Southampton		
<b>Unit of Assessment:</b> 14 Geography and Environmental Studies		
<b>Title of case study:</b> 14-03 Mobile network data for disaster relief and infectious disease control		
<b>Period when the underpinning research was undertaken:</b> 2013 – 2020		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Andrew Tatem	Professor	January 2013 – present
Nick Ruktanonchai	Research Fellow	September 2014 – present
Shengjie Lai	Research Fellow	March 2018 – present
Alessandro Sorichetta	Senior Research Fellow	January 2014 – present
Robin Wilson	Research Fellow	October 2015 – May 2017
Elisabeth zu Erbach-Schoenberg	Research Fellow	March 2014 – December 2017
Victor Alegana	Research Fellow	May 2015 – October 2018
Jessica Steele	Senior Enterprise Fellow	February 2015 – present
Carla Pezzulo	Senior Enterprise Fellow	January 2013 – present
Cori Ruktanonchai	Research Fellow	April 2020 – present
Jessica Floyd	Research Fellow	October 2017 – present
Alessandra Carioli	Research Fellow	May 2016 – present
<b>Period when the claimed impact occurred:</b> October 2013 – December 2020		
<b>Is this case study continued from a case study submitted in 2014?</b> N		
<b>1. Summary of the impact</b> <p>Staff at the University of Southampton's WorldPop research group have used mobile phone network data to produce rich spatio-temporal population mobility metrics that underpinned infectious disease control and disaster relief. There are two main impact strands: (i) quantifying population mobility to target global and regional infectious disease control and elimination strategies (including for malaria, contributing to a 98% fall in cases in northern Namibia, and for COVID-19), and; (ii) mapping displaced populations following major natural disasters, such as the 2015 Nepal earthquake and Hurricane Matthew in Haiti in 2016, to aid swift and effective relief interventions.</p>		
<b>2. Underpinning research</b> <p>In the late 2000's Tatem was working with the World Health Organization (WHO) and Clinton Health Access Initiative (CHAI) to develop methods and guidelines for countries to assess the feasibility of eliminating malaria. A key issue is the importation of malaria by infected travellers, but at that time no reliable data existed that could quantify such mobility at national scales. Tatem realised that most travellers used a mobile phone, and that the communications and towers they were routed through were being recorded by mobile network operators. Through collaboration with the operators, anonymised mobile data integrated into a disease transmission model enabled estimation of importation rates for the first time (in this first instance to Zanzibar).</p> <p><b>Tatem</b> and his WorldPop group have, since 2013, continued to lead in this research area, producing rich records of individual and population level dynamics through space and time, unobtainable through any previous methods, which reveal new insights into human movement patterns. The team has also developed approaches for measuring and accounting for biases in the data to produce population-level insights. In 2014, <b>Tatem</b> oversaw the development of affordable methods for the modelling of population distributions at high spatial resolution from mobile network data, which were then used to capture spatiotemporal population dynamics [3.1]. In 2019, <b>Lai</b> developed and tested methods for the use of mobile data in producing national migration statistics [3.2]. Population statistics underlie almost all government operations and interventions, but these statistics can be expensive and logistically challenging to collect and update regularly, meaning that many low income countries have to rely on outdated and poor quality data. It is well established that this can lead to challenges in efficient and equitable</p>		

delivery of health interventions and inaccurate health statistics, resulting in sub-optimal health outcomes and certain populations and regions being left behind, with poor access to care.

The movement of people as carriers of pathogens is critical to disease transmission and spread. Building on **Tatem's** work in 2014 using anonymised phone records to identify populations critical in malaria transmission [3.3], **N. Ruktanonchai** developed approaches for mapping population flows and connectivity from these data, based on estimating home locations through frequency of communications and quantifying trips away. In 2016, **N. Ruktanonchai** then integrated these flows with disease transmission data in mathematical models to map transmission foci and support elimination strategy design in Namibia [3.4], through funding from the Bill and Melinda Gates Foundation and CHAI. Spatial metapopulation models of COVID-19 transmission utilising mobile network data were also built by the team and utilised to examine the impact of non-pharmaceutical interventions (NPIs) in China [3.5] and the effects of coordinating NPIs on COVID-19 dynamics in Europe [3.6].

Twenty to thirty million people are displaced every year by natural disasters. During disasters and crises, especially in low income nations, basic information is lacking on the locations of affected people. By measuring residences and typical mobility patterns of mobile users with Call Detail Records (CDRs), then deviations away from these in disaster situations such as earthquakes and hurricanes, **Wilson** and **Tatem** produced rapid, unique and rich insights into the reaction of populations to such events, with application in Nepal, Haiti and Bangladesh [3.7, 3.8].

### 3. References to the research

**3.1** Deville, P., Linard, C., Martin, S., Gilbert, M., Stevens, F. R., Gaughan, A. E., ... Tatem, A. J. (2014). Dynamic population mapping using mobile phone data. *Proceedings of the National Academy of Sciences*. <https://doi.org/10.1073/pnas.1408439111>

**3.2** Lai, S., Zu Erbach-Schoenberg, E., Pezzulo, C., Ruktanonchai, N.W., Sorichetta, A., Steele, J., Li, T., Dooley, C.A. and Tatem A.J. (2019). Exploring the use of mobile phone data for national migration statistics. *Nature Palgrave Communications*, 5, 34. <https://doi.org/10.1057/s41599-019-0242-9>

**3.3** Tatem, A. J., Huang, Z., Narib, C., Kumar, U., Kandula, D., P., Deepa K., Smith, D.L., Cohen, J.M., Graupe, B., Uusiku, P. and Lourenco, C. (2014) Integrating rapid risk mapping and mobile phone call record data for strategic malaria elimination planning. *Malaria Journal*, 13 (52) <https://doi.org/10.1186/1475-2875-13-52>.

**3.4** Ruktanonchai, N. W., DeLeenheer, P., Tatem, A. J., Alegana, V. A., Caughlin, T. T., Zu Erbach-Schoenberg, E., ... Smith, D. L. (2016). Identifying malaria transmission foci for elimination using human mobility data. *PLoS Computational Biology*, 12(4), 1-19. <https://doi.org/10.1371/journal.pcbi.1004846>

**3.5** Lai, S., Ruktanonchai, N.W., Zhou, L., Prosper, O., Luo, W., Floyd, J.R., Wesolowski, A., Santillana, M., Zhang, C., Du, X., Yu, H. & Tatem, A.J. (2020). Effect of non-pharmaceutical interventions to contain COVID-19 in China. *Nature*, 585, 410–413. <https://doi.org/10.1038/s41586-020-2293-x>

**3.6** Ruktanonchai, N.W., Floyd, J.R., Lai, S. Ruktanonchai, C.W., Sadilek, A., Rente-Lourenco, P. Ben, X. Carioli, A., Gwinn, J., Steele, J.E., Prosper, O., Schneider, A., Oplinger, A., Eastham, P., Tatem, A.J. (2020). Assessing the impact of coordinated COVID-19 exit strategies across Europe. *Science* 369 (6510), 1465-1470, <https://doi.org/10.1126/science.abc5096>

**3.7** Lu, X., Wrathall, D., Sundsøy, P., Nadiruzzaman, M., Wetter, E., Iqbal, A., Qureshi T., Tatem, A., Bengtsson, L. (2016). Detecting climate adaptation with mobile network data in Bangladesh: anomalies in communication, mobility and consumption patterns during cyclone Mahasen. *Climatic Change*, 1-15. <https://doi.org/10.1007/s10584-016-1753-7>

**3.8** Wilson R., zu Erbach-Schoenberg E., Albert M., Power D., Tudge S., Gonzalez M., Guthrie S., Chamberlain H., Brooks C., Hughes C., Pitonakova L., Buckee C., Lu X., Wetter E., Tatem A., Bengtsson S. (2016). Rapid and near Real-time Assessments of Population Displacement Using Mobile Phone Data Following Disasters: The 2015 Nepal Earthquake. *PLOS Currents Disasters*, 8: <https://doi.org/10.1371/currents.dis.d073fbee328e4c39087bc086d694b5c>.

*Funding supporting the research*

- Bill and Melinda Gates Foundation, \$1.5M, 2015-2017, Population demographics and dynamics mapping in Nigeria
- Clinton Health Access Initiative, \$500k, 2016-present, Malaria elimination support on population mobility
- Bill and Melinda Gates Foundation, \$100k, 2016-2017, Mapping poverty using mobile network data.
- Bill and Melinda Gates Foundation, \$1M, 2019-2020, Seasonal population dynamic mapping.

**4. Details of the impact***Shaping new infectious disease control and elimination strategies*

In Namibia, limited information meant that the government classified its entire northern region as high risk for malaria and focussed on delivering interventions accordingly to the 1.2 million people living there. However, mapping work led by **Tatem** from 2013 onwards that integrated satellite, survey and mobile network data, highlighted areas of much higher risk within this northern region for precise targeting [5.1]. Namibia's Mobile Telecommunications Ltd provided the Ministry of Health and Tatem's WorldPop group with anonymous phone records for more than 2 million users – 70% of the country's total population – between 2010 and 2014. WorldPop analysed the phone records to track call frequencies and locations, and integrated these with surveillance data to map sources and sinks of malaria parasite movements. Nine billion communications were examined to track aggregated movement patterns in regions where malaria is endemic. With support from the Global Fund and CHAI, in Oct-Dec 2013 the Ministry of Health's National Vector Borne Disease Control Programme used WorldPop's risk maps to provide insecticide-treated bednets to the most 80,000 at-risk individuals: *'without the maps produced by WorldPop, the program would simply have reverted to standard practice'* [5.2]. The work therefore allowed Namibia's government to more efficiently use limited funds by targeting interventions to the most vulnerable. Through the partnership, Namibia was able to target its distribution of insecticide-treated bed nets and allocation of community health workers to the Omusati, Kavango and Zambezi regions from October 2013. Until 2004, about 600,000 new malaria cases were reported every year. By 2016, cases had fallen 98% to 14,400 per year as the result of several malaria elimination schemes, including this one [5.1]. Elsewhere, subsequent human and parasite mobility models based on mobile data have been used since 2016 in Meso-America (e.g. Nicaragua) and southern Africa (e.g. Mozambique) [5.3]. They *'provided an important basis for [CHAI's] government support'* [5.2] via ongoing analyses of malaria importation and the mapping of sources and sinks to guide cross-border strategy.

Following the analysis and use of mobile network data in sub-Saharan Africa and the Americas, multiple major international policy and strategy documents based their recommendations around the WorldPop team's methods and examples. These include the Aspiration2Action document co-authored by the Bill and Melinda Gates Foundation and UN in 2015 [5.4], which underpinned multi-billion investments in international malaria strategies, and in October 2018, the WHO Expert Reference Group Manual on Measuring Receptivity and Vulnerability for Malaria Elimination [5.5], which guides country governments aiming for malaria elimination.

Aspiration2Action noted *'combining parasite positivity data with modelling of human movement patterns based on census data and mobile phone call data records [CDRs]...enables malaria interventions to be coordinated for maximum impact and efficiency'*. Moreover, in 2015 Tatem presented to the Global Fund in Geneva WorldPop's analysis on southern Africa malaria connectivity, showing how strongly the region is connected by parasite flows and therefore needs to coordinate malaria elimination activities. Following this, the Global Fund provided its first multi-country regional grant to eight countries in southern Africa to accelerate progress towards malaria elimination [5.6]. WorldPop's adaptation of mobile phone-based mobility methods to COVID-19 applications informed public debate over the pandemic. For example in July 2020, BBC's Panorama used **Tatem, N. Ruktanonchai** and **Lai**'s analysis of population mobility in China in their investigation of the pandemic's origins, and in May 2020 Chinese State Media reported on the work [5.7]. Moreover, the China analyses fed into the design of COVID-19 interventions used by the China CDC. Similar analyses undertaken by **Tatem, N. Ruktanonchai**

and Lai for Europe were used in European Centre for Disease Prevention and Control guidelines provided to all European Union member states and the UK [5.8].

#### *Supporting disaster relief operations*

In disaster situations, displaced populations tend to be those most vulnerable and in need of aid, but obtaining data on their numbers, locations, and trends remains a major challenge in chaotic post-disaster settings. Flowminder [5.9] is a non-profit foundation focussed on the use of mobile network data for international development, of which Tatem is a director and in which he has been instrumental in shaping the direction of the organisation. For many years Nepal has been one of the countries with greatest potential for a devastating earthquake. Given this high potential risk, WorldPop/Flowminder and Ncell (the largest mobile operator in Nepal) agreed a collaboration in December 2014 to be able to respond to potential future earthquakes and to support long-term development objectives in Nepal. The anticipatory project was initiated and rapid response capacity set up in Kathmandu, just one week before the major M7.8 Gorkha earthquake (epicentre ~80km NW of Kathmandu) occurred in April 2015, killing 8,964, injuring 21,952 and making 3.5 million more homeless.

Following the initial earthquake, within two days the WorldPop team produced updated population density maps, including gender and age distributions for the whole of Nepal. These data were used by key relief agencies such as the World Food Program [5.10] and the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA) [5.11]. The WorldPop/Flowminder team then combined these population data with the Ncell anonymised data from 12 million mobile phones in Nepal, to quantify the earthquake's impact on population displacement, producing first reports within four days of the initial quake, thereby providing *"vital information for directing strategies and resource allocation"* [5.11]. These fed into the multi-stakeholder situation reports used by disaster response agencies to guide their delivery of aid to the displaced populations [5.10; 5.11]. As highlighted by Kurt Burja of the UN's World Food Program [5.12], *"When the first... report came out after the Nepal earthquake, we used it right away in our national assessment of food security. Displaced people are often the most food insecure. Getting national and district level numbers on displaced populations was thus an important component in our assessment of where to focus support after the earthquake. The (WorldPop/Flowminder) analyses were widely read and circulated in the humanitarian community during the Nepal earthquake disaster response operations."* Kimberly Lietz of UN OCHA notes *"This data is regularly used in producing analysis for Flash Appeals and Humanitarian Needs Overview documents as part of the Humanitarian Programme Cycle"* [5.11]. The work was awarded the Global Mobile Award for 'Mobile in Emergency or Humanitarian Situations' in February 2016 [5.13], cited as *"A brilliant example of how the application of big data analysis to mobile technologies can be used to accelerate emergency aid, and provide intelligence to help prepare for future disasters."* Similar analyses for Hurricane Matthew in Haiti in 2016 in partnership with the World Food Program [5.10] were used to guide response efforts, enabling assessment of displaced populations in need of food aid and more effective planning of delivery.

In recognition of his pioneering use of mobile data to track population mobility, the Royal Geographical Society presented its 2020 Back Award to Prof Tatem *"for leading the development of geospatial and demographic data to assist the work of public policy around the globe"* [5.14]. This annual award is for outstanding contributions to national or international policy.

## **5. Sources to corroborate the impact**

### **5.1 Independent reporting of the impact of the mobile data work in Namibia:**

a) Case study by Data Impacts, an initiative led by Open Data Watch (an international non-profit organisation): <https://dataimpacts.org/wp-content/uploads/2015/06/phone-records-track-malaria.compressed.pdf> [see final paragraph];

b) Article by Apolitical (an inter-governmental organisation running a global learning platform for government) on government network site documenting project impacts: [https://apolitical.co/solution\\_article/phone-records-help-namibia-clamp-malaria](https://apolitical.co/solution_article/phone-records-help-namibia-clamp-malaria)



**5.2** Testimonial letter from Dr Chris Lourenco (formerly of CHAI, now Deputy Director of Malaria Dept., Population Services International), 8 Dec 2020.

**5.3** Description by Vodafone (24 April 2020) of its ongoing project with the Mozambican Ministry of Health and CHAI: <https://www.vodafone.com/perspectives/blog/world-malaria-day-2020-vodafone-fighting-malaria>

**5.4** Report and website co-authored by the Bill and Melinda Gates Foundation and UN in 2015 including regional population and malaria connectivity work by the WorldPop team: <http://endmalaria2040.org/> (see p. 17, Exhibit 3, Acknowledgements, p. 31)

**5.5** WHO Expert Group Reference Manual on Measuring Receptivity and Vulnerability for Malaria Elimination: <https://www.who.int/malaria/mpac/mpac-april2019-session7-report-erg-malariogenic-potential.pdf?ua=1> [See p. 20 'Conclusions' for WHO expert group's adoption of mobile network metrics, following Prof. Tatem's presentation]

**5.6** Article in Aidspan, the independent observer of the Global Fund on the southern Africa malaria elimination grant, using WorldPop's mapping and analysis (see 8. *New regional grant has sights set on malaria elimination in Southern Africa*, particularly figure on p. 15): <http://www.aidspan.org/sites/default/files/gfo/272/English/GFO-Issue-272.docx>

**5.7** Media coverage of analysis of population mobility in China:

a) China State Television broadcast of Lai et al.'s work, 8 May 2020 (translation supplied):

[https://www.youtube.com/watch?v=qfG0ib9jr-Q&list=PLfAyWdGHnLdHpH6\\_RRNLALpGhXPTUZTh2&index=154](https://www.youtube.com/watch?v=qfG0ib9jr-Q&list=PLfAyWdGHnLdHpH6_RRNLALpGhXPTUZTh2&index=154);

b) BBC Panorama interview with Tatem, first broadcast 27 July 2020 (see interview at 12:49 in video): <https://www.bbc.co.uk/programmes/m000k4dq>;

**5.8** Analysis of population mobility in China feeding into COVID-19 policy:

a) China CDC policy paper citing the work of Lai, Tatem and Ruktanonchai:

[https://doi.org/10.1016/S0140-6736\(20\)31278-2](https://doi.org/10.1016/S0140-6736(20)31278-2) (see p. 65, para 3);

b) European Centre for Disease Prevention and Control (2020): *Considerations relating to social distancing measures in response to COVID-19 – second update*:

<https://www.ecdc.europa.eu/sites/default/files/documents/covid-19-social-distancing-measuresq-guide-second-update.pdf> (see p. 5, para 2).

**5.9** About Flowminder: <https://www.flowminder.org/about-us/>

**5.10** World Food Programme (2018): *Vulnerability Analysis & Mapping: Food security analysis at the World Food Programme*. <https://docs.wfp.org/api/documents/WFP-0000040024/download/> (see p. 3, subsection 'call detail records')

**5.11** Testimonial letter from Kimberly Lietz, Officer in Charge, Needs and Response Analysis Section, United Nations Office for the Coordination of Humanitarian Affairs, 8 March 2021.

**5.12** <https://www.oecd.org/sti/ieconomy/1%20-%20Linus%20Bengtsson.pdf> [see p. 23]

**5.13** 2016 Global Mobile Awards announced: <https://www.gsma.com/newsroom/press-release/gsma-announces-winners-of-the-2016-glomo-awards/> Cited quote is from:

[http://www.mynewsdesk.com/se/handelshogskolan\\_i\\_stockholm/pressreleases/sse-researcher-receives-global-mobile-award-for-nepal-earthquake-relief-work-1333291](http://www.mynewsdesk.com/se/handelshogskolan_i_stockholm/pressreleases/sse-researcher-receives-global-mobile-award-for-nepal-earthquake-relief-work-1333291)

**5.14** Royal Geographical Society: *2020 medal and award recipients announced*.

<https://www.rgs.org/geography/news/2020-medal-and-award-recipients-announced/>