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# Evidence and future potential of mobile phone data for disease disaster management

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ABSTRACT

Global health threats such as the recent Ebola and Zika virus outbreaks require rapid and robust responses to prevent, reduce and recover from disease dispersion. As part of broader big data and digital humanitarianism discourses, there is an emerging interest in data produced through mobile phone communications for enhancing the data environment in such circumstances. This paper assembles user perspectives and critically examines existing evidence and future potential of mobile phone data derived from call detail records (CDRs) and two-way short message service (SMS) platforms, for managing and responding to humanitarian disasters caused by communicable disease outbreaks. We undertake a scoping review of relevant literature and in-depth interviews with key informants to ascertain the: (i) information that can be gathered from CDRs or SMS data; (ii) phase(s) in the disease disaster management cycle when mobile data may be useful; (iii) value added over conventional approaches to data collection and transfer; (iv) barriers and enablers to use of mobile data in disaster contexts; and (v) the social and ethical challenges. Based on this evidence we develop a *typology* of mobile phone data sources, types, and end-uses, and a *decision-tree* for mobile data use, designed to enable effective use of mobile data for disease disaster management. We show that mobile data holds great potential for improving the quality, quantity and timing of selected information required for disaster management, but that testing and evaluation of the benefits, constraints and limitations of mobile data use in a wider range of mobile-user and disaster contexts is needed to fully understand its utility, validity, and limitations.



## 1. Introduction

Novel sources of data coupled with new data mining techniques and data-driven logics are transforming science, business, governance and society more generally. In this age of so-called *big data*, there is potential for transformative change in the role of information in decision-making as we move from a mode of decision-making defined by data scarcity to a new era of data abundance (Hey et al., 2009; Miller, 2010; Miller and Goodchild, 2015). The potential of new sources of data to address global data inequities holds particular promise in low- and middle-income countries (LMIC) where conventional sources of social, environmental, and economic data are often patchy, many years out of date, or simply non-existent (Center for Global Development, 2014; Cinnamon and Schuurman, 2013; Deville et al., 2014). Kitchin (2013) describes three approaches to the way big data are produced: *directed* – in which a human operator focuses a data capturing technology on a person or place (e.g. surveillance camera, remote sensing); *automated* – in which data are passively collected via the normal operation of a system or technology (e.g. mobile phone use, Web browsing, credit card transactions); and *volunteered* – data which are actively or passively produced by citizens, typically via user-generated platforms including social media and crowdsourcing applications. These *active* and *passive* approaches to big data production can rapidly produce new sources of data in real or near-real time, which opens up a range of opportunities for understanding diverse social phenomena, especially for 'data poor' settings characterized by inadequate data infrastructures. The potential of big data to improve disaster response and management is stimulating significant interest from researchers, government, and the humanitarian community (e.g. Fadiya et al., 2014; Pu and Kitsuregawa, 2013; Shelton et al., 2014; Zoomers et al., 2016). This paper critically examines the existing evidence and explores the future potential for the use of actively and passively produced mobile phone data for managing humanitarian disasters caused by communicable disease outbreaks.

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**Fig. 1.** Phases of the disaster management cycle.

A disaster can be defined as a "serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (UN International Strategy for Disaster Reduction, 2009, p. 9). Although attention and resources are concentrated on responding to disasters, the *disaster management cycle* (Fig. 1) is commonly conceptualized as having four overlapping and interconnected phases focusing on risk management (*prevention* and *preparedness* phases) and crisis management (*response* and *recovery* phases) (Alexander, 2002, p. 6). Together these phases represent the "sum total of all activities, programs and measures which can be taken up before, during and after a disaster with the purpose to avoid a disaster, reduce its impact or recover from its losses" (Vasilescu et al., 2008, p. 46).

Rapid evidence-based response to events such as natural disasters, disease outbreaks, and political emergencies is essential to minimize losses and damage, and build community resilience. To decide how to distribute emergency resources in the immediate aftermath of a disaster, relief agencies need access to information about the magnitude of the event, the locations where people have been impacted, population characteristics and dynamics, and existing distribution of relief resources and infrastructure (MapAction, 2016). Data inadequacies can result in excessively slow, ineffective, and in some cases negligent disaster response and recovery as illustrated by the widely criticized response to Hurricane Katrina (Thompson et al., 2006). Poor decision-making during the response and recovery phases can be amplified by inadequate knowledge about vulnerabilities during the prevention and preparedness phases of the disaster management cycle (Pu and Kitsuregawa, 2013), highlighting the importance of access to data through all phases of disaster management.

A range of data types can support disaster management. Some directed sources of big data such as remotely-sensed satellite imagery are already relatively widely used in disaster management (Voigt et al., 2007). Use of other direct data sourcing technologies, notably unmanned aerial vehicles (UAV), is not yet standard practice but hold great promise for rapid access to high spatial and temporal resolution imagery from before and after natural disasters (Griffin, 2014) and for enhancing situational awareness in humanitarian emergencies (Aubrecht et al., 2015). Similarly, the use of volunteered sources of data in disaster management has been widely reported in recent years as part of the field of 'digital humanitarianism' (Burns, 2014; Meier, 2015), particularly the passive harvesting of spatial information about crisis events from social media including geotagged tweets (Shelton et al., 2014; Zook et al., 2010), and active production of data using Web-based crowdsourcing platforms (Goodchild and Glennon, 2010; Roche et al., 2013). These technologies are transforming communications during emergencies, however the representativeness, credibility, social and ethical consequences, and overall value of the data for decision-making during disasters is not well understood (Buscher et al., 2014; Crawford and Finn, 2015; Shanley et al., 2013).

Comparatively, actively and passively produced big data generated through mobile phone communications have received considerably less attention from within the academic and humanitarian communities and is an underused data source in disaster management (Madianou et al., 2015; The Economist, 2014), despite the rapid global diffusion of mobile phones in recent years. Mobile networks now cover 50% of the globe, supplying almost 8 billion mobile phone connections, and over half of the world's population is estimated to have a mobile subscription (GSMA, 2015). Although worldwide penetration of mobile phone usage is uneven – loosely paralleling global patterns of development – access to mobile phones is one metric for which many LMIC are rapidly catching up with the rest of the world. In sub-Saharan Africa, 50% of the adult population are expected to have mobile phones by 2020, with some countries far surpassing this already, including Nigeria (89%), Senegal (84%), and Ghana (82%) where subscription rates are similar to many high-income countries, although smartphones are still relatively rare in this region (Pew Research Center, 2015). These data assume that each mobile phone owner is independent while in reality some or even many individuals may be owners of two or more mobiles, meaning coverage could be more limited than it appears. Nonetheless, there is no doubt that the number of mobile phones in use in LMIC is increasing. This technological leapfrogging to digital communication methods in LMIC has been driven by its use for a range of purposes beyond personal communications, including mobile money (digital bank accounts and financial services) which can be accessed via short message service (SMS) on basic mobile phones.

In this paper, we critically examine the current and future potential of two types of data produced via mobile phone communications: passively produced call detail records (CDRs), and active produced data through SMS. Mobile communications produce massive longitudinal datasets recorded and maintained by mobile network operators (MNO). These CDRs typically include the time a communication was made, a unique identifier for the caller, receiver's telephone number, call duration, size of data transmitted, and the geographic location of the cellular tower the call was routed through and received from for every communication (call or SMS) made by every mobile phone user (FCS, 2012). CDRs are routinely collected by MNOs to facilitate customer billing, problem diagnostics, and network planning, and they have a massive potential to illuminate the spatio-temporal dynamics of individuals and populations at a very high resolution in near real-time (Deville et al., 2014). Researchers are starting to tap into these data sources to understand population characteristics (Douglass et al., 2015), transportation and mobility (Doyle et al., 2014), socio-spatial behaviours and interactions (Gao et al., 2013; Järv et al., 2014), urban spatio-temporal dynamics (Ahas et al., 2015) and inferred aggregate economic activity (Scepanovic et al., 2015). CDRs are thus poised to significantly advance knowledge in these areas, especially in domains that have conventionally relied on out-dated, unrepresentative, or low-resolution data sources (e.g. national census, surveys, modelled estimates).

Mobile phones can also be used to communicate and gather data directly from citizens via mobile apps and SMS. We focus on SMS, as this is available to all types of mobile phone – basic, feature, and smart – and may therefore be the most appropriate starting point for mobile-based disaster management in LMIC. SMS technology has been available since the 1990s and has been widely used as a medium for *sharing* information with the public during