Information Communication Technologies and Research in Developing Countries

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Information Communication Technologies and Research in Developing Countries

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INFORMATION COMMUNICATION TECHNOLOGIES AND RESEARCH IN DEVELOPING COUNTRIES

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Introduction – Global Trends in Information Communication Technologies

The advances in information and communication technologies (ICTs) have improved the usefulness and ease of data analysis. These changes have generated a frenzied expansion of new data collection, interpretation, visualization and communication methods. "Frenzied" seems to be an appropriate word to describe this contemporary and global movement: according to IBM¹, 90% of the world's data was created in the last two years and every two years, this amount is projected to double in size (Spratt, 2015). The collected information can, and has been, used in a myriad of fields for many purposes. With increased access to ICT, it is likely that data will be more ubiquitous in every-day life and global decision making. Globally, from 2005 to 2015, the number of individuals with daily access to the internet rose from 1 billion to approximately 3.2 billion persons. These statistics indicate that ICT growth is a worldwide phenomenon with most of the rapid growth occurring in the developing world (The World Bank, 2016).

ICTs can transform various forms of information into an electrical signal, which then can be further analyzed (Seth, Faith, Martín & Ramalingan, 2016). Since the form of this signal is digital (binary), large amounts of information can be stored, shared, and transmitted by inexpensive and compact devices. Portable ICTs provide an easier means for people to communicate and connect. This statement is supported by evidence that ICT devices are used in some of the most remote and impoverished places in the world. Examples of such devices include Personal Digital Assistants (PDAs), tablets, and mobile phones.

The Digital Adoption Index (DAI), developed by the World Bank, represents how pervasive digital technologies are among a country's businesses, people, and governments (The World Bank, 2016). The sub-indices for businesses, government, and people are calculated

¹ https://www-01.ibm.com/software/data/bigdata/what-is-big-data.html
through 16 different technical indicators\textsuperscript{2}. Figure XX below shows the sub-index level DAI for the reportable businesses, people, and governments in 171 different countries. In this figure, each country’s Digital Adoption Index is plotted as a function of their per capita GDP, a common indicator of national economic status.

![Digital Adoption vs. GDP Per Capita](image)

**Figure 1 - Digital Adoption vs. GDP Per Capita\textsuperscript{3}**

Despite stark disparities in economic wealth, most countries have at least 50% digital penetration (by people), with many of these countries exceeding the global average. Regardless of wealth, every country has some degree of digital penetration per capita (The World Bank, 2016).

There are very few products/concepts with such a worldwide presence. Thus, it is important to address how ICT can be used to help address some of the world’s more critical social and economic matters. This paper is concerned with the use of portable and physical ICT devices for data-driven research in low and middle income countries (LMIC). Examples include the use of mobile phones to monitor positive cases of malaria in South Africa (Quan et al., 2014), the use of PDA devices when conducting a global tobacco survey in LMIC (Pujari et al., 2012), and the use of portable biometric devices to create India’s ID program, Aadhaar—the largest biometric system in the world (Gerdeman, 2012).


Before examining a few case studies, some applications of portable ICT will be explored.

**Uses and Benefits of Portable ICT**

Traditional (paper-and-pencil) data collection methods require the physical transfer of information: forms are exchanged and information is manually entered. Manual input and transmission may not be suitable in situations where rapid and comprehensive data is necessary. Field researchers are continuously challenged to collect data that is robust, timely, and accurate (Ali et al., 2010).

Portable ICT offer a variety of benefits to researchers in LMIC. A study from Zanzibar, Tanzania (Thriemer et al., 2012) compared electronic and paper-based entry methods. The authors found that electronic collection was cheaper (total costs of $17,710 vs. $23,500), more accurate (1% vs. 7% non-accurate data), and faster (data turnaround time: <24 hours vs. 5-7 days, data entry time: 5 minutes vs. 10 minutes) than the equivalent paper-based method (Thriemer et al., 2012). This comparative study was not unique in its findings. Many other researchers have found similar benefits (accuracy, cost, speed) to be true (Ali et al., 2010, Seebregts et al., 2009, Were et al., 2010, Gelb & Clark, 2013, amongst others).

A few common potential benefits will be outlined in the following section.

*Reduction of Transmission Time*

Portable ICTs are well-suited for a variety of applications, most of which desire a rapid collection of large amounts of information. Time sensitive information, like an infectious disease outbreak or the identification of a malnourished child, requires data collection to be comprehensive and swift. Mobile technical devices permit data to be directly entered and, if signal is available, immediately transmitted elsewhere (Missinou et al., 2005). ICTs can transfer large amounts of information at near-instantaneous speeds, thus they have the capability to
provide significant in-situ data and update persons in real time (Seth et al., 2016). Automated entry checks are also available on software that is supported by mobile devices. These checks also lower the time it takes to create usable sets of data, since information no longer needs to be manually checked for errors.

LMIC are often hosts to a variety of programs that are designed to raise the quality of lives of their residents. These initiatives are typically large endeavors that require the asking of proper evaluation questions, such as “what is the problem the program is trying to solve?”, or, “how effectively does this program deploy its good/services to its target population?” (Boruch, 2015). These questions can only be answered with the collection of high quality data. High value evidence, regardless of the site, can be difficult to collect, because such data needs to be time-sensitive and thorough. Program evaluators are increasingly turning to portable ICTs to gather data from various stakeholders, since such mobile technologies are suited for quick and effective monitoring (Mtema et al., 2016).

Automated data entry has also lessened the time taken to conduct surveys. Surveys can be completed with the Computer-Assisted Personal Interviewing (CAPI) method. Although CAPI does not require using a portable device, these tools can be quite valuable. This form of “portable CAPI” (pCAPI) offers researchers the ability to collect field data in a variety of environments. pCAPI requires the use of a handheld device, typically a PDA, tablet, or mobile phone, to conduct a pre-programmed survey (Goldstein, 2012). Surveys using pCAPI can instantaneously evolve through automated routing, which changes based on each respondent’s answers. pCAPI’s ability to automate survey skip-codes reduces administration time, and use of extraneous questions (Caeyers et al., 2011).
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Timely judgments help to optimize the proper use of resources, such as time, personnel and money, being spent to conduct research. When considering the research applications in LMIC, where resources may already be scarce, this seems especially beneficial. One example in South Africa (Quan et al., 2014) highlights how PDA devices have reduced the notification time of positive malaria cases. This study will be explored in greater detail later.

Reduction of Data Entry Errors

Data entry errors pose a major challenge for researchers, because they lower the reliability of gathered information. For many surveys and evaluations in LMIC, paper-based data capture is still commonplace (Pujari, Palipudi, Morton, Levinsohn, Litavec & Green, 2012). Potential errors from paper-based methods include lost forms, and illegible or misread handwriting. Random missing and erroneous data reduce the size of usable data, which makes it more difficult to find significant findings (Caeyers, Chalmers & DeWeerdt, 2011). For large-scale surveys and evaluations, random error is not necessarily problematic; however, for inquiries on a smaller sample size, random error may require entire observations to be dropped. Thus, even unassuming, random mistakes can pose challenges for researchers.

Mentioned previously, electronic data collection can automate checks on entered data. Software supported on portable devices can notify researchers if there are any omitted, erroneous (out of range, etc.), or impossible values. Prior to transmission, while still in the field, errors can be immediately identified and efficiently remedied (Goldstein, 2012). Automated checks are commonly offered on pCAPI survey software, like SurveyCTO4. SurveyCTO, like other data collection software, requires the support of a portable device, such as a mobile phone or tablet.

The reduction in data entry errors is a demonstrated benefit and is shown in many portable ICT studies. A study on Malawi childhood malnutrition (Blaschke et al., 2009) is one

4 https://www.surveycto.com/index.html
of such studies. This analysis demonstrated how mobile phones were used to reduce the program’s data entry errors. This example will be discussed in a later section.

Closing Identity Gaps

Most LMIC lack some of the more thorough methods of personal record keeping that developed countries have (Gelb & Clark, 2013). Individuals in developing countries are often “not counted”, because they do not have access to official identification. Many of these individuals were never issued birth certificates or official ID numbers (ex: social security, license, or passport number). Some authors refer to this problem as an “identity gap”, where there are large groups of people who were never enumerated (Gelb & Clark, 2013).

Contrary to the lives of most in developed countries (approximately 98% of residents in the developed world have been registered at birth), there are many individuals in LMIC who were never uniquely counted or identified (Gelb & Clark, 2013). According to UNICEF (2005), 40% of all children in LMIC are never registered at birth. Non-registered percentages range from the highest in South Asia (63%) to Eastern Europe (23%). Still, with Eastern Europe being the “best-case” LMIC region, approximately a quarter of its population remains unregistered (UNICEF, 2005). The unregistered population exceeds 70% in some of the most underdeveloped and neediest countries (Storisteanu, Norman, Grigore & Norman, 2015).

One’s identity cannot be solely defined by a birthday, age, name and/or address, because these can still be shared by multiple individuals. Since many individuals in LMIC lack formal identification, their identity cannot be linked to other important non-governmental records, such as land-ownership, health, banking, and school records (International Records Management Trust, 2009). This also poses a big problem for social programs, because there is no way to guarantee that goods and services have been properly delivered.
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A lack of accurate and thorough administrative records is also an issue for governments of LMIC who may rely on administrative records when promoting effective policies and actions. Since many individuals are not properly identified and/or linked to their unique records, there is a troublesome lack of personal and organizational accountability (International Records Management Trust, 2009). By connecting a person’s identity to their public records, a resident can more effectively participate in daily life and maintain their responsibilities (Gelb & Clark, 2013).

There are newer methods to count hard-to-reach populations that do not rely on paper-based records. Biometric devices, such as portable fingerprint and iris/retina scanners, are increasingly being used to enumerate people in LMIC. These devices use a person’s unique biological marker as their identity. One’s biological identity cannot be lost, in contrast to an ID number or birth date, which can be misplaced (or never issued). Biometric devices are also used to authenticate one’s identity; for example, to ensure that the person claiming a specific identity is who they say they are (Gelb & Clark, 2013).


*Figure 2 - Biometric Device Using Eye Pattern. India*

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Biometric portable devices are frequently used in LMIC to identify and verify the identities of residents. India’s Aadhaar program is currently the largest biometric identification program in the world. This ongoing program will be studied in greater detail later.

Varied Portrayals of Data

Portable forms of ICT can deliver information at a low cost and in a variety of formats. Data can be presented in raw, numerical, graphical, and even auditory forms. Since data can be interpreted and evaluated at different scales and arrangements, better suited evidence can be delivered to and interpreted by program stakeholders (Vital Wave Consulting, 2012). Most often, raw data is transformed into graphical portrayals. This technique is referred to as data visualization. Benefits from advancements in data visualization are not limited to portable devices; however, these devices create additional benefits that cannot be obtained from other forms of technology. In-situ data visualization allows users to access and directly work with the data without spending additional resources for travel.

There are many visualization programs that offer mobile-supported versions of their software. One of these, Tableau⁶, offers Tableau Mobile and Tableau Desktop, which can be used on mobile phones and portable computers, respectively. Tableau Mobile has been used by doctors in various LMIC (Haiti, Vietnam, Sierra Leone) to visualize and compare data on their daily patient case load and clinic performance to other doctors in the region. This visualization has also allowed researchers to focus their efforts on clinics and areas with heavier case-loads (Tableau, 2017).

⁶ https://www.tableau.com/
Remote Data Collection

The use of portable ICT can be helpful in reaching and identifying harder-to-reach populations in LMIC. There is a utility in using portable devices for remote data collection in areas with conditions unfit for researchers—some possible situations include war/terrorism, natural disasters, and disease outbreaks. Two examples of such circumstances are the 2010 Haitian earthquake and the 2014 Ebola outbreak in West Africa (The Nielsen Corporation, 2015). Such settings make conventional data collection nearly impossible and dangerous for data collectors; however, in these situations, data is even more important for responders to act swiftly and effectively.

Data, collected on any scale and by any method, is greatly affected by systematic error. Biased data is dangerous for researchers, because the information is not fully representative of the real target. These types of errors can result in invalid findings, and are particularly worrisome in LMIC research, because access to some populations is limited. Geographic, economic, political and/or social remoteness can all contribute to population inaccessibility (Seth

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https://www.tableau.com/solutions/customer/stepping-treatment-mobility-outreach-international
High levels of mobility also pose a problem for accessing residents within LMIC. For example, it is quite difficult to reach a nomadic population (Seidenfeld, 2017).

Remote data collection is also important in LMIC, because it allows residents and researchers to reach one another without spatial constraints. Doctors practicing telemedicine, the practice of remote medical care, routinely use portable devices to communicate with their patients in LMIC. Human capital and resources are often scarce in LMIC; thus, telemedicine offers a new solution to provide more residents with higher quality and personalized health-care (Wamala & Augustine, 2013). Researchers from the University of Michigan conducted a mobile outreach program in Bolivia (Bickel, 2015). Patients suffering from chronic health ailments, like high blood pressure and diabetes, were contacted weekly about their symptoms. Many Bolivians are poor and have minimal access to health care workers; however, most own a cell phone (Bickel, 2015). This is just one example of how portable ICT can be used to exchange information with hard-to-reach populations.

![Figure 4 - Telemedicine Suitcase with Portable Tablet in Gamo, Africa](https://vacc.com/blog/vacc-telemedicine-for-ulbert-schweitzer-centennial/)

**Reduction of Cost**

The manual collection and entry of data can be expensive and laborious, creating additional obstacles for researchers in LMIC. Many cost-comparative studies have found that
electronic data collection is cheaper than the equivalent paper-based method. Electronic methods typically incur a higher initial cost, most of which stems from purchasing and setting-up the devices. Additional costs are also incurred by the training of personnel and, if necessary, device replacement. The cost to conduct future research may be further reduced, since devices are already purchased. Overall, paper-based data collection is typically more expensive, because more staff is required to manually collect and review data. Money is also spent to supply printing material. Traditional paper-based data collection is typically more time-consuming and error-prone, which adds to its overall cost (Thriemer et al., 2012).

Over a three-year study in Western Kenya, researchers found that electronic and manual data collection had cost about $0.15/person and $0.21/person, respectively (Were et al., 2010). Another study in Zanzibar reported that PDA-based data collection was 25% cheaper than using paper-based forms (Thriemer et al., 2012). A meta-analysis, which reported on PDA-use in survey data collection, had found that electronic data collection is initially more expensive; however, its final cost converges to the cost of traditional methods (Seebregts et al., 2009). Considering the other benefits offered by portable ICT, electronic data collection appears to be a feasible and cost effective alternative to paper-based methods in LMIC.

**Overview of Uses – By Portable Device**

The following section provides a brief overview on the uses of three common ICT devices: mobile phones, portable computers/PDAs, and biometric devices. Each subsection, separated by portable device, includes two specific case studies that detail how these devices have been used to collect data in LMIC.
Mobile Phones

With regards to technical devices with an impact, there is perhaps no more important device than the mobile phone. Based on the World Bank’s (2016) report, 8 out of 10 people living in the developing world have access to a mobile phone. Even within the bottom 1/5 of these populations, almost 70% have access to a mobile phone. Access was determined at the household level (World Bank, 2016). Based on the data in Figure XX, there are more homes with access to a mobile phone than to clean water or electricity.

![Graph showing access to various technologies from 1990 to 2015.](http://documents.worldbank.org/curated/en/896971468194972881/pdf/102725-PUB-Replacement-PUBLIC.pdf)

Figure 5 - Globalized Rapid Growth and Access to ICT

Trucano (2014) states, “the best technology is often the one you already have, know how to use, can maintain and can afford, for most of the world, the mobile phone fits these criteria quite well” (Trucano, 2014). As shown in Figure XX below, the mobile phone is not only popular in developed countries, but has a substantial presence and growth rate in developing countries (International Telecommunications Union, 2016). For example, India’s rural population had increased their mobile phone usage from 0.7% to 21% in a single decade (2001-2010) (The Nielsen Corporation, 2015). Globally, there is approximately one mobile phone per
inhabitants/households. Based on the data in Figure XX, the gap in mobile phone ownership, between individuals in developed and developing countries, is smaller than all other included measures of technology access.


*Figure 6 - Global Distributions of Technology Use/Access*

Mobile phones invite a large and varied market for mobile applications (apps) that can suit the specific needs of an individual. As such, there are numerous examples of mobile devices and apps that function to ease the collection of personal data. Additionally, there are programs that use SMS (short message service) to gather and disseminate data to LMIC populations. Approximately 86% of all NGO workers reported to the UN that they had used mobile phones to accomplish their work (Blaschke et al., 2009). To highlight the variety of uses in LMIC, examples are explored in what follows.
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Case Studies

Malaria Eradication Program in South Africa

South Africa remains one of 34 countries still endemic with malaria. South Africa has set a goal to achieve country-wide malaria eradication by 2018; however, there are currently three endemic provinces remaining (Quan, Hulth, Kok & Blumberg, 2014). The graphic in Figure XX below shows substantial reductions in South Africa’s malaria infections. However, positive cases remain in KwaZulu-Natal, Limpopo and Mpumalanga provinces (Maharaj et al., 2013).

Figure 7 - Positive Malaria Cases - Three Endemic Provinces\(^{11}\)

Plans to control and eradicate malaria focus on the importance of a fast diagnosis and treatment for the patient, and for subsequent prompt community notification. Two of the provinces, Mpumalanga and Limpopo, were unable to provide swift malaria notification, resulting in numerous preventable positive malaria outbreaks (Maharaj et al., 2013). Once the local population has been notified of a malaria case, efforts are focused on reducing the number of available hosts for the parasite. Simply, a crucial step towards malaria eradication is timely notification and action. South Africa’s expectation\(^ {12}\) for a patient’s notification of a positive

malaria case is 24 hours; time for local community notification is 48 hours and for provincial notification is 72 hours (Quan et al., 2014).

![Regions Where South African Malaria Prevention, Elimination & Pre-Elimination are Located](https://malariajournal.biomedcentral.com/articles/10.1186/1475-2875-13-151)

South Africa’s health care system still reports cases of positive malaria infection using paper forms. Each week, a health investigator collects any positive forms from all local clinics; however, he/she only does so once or twice per week (Quan et al., 2014). The appropriate and timely notification of a positive malaria case is dependent on the timing of this investigator’s visit. Once the investigator has all positive case forms, he/she enters patients’ information into their provincial database; however, on average, it takes about a month for such information to be entered (Quan et al., 2014). Case investigators had to waste a substantial amount of resources to travel to clinics to see if there were any positive malaria cases. Since this process is quite inefficient and resource intensive, researchers have worked to improve the existing system.

One of the three endemic provinces, Mpumalanga Province, was the site of an eight-month study ascertaining whether use of a mobile device could improve malaria reporting. The
study ran through the entire South African malaria season (October-May from 2012-2013). Although Mpumalanga is a rural province, they are fairly developed with mobile technology. Over 93% of South Africans are subscribed to a cell phone service (Quan et al., 2014). This factor was considered when selecting the appropriate device to use. When there was a positive case, the Java-based application, ODK Collect\textsuperscript{14}, was selected for data entry. The application required the support of an Android phone. An important benefit to using ODK Collect was that this program allows information to be temporarily stored on the device; there were occasional areas where cellular service was unavailable (Quan et al., 2014). Large quantities of data could be held on the application until the device was in a region with adequate service.

The researchers sought to understand if ICT was a feasible alternative to traditional methods of data entry. To test this hypothesis, one nurse was selected as the case investigator for this study—she was 71 years old and had virtually no experience with smartphones and computers. The researchers chose this specific nurse, because they believed if she could successfully work with this solution, then other case investigators could as well (Quan et al., 2014). Each day, the nurse would call her assigned health clinics to learn of any positive malaria diagnoses; daily calls were made to comply with the 24-hour notification standard. When there was a positive case, she would travel to the clinic and record all patient information (local clinic, patient’s age/name) on the software platform. This simple action ensured that the nurse’s time and resources were only used when her action was required. The nurse averaged approximately three minutes to enter and send all patient information. Notifications of new entries was no automated, so the nurse also used SMS messaging to notify regional centers of any positive cases (Quan et al., 2014). Once the centers were aware of positive cases, they could take immediate preventative actions (insecticide spraying, community notification, etc.).

\textsuperscript{14} https://opendatakit.org/use/collect/
The nurse worked in both mobile and non-mobile reporting clinics. To assess the results, clinic outcomes were compared. The results from this study were also compared to other provincial clinics that used other case investigators and did not use mobile reporting (Quan et al., 2014). This served as an unbiased control, since the study’s nurse worked in both types of clinics (mobile vs. non-mobile reporting) and may have suffered from an ‘observer effect’. One measure, the time between a patient’s initial diagnosis and their entry into the provincial database, was compared among the three types of health clinics. The results are shown below in Table XX. Time is reported as number of days.

<table>
<thead>
<tr>
<th></th>
<th>Study Nurse – Mobile Reporting Clinics</th>
<th>Study Nurse – Non-Mobile Reporting Clinics</th>
<th>Other Investigators – Non-Mobile Reporting Clinics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time 1</td>
<td>33.0</td>
<td>35.2</td>
<td>33.4</td>
</tr>
<tr>
<td>Time 2</td>
<td>7.3</td>
<td>28.9</td>
<td>42.6</td>
</tr>
</tbody>
</table>

*Table 1 - Number of Days Between Initial Diagnosis and Provincial Database Entry*

The nurse’s assigned clinics (mobile and non-mobile reporting) all had a reduction in data entry time. Clinics with other case investigators did not experience a reduction in diagnosis-database entry time. At time 1, prior to the study, all three clinics had a similar number of entry time; however, the mobile reporting clinics had the most dramatic reduction.

The researchers also analyzed the number of cases that were followed up within 48 hours of initial diagnosis. Set by South African officials, this time was the standard for effective preventative actions to be taken against the spread of malaria. For the study’s mobile reporting clinics, the percent of cases falling within the desired time window went from 5% to 65% of all positive cases. The nurse’s other clinics went from 12% to 33%; clinics with other case investigators went from 13% to 36%. All clinics had a positive increase in the percent of cases followed up within 48 hours, although the mobile-reporting clinics had the most dramatic increase (Quan et al., 2014).
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The results from this eight-month case study showed that personal use of a mobile device can be a feasible solution to reducing malaria notification time. One individual, a 71-year-old non-technical nurse, was the sole participant in this study, so, the generalizability of this study is not currently merited. The researchers found smartphone mobile reporting was not only possible, but also effective in improving existing malaria control programs. The nurse, who had effectively no computer or smartphone experience, was only trained for two hours—by the third week of the study, she reported feeling completely at ease when using the device and application platform (Quan et al., 2014).

Valuable resources, like transportation cost and time, was saved through SMS communication between clinics and case investigators, which allowed the investigator to only travel to health clinics when necessary. One of the nurses at a mobile reporting clinic stated that SMS notification improved investigation response: “the malaria team came 20 times quicker than normal” (Quan et al., 2014, p. 7). This study has demonstrated that existing disease control and eradication programs in LMIC, like South Africa, could benefit from the use of mobile devices.

*Nutrition Surveillance in Malawi*

Located in sub-Saharan Africa, Malawi is a low-income country with some of the lowest scores on socioeconomic development. Residents have an average life expectancy of 46.3 years. Roughly 22% of Malawi children are malnourished and underweight (Blaschke et al., 2009). Approximately 13% of Malawi children die before they reach their fifth birthday. Although there are other causes for the high childhood mortality rate, such as AIDS and malaria, childhood malnutrition has been linked to at least 1/3 of all Malawian children’s’ deaths (Blaschke et al.,
Although the Malawi government had deployed multiple programs to address this problem\textsuperscript{15,16}, childhood malnourishment persists at a high rate.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{Figure9.png}
\caption{Childhood Height and Weight Demographics - Malawi Survey 2010\textsuperscript{17}}
\end{figure}

Starting in 2009, UNICEF worked with Columbia University to make improvements on the existing government childhood nutrition program called the Integrated Nutrition and Food Security Surveillance System (INFSS). The system was designed to monitor and measure health conditions from randomly selected Malawian children. Monthly measurements were made at a child’s local Growth Monitoring Clinic (GMC); however, INFSS was noticeably flawed—most of the collected data never entered its national database. The data was often delayed and riddled with incomplete or incorrect entries. Early in the program’s start, data entries took approximately two months to be transmitted; however, by 2008, nearly all patient data was never entered (Blaschke et al., 2009). Time-sensitive information, like a child’s weight and medical records, was not quickly accessible; therefore, efforts to identify and support malnourished children were slowed.

\begin{minipage}{\textwidth}
\textsuperscript{17} http://dhsprogram.com/pubs/pdf/FR247/FR247.pdf
\end{minipage}
The data was originally recorded and entered on paper forms, and there was a lack of consistency and clarity in record organization. An average of 14% of all data had to be discarded due to entry errors and illegible paper records (Blaschke et al., 2009). The figure below shows an excerpt of one INFSS paper form. Here, age is in months and weight is in kg. The last three columns are three measures of childhood health: MUAC (mid-upper arm circumference, in cm), edema, and diarrhea.

<table>
<thead>
<tr>
<th>Child #</th>
<th>Sex</th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>% Weight for Height</th>
<th>MUAC</th>
<th>Edema</th>
<th>Diarrhea</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>M</td>
<td>24</td>
<td>7.6</td>
<td>66.6</td>
<td>13.6</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>12</td>
<td>6.7</td>
<td>66.4</td>
<td>11.1</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>41</td>
<td>F</td>
<td>42</td>
<td>8.6</td>
<td>66.8</td>
<td>13.8</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

*Figure 10 - Original Example of INFSS Paper-Based Health Form*¹⁸

INFSS’ system had deficiencies with its system – missing and erroneous information had led to incomplete datasets, making analysis difficult, if not, impossible. With cases of malnutrition, slow data transmission limited the possible responses that staff and researchers could do (Blaschke et al., 2009).

Although Malawi has a high level of individual ownership and use of mobile phones, they remain technologically underdeveloped (Blaschke et al., 2009). Internet access is quite limited and many residents do not have experience with other devices, such as Smartphones or PDAs. These conditions made basic mobile phones and SMS the most appropriate means for communication—to ensure the greatest rate of program involvement, the evaluators chose the technology with the “lowest common denominator” (Blaschke et al., 2009, p. 10).

Through the mobile platform RapidSMS¹⁹, text messages were used to communicate relevant health measures and information among the program’s stakeholders. To make each child

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¹⁹ https://www.rapidsms.org/
and center distinguishable, unique identifiers were assigned to GMCs and participating children. Their information was immediately classified and stored in INFSS’ central database (Blaschke et al., 2009). The data entry time was cut down from 2 months to, on average, 2 minutes. Once sent to the central database, the information was immediately available to all stakeholders, allowing for transparency and rapid response. INFSS forms were changed to the format shown below in Figure XX (Blaschke et al., 2009).

![Image of RapidSMS Format to Monitor Child Health](image source)

Before being stored in the central database, all entries were sent back to the GMC to be verified. Entry errors were immediately vetted (ex: a child’s height/weight is unreasonable or impossible) by using previously defined health criteria. The error/discard rate went from approximately 14% (2008) to 2.8% (first 2 months of RapidSMS’ launch). It is hypothesized that errors were quickly reduced due to automatic feedback messages sent back to the GMC. These messages gave health-care workers an opportunity to fix entry mistakes. The researchers added that in the last two months of 2009, there was not a single-entry error (Blaschke et al., 2009).

Health situations requiring immediate action were handled by RapidSMS. If a child’s health was recognized as problematic (malnourishment, edema, etc.), RapidSMS automatically sent a message to the local GMC and Health Service Assistants (HSAs) with appropriate actions to take. Prior to the RapidSMS launch, HSAs subjectively determined whether a child required

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further medical attention. Since most of the data was either error prone or missing, there was little monitoring at INFSS’ national level. Because of this, only the most severe health crises were recognized and many cases of mild malnourishment went unaided (Blaschke et al., 2009). After the 2009 pilot launch, GMCs found dozens of mildly malnourished children who would have otherwise been overlooked. In fact, at the local Salima GMC, “HSAs proudly noted that they had identified and treated ten mildly malnourished children who would have otherwise been missed” (Blaschke et al., 2009, p. 24).

Figure 12 - INFSS Flow of Information through RapidSMS\(^{21}\)

The use of portable ICT devices allowed program stakeholders to act quicker and with more accuracy. Time spent entering and transmitting manual data was instead used to provide additional care to patients. Community members reported feeling more confident in the utility of the revised INFSS program. Their average participation rate rose from 40.9% (2007) to 76% (2009) (Blaschke et al., 2009).

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Summary/Findings: Mobile Phone Use in LMIC

Only two cases were highlighted here. There are numerous past and present-day applications of mobile phone use in LMIC. Mobile phones are generally the most feasible devices to use in LMIC applications, since they are popular and efficient in transmitting large quantities of information quickly. Training is minimal, due to its widespread global exposure and low learning curve. Even individuals with no prior experience, like the nurse in the South African malaria eradication study, have demonstrated that mobile device-driven data collection can be feasible and beneficial.

There is a lot to gain in applications where timely and comprehensive action is necessary. Thus, the largest growth of ICT use has been in healthcare (mobile-health, or, “mHealth”). Mobile phones have been used to support many social programs: in Tanzania’s national rabies surveillance and eradication program (Mtema et al., 2016); in the UN and Nielsen’s World Food Programme (WFP) (The Nielsen Corporation, 2015); mHealth initiatives in Bangladesh (Ahmed et al., 2016); in the Ugandan UPPET education program (Brar & Relhan, 2014), amongst others.

Tablets and Portable Computers

Tablets and other portable computers (laptops, PDAs, etc.) are also relatively inexpensive and important portable devices used in data collection within LMIC. While mobile phones require cellular service, tablets and portable computers can be constrained by a region’s internet access. For some LMIC, access is still limited. Even so, there are many contemporary examples of these devices used to educate, connect, empower, and better the lives of residents in LMIC.
The Global Adult Tobacco Survey

The Global Adult Tobacco Survey (GATS) was conducted by the World Health Organization (WHO) and the United States’ Center for Disease Control and Prevention (CDC) to geographically characterize levels of tobacco use. The survey’s primary stakeholders, WHO and CDC, argued that personal tobacco use is linked to avoidable illnesses and mortality (Pujari et al., 2012). The WHO and CDC sought to estimate the size and patterns of tobacco use. These findings would then be shared with other stakeholders (NGOs, governments, etc.) to create and administer anti-smoking programs. Fourteen LMIC were included in the survey; residents totaled approximately 3.6 billion people (Pujari et al., 2012). A pCAPI-administered survey was used, since GATS focused on a large and varied target population, with a high level of mobility and structural constraints.

During 2008-2011, GATS was administered using pre-programmed PDAs; however, based on a country’s specific needs/capabilities, the survey was conducted through one of three data management plans (Pujari et al., 2012). Countries with extensive experience and access to wireless internet were assigned “Model A”, which was a purely web-based data management procedure. Model A used the most technologically advanced method of obtaining and organizing GATS data. Survey and sample information was wirelessly transmitted to portable devices. After administering the survey, the results were sent to a field-supervisor for consistency checks. Finally, checked results from the field were wirelessly sent to a national data center for further analysis (Pujari et al., 2012). Many LMIC did not fit Model A’s requirements, so Model B and C were also designed to accommodate specific needs and capabilities.
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Model B was assigned to countries with wireless capabilities and experience, but whose access was not particularly far-reaching. This method combined virtual and physical methods of data transmission. Data collected from the portable device was transmitted to a field-level center via SD card, requiring physical contact. Once at the field, data was aggregated and transmitted wirelessly through supported file transfer sites (FTP) or through email (Pujari et al., 2012).

![SD Card](https://images-na.ssl-images-amazon.com/images/I/715mkNMEXAL._SL1500_.jpg)

Figure 13 - SD Card. Physically Transfers Data to Other Devices

Finally, Model C was used to support countries with minimal or no wireless capabilities. No country used this method exclusively; however, some countries had remote regions which required the use of Model C. Although the data was administered on a portable electronic device, the data itself was manually transferred through SD cards. Here, there was no aggregation at the field level; survey-level data was manually delivered to the national data center for analysis (Pujari et al., 2012).

Nearly all surveyors finished their fieldwork prior to the scheduled end date. Staff commented that their work was made simpler, since all questions were rerouted automatically. Money and time were saved due to automated data checks, and globally, no data was lost (Pujari et al., 2012). Surveys were still conducted in challenging conditions, including Bangladesh’s monsoon season and in Egypt’s desert regions. PDAs stored and transmitted high quality survey data without the logistical challenges of manual record keeping. Initially, the cost of electronic data collection was higher than paper-based methods; however, later costs were reduced from

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improved data quality and availability (Pujari et al., 2012). Overall, there was not a significant
difference in cost between the two methods.

![GSS Portable Interface Screenshot](image)

The GATS survey also highlighted how the use of a technical device (portable computer),
in a large-scale application, must be designed to meet the standards for all participants. Not all
LMIC have the same technical capabilities, thus, the device itself must be adaptable to meet a
variety of situations. Poland’s technical capacities allowed Model A to be used, while Turkey
and Ukraine required Model B. Some countries, like China and Egypt, used Model B; however,
these countries had some areas with little capacity to support a wireless network, so Model C
was used (Pujari et al., 2012). This example highlights that all regions, even those with the least
 technological access, can be accommodated to reap benefits from electronic data collection.

*HIV Patient Care System in Kenya*

Sub-Saharan Africa has been described as the “epicenter” of the global HIV epidemic—
approximately 2/3 of all HIV positive individuals live in this region. Unfortunately, within sub-
Saharan Africa, approximately 50% of all HIV positive individuals live in rural regions, typically

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in areas where sufficient outreach and care is harder to implement (Wools-Kaloustian et al., 2009). Establishing HIV treatment centers is difficult in these resource-strapped regions. For instance, only four sub-Saharan countries (Namibia, Rwanda, Botswana, and Senegal) have met the goal of having at least half of their HIV-population receive antiretroviral treatment (ART).

Kenya, an African LMIC, has continuously struggled to provide adequate ART to its HIV-positive residents. WHO has estimated that Kenya falls short of approximately 730 doctors and medical staff who are trained in HIV treatment (Wools-Kaloustian et al., 2009). Similar shortages in medical staff plague most of the sub-Saharan region, thus, researchers are now conceptualizing alternative solutions to provide critical ART to persons in need.

![HIV Prevalence in Kenya, by Division](https://openi.nlm.nih.gov/imgs/512/228/3257551/PMC3257551_TOAIDJ-5-125_F2.png)

One of the technology-based solutions was tested in the Kosirai Division, located in western Kenya. The Kosirai Division, comprised of 24 sub-locations, was served by the Mosoriot Rural Health Center. This center served approximately 3500 HIV-positive patients that required ART (as of March 2008). Of these patients, only 1845 had received their treatment (Wools-Kaloustian et al., 2009). The center was severely understaffed: three clinical staff supported the clinic five times per week, and one physician worked one day per week.

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The health center did not have enough personnel or resources to provide adequate care for its patients. An alternative solution was proposed using non-clinical staff to provide non-critical medical care and administer ART. The plan included using PDA devices to create and support a community-based HIV treatment system. The community care coordinators (CCCs), who would provide care for other HIV patients, were HIV-positive themselves. The nine selected CCCs were from the Kosirai Division, were clinically stable, and had already been receiving ART. Vetting of CCCs occurred by age, level of interest in promoting HIV patient care, and inclination to maintain patient privacy (Wools-Kalousian et al., 2009).

The CCCs handled all their duties through PDA-administered instructions and automated electronic forms. All symptoms and vital signs were entered in the portable device; if a patient answered ‘yes’ to any HIV-specific symptoms, an algorithm would automate additional questions related to that symptom. An example of the vomiting symptom’s algorithm is depicted below in Figure XX. Within the questionnaire, if an entry triggered any pre-defined health alerts (ex: problematic side effects, low vital signs, etc.), the device immediately delivered a detailed list of instructions for the patient and CCC. For example, if the patient’s condition required an immediate visit with the local health clinic, the PDA would prompt specific steps to do so (Wools-Kalousian et al., 2009).
The goal of the program was to alleviate the clinic’s medical staff of their non-critical duties: there was a 50% drop in clinic visits, although, the same level of patient care was provided. In a later follow-up study, there were virtually no differences in health outcomes between patients receiving CCC visits vs. only clinical visits (Selke et al., 2011). The PDAs collected patient data, which was transferred to the clinic staff; however, the time-consuming task of gathering this information was completed by individuals motivated by HIV patient care. In the impoverished area of sub-Saharan Africa, where local taboos and resource limitations make receiving care difficult, the use of PDA devices by community-based health advocates has shown to be a feasible alternative.

Summary/Findings: PDA/Portable Computer Use in LMIC

Like mobile phones, portable computer devices, like PDAs and tablets, can be useful solutions to collecting and transmitting information in LMIC. They provide accessibility to hard-to-reach populations, like HIV patients in rural Kenya, thus, these devices can promote effective outreach and visibility when transmission was otherwise difficult or impossible. There have been many recent studies done on the feasibility of portable computer devices: a GPS-

25 http://www.jiasociety.org/content/12/1/22
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referenced survey conducted in rural Burkina Faso (Byass et al., 2008); large-scale collection of tuberculosis patient records in Peru (Blaya et al., 2009); the compilation of baseline survey data in rural sites within Bolivia (Escandon et al., 2008).

Many of these feasibility studies have found similar results: the proper use of these portable devices can significantly reduce entry errors and submission time. Automated data entry and checks have also improved the accessibility to important and accurate information.

Biometric Devices

Biometric devices, like mobile phones and portable computer technologies, replace the need for paper-based record collection. Biometric devices function by taking a measurable and exclusive attribute (physical or personal) to identify or verify an individual (Woodward, Orlans & Higgans, 2003). Verification occurs remotely through a database, which, due to the feasibility of other forms of ICT in LMIC, is becoming easier to create. Developed countries typically use biometric devices for criminal justice and security. On the other hand, in LMIC, biometric devices are increasingly replacing traditional forms of resident identification and administrative records. Between 2005 and 2010, the use of biometric devices grew an average of 34% in developing countries (Gelb & Clark, 2013). As seen in Figure XX below, dated in 2012, there had been over 150 different examples of biometric devices used to identify persons within LMIC. There are already over one billion individuals that have been identified by use of a biometric device (Gelb & Clark, 2013).
The most popular biometric devices use one's fingerprint, iris pattern, and/or facial features. Newer methods have also been developed, using personal characteristics like ear and vein features (Gelb & Clark, 2013). These techniques offer an alternative to identifying individuals who may not be able to be identified using fingerprints or iris scanners (e.g., manual workers, elderly, infants, patients with eye degradation/surgery). Most of these alternative forms will likely not be feasible or useful in a large application (Gelb & Clark, 2013).

There are many cases of biometric devices being used in LMIC schools, hospitals and clinics, voter registration, among others. A few examples are considered.

Case Studies

**Biometric Linking of Community and Hospital Data in Ghana**

Ghana’s healthcare system uses patients’ paper records to link their personal data and health-care information. Like many systems still reliant on paper-based records, much of the system is afflicted with high incidents of duplicate, mismatched, and misplaced records (Odei-
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Lartey et al., 2015). Multiple patients identified with the same identity is a common occurrence, which raises the possibility of identity theft and/or improper diagnosis and treatment. The Kintampo Health and Demographic Surveillance System (KHDSS), directs attention to personal demographic, health, household, and education data. KHDSS serves approximately 140,000 people with a dozen rural health clinics, two regional hospitals, and almost fifty health-planning service centers (Odei-Lartey et al., 2015). Although the system is quite large, it suffers from the same record-based challenges discussed above.

Biometric devices were used in a 16-month study (January 2010-June 2011) within Ghana’s Kintampo District, to assess their feasibility in building a patient database. After this 16-month period, the sensitivity, specificity and precision of this system was accessed. This project used multiple types of portable devices – a biometric fingerprint scanner, portable web-camera, and a mini-laptop (Odei-Lartey et al., 2015). First, a district-wide database was created. It included biometric indicators, notably all ten fingerprints, and demographic, and photographic information for each resident.

The researchers believed that multiple forms of identity verification would be helpful in circumstances where one form was not sufficient. This is helpful within the Kintampo District, because many of its residents are rural/manual hard laborers and youths. These subpopulations are known to have difficulties with fingerprint identification (Odei-Lartey et al., 2015). For instance, young children’s fingerprints are still developing between the ages of 0-12, making their fingerprint unreliable. The data was gathered by twenty district members—each had received their high school diplomas and had some basic computer experience (Odei-Lartey et al., 2015). Thus, training was minimal, and they were briefly instructed how to properly use the fingerprint scanner, web-camera and mini-laptop.
The data collection process was mobile. Most residents were enrolled in the areas in and around the two hospitals. All other residents were enrolled at other local health clinics and their residences (Odei-Lartey et al., 2015). The program staff completed the database with approximately 83.4% of all residents being covered (117,403/140,000). The immediate areas around the two major hospitals had collected 100% of residents’ information (Odei-Lartey et al., 2015). The staff reported that there were no residents who refused fingerprint or photograph collection. Once a resident was enrolled in the registry, the hospital staff used the information to verify a patient’s identity.

Patient identification was first made with fingerprint and photograph information. If the patient’s fingerprint was matched to database records, a photo of the patient would appear. Staff had to verify that the patient had matched the image. Approximately 65.7% of all visiting patients were matched to an identity in the database—all of whom were correctly identified (0% mismatch) (Odei-Lartey et al., 2015). Other patients were unable to be identified by fingerprint data. Most of these individuals were described as manual laborers, farmers, and/or children.

Other personal/demographic information was used for individuals in unsuccessful cases of fingerprint verification.

Overall, when combining the fingerprint and personal information from all patients, 85.3% of individuals were identified. Of the individuals identified, approximately 82.5% were then correctly verified by photograph. Personal identification alone, without use of any biometric measurement, resulted in 57.6% of individuals being identified; of these, 82.5% were identified successfully (Odei-Lartey et al., 2015).

The use of personal identifiers alone was unsuccessful, because of situations with name inconsistencies and misspellings, and unreliable personal details (age/birth date). Using a combination of fingerprinting and other personal information had resulted in the highest percentage of correct identity verification. The results from the study indicated that, if an individual’s fingerprint can be read, it resulted in a 100% correct identification. The use of personal information helps to supplement the identification of those not identified by fingerprint; unfortunately, it is far less accurate (Odei-Lartey et al., 2015).

India’s Aadhar Program

When looking at applications of portable biometric devices in LMIC, there is perhaps no bigger undertaking than India’s present-day Universal ID program, Aadhaar. India’s government began the national biometric identification system in 2009. As of 2017, the Aadhaar system has been used over 4 billion times in nearly all regions of the country. Over 1.1 billion Indians have been enrolled, encompassing approximately 86% of India’s population (Parussini, 2017). Most of the individuals who are not enrolled in Aadhaar are infants—approximately 99.5% of Indians 18 and older have already enrolled.
Aadhaar issues all residents a unique 12-digit ID number and official ID card (Gerdeman, 2012). The identification process links a resident’s unique biometric data to his/her personal and demographic information, including their name, age, birthday, sex, and place of residence. An enrollee’s information is linked by their ten fingerprints, two iris patterns, and a recent photograph (Gerdeman, 2012).

![Image](image)

*Figure 19 - A Woman Getting Her Irises Scanned, India*  

A large-scale program like Aadhaar requires multiple forms of biometric information to be successful. Iris information includes much more personal data (thus, uniqueness) than what is offered by fingerprints; however, fingerprints are simpler to capture (Gelb & Clark, 2012). Thus, if fingerprints do not authenticate a resident’s identity, the alternative option, iris scans, is used.

Multi-mode biometric identification is thought to be more inclusive of the entire population, since many residents may have worn-down (or undeveloped) fingerprints and eyes—but likely not both. Although, approximately 0.14% of the population did not have usable irises or fingerprints (Zelazny, 2012). In these cases, photographs and other demographic information must be used for their identification. These situations do require manual processing; however, most identifications are automated through biometric devices.

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Prior to the implementation of the Aadhaar system, India had virtually no national program of identifying and verifying its residents and their records. In the early years of 2000, it was estimated that only 55% of all births and 46% of all deaths were registered in India (Gerdeman, 2012). Many of India’s poorest and neediest residents were unable to receive any government-issued goods and services, since they required access to official identification documents. India also had a problem with fraudulent and stolen personal identities, since there was little officials could do to verify one’s identity. This resulted in massive costs for the state, since services were not properly delivered (Gerdeman, 2012).

Aadhaar’s primary purpose is to prevent identity fraud and theft, and to ensure and extend services to Indians who had never been previously registered. The Aadhaar program provides an opportunity for disadvantaged peoples to participate in activities that promote economic development. Doshi (2016) had stated: "millions of people under the scheme will also get access to bank accounts for the first time" (Doshi, 2016).

![Figure 20 - Portable Fingerprint Scanner, India's Aadhaar Program](https://qxprod.files.wordpress.com/2017/03/aadhaar-1.jpg?quality=80&strip=all)

The biometric devices used in the Aadhaar program are not uniform by model and supplier. As of 2017, there are four different fingerprint devices and four different iris
scanners\textsuperscript{30}. Although different devices and suppliers can be used, all are certified to meet standards established by the Indian Government\textsuperscript{31}. Some examples of required standards include robustness (e.g., temperature, drop shock, dust, humidity), and accuracy (Zelazny, 2012). Once these standards are met, a certification is issued for that supplier for 3 years; however, once this period ends, suppliers must continue to meet Aadhaar standards. Companies must create portable devices that can be applied in challenging and diverse environments, while still meeting important validity and reliability standards (Gelb & Clark, 2013).

"When combined with technology such as mobile phones, biometrics can help streamline and facilitate payments and services in remote, underserved locations" (Gelb & Clark, 2012, p. 2). Aadhaar is a great example of how technology can be used to link one’s identity to their records. It also shows that such an endeavor is feasible in a LMIC setting. Across India, Aadhaar is now the primary method of identity verification, and in many applications, is mandatory to receive services (Parussini, 2017). As of June 16\textsuperscript{th}, 2017, all bank accounts must be linked to an Aadhaar account: over 377 million unique Aadhaar IDs are now linked to bank accounts (Parussini, 2017). All staff within India’s government must now take attendance using identity verification through Aadhaar’s biometric devices (Pandey, 2014). Other emerging applications include enrollment in India’s state-funded schools and elections.

\textit{Summary/Findings: Biometric Devices in LMIC}

When it comes to identification and verification within LMIC, biometric devices have been proven quite helpful in closing "identity gaps". The two examples detailed in this paper had shown how these devices can serve on different scales and applications.

\textsuperscript{30} http://www.stqc.gov.in/sites/upload_files/stqc/files/List_BDCS_Enrollment\%20Devices_ver2.4_16May2017.pdf
\textsuperscript{31} https://uidai.gov.in/images/resource/aadhaar_registered_devices_2_0_09112016.pdf
Other contemporary examples include SimPrints, a company that delivers portable fingerprint scanners to LMIC. SimPrints has been used in a variety of applications and regions, including Zambia and Bangladesh\textsuperscript{32}. In Zambia, eSchool 360, uses SimPrint fingerprint devices to conduct their daily school attendance (Patel, 2017). Biometric devices replaced paper-based attendance to combat issues of low student and teacher attendance.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{simprints.png}
\caption{How SimPrints Work\textsuperscript{33}}
\end{figure}

Biometric devices have demonstrated viable benefits in many applications where personal identification and verification is desired. These advantages may be more pronounced in LMIC, where many individuals are wrongly identified (or, never at all). Although most biometric devices are still used in small-scale applications, there is some evidence that large-scale applications, like Aadhaar, can be feasible. When linked with other technical devices, like mobile phones and portable computers, information from a variety of sources can be linked, making findings and decisions more thorough.

\textsuperscript{32} \url{https://www.simprints.com/projects/}
\textsuperscript{33} \url{https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4356282/}
Other Considerations: Software, Training and Potential Challenges

Effectual data collection in LMIC is not solely attributed to hardware technology. For successful data-driven research, important considerations must also be given to software and technical training.

Software

The hardware (i.e., portable technical devices) would be insignificant without the support of adequate software. Both hardware and software create the user interface that makes research undertakings possible. The cost of software can range from free to expensive (in thousands of dollars). Software varies in style, function, complexity, and availability. Programs can be selected and designed specifically for data visualization, survey development, geospatial mapping, mobile and automatic messaging, and general data collection. Software can be open- or closed-source. The former type, open-source software, gives users more flexibility to design an interface that is best suited for their application.

One example, Open Data Kit (ODK) Collect is a free and open-sourced data collection software, and was originally designed for LMIC research. Developers have used this software to create their own data collection solutions, which can vary in complexity and scope. Cited in a previous example, ODK Collect was used by the researchers in the South African malaria eradication program.
Other notable software used in data collection are Magpi\textsuperscript{35} (rapid and automated mobile messaging software), Formhub\textsuperscript{36} (open-source data collection software), Fulcrum\textsuperscript{37} (geospatial mapping and data software), and Universal Registration Client\textsuperscript{38} (biometric database builder). These examples are just a few of the many programs available for use in LMIC research.

Mobile phones, portable computers, biometric devices, among other forms of hardware, function because of software. It would be unjust to describe how portable devices can aid in LMIC research, without also acknowledging the importance of data-focused software.

**Technical Training**

Technical proficiency is a significant concern, because accurate and reliable data can only be gathered if users understand how to collect it. Although hardware and software is typically designed to be “user-friendly”, there are no guarantees that program staff will have previous technical competence. When addressing whether technical training should be

\textsuperscript{35} http://home.magpi.com/
\textsuperscript{36} http://formhub.redcross.org/
\textsuperscript{37} http://www.fulcrumapp.com/
\textsuperscript{38} https://www.aware.com/biometrics/urc/

The duration of a training program depends on many factors, including staff members’ previous experience with the technology of interest, and the importance of collected data (Tyson & Dietlin, 2004). Many studies have provided evidence that technical training can be accomplished rapidly, even in cases of technical illiteracy (Aviles et al., 2008). In South Africa’s malaria eradication program, an elderly nurse used a mobile device to disseminate her patients’ information. She had no previous technical experience and only received two hours of technical training (Quan et al., 2014). Even so, her use of a mobile device had reduced the time between diagnosis and follow-up (14.7 to 2.5 days), as well as the time between diagnosis and entry into a provincial malaria database (33.0 to 7.3 days). From the other cited case studies, durations of training sessions ranged from four hours (Malawi’s child malnutrition program) (Blaschke et al., 2009) to over one week (Kenya’s Mosoriot HIV study). Some studies did not cite the exact duration of their training session; however, all studies did mention using technical training in their programs.

In situations where data security, accuracy, and time-sensitivity are the highest, technical competence is imperative. Such circumstances include critical health initiatives (e.g., South African malaria eradication, Malawian child malnutrition program), and programs with higher personal privacy concerns (e.g., sensitive-topic surveys, Aadhaar’s national database). Adequate technical ability must be ensured prior to the deployment of program staff. When estimating the cost for a program with electronic data collection, it is important to consider the cost of technical training.
Conclusion

Portable devices continue to demonstrate their utility in LMIC research. Mobile phones, portable computers/PDAs, and biometric devices have served in variety of challenging applications. These devices can transmit information faster and more accurately than paper-based collection methods. In many cases, the cost of electronic data capture is equal to or less than the cost of traditional paper-based procedures. The other benefits offered by portable technical devices make electronic data capture a favorable method to conduct research in LMIC.

The developments in ICT are far-reaching. Businesses and researchers share a great interest in increasing developing countries’ access to ICT. For example, Airbus and OneWeb have recently begun the construction of a “mega-constellation” satellite program, whose goal is to provide worldwide broadband internet access (Amos, 2017). The Airbus/OneWeb program plans to have the satellite constellation operational by 2019; however, the companies do not expect the program to be fully operational until approximately 2025. Other programs with a similar goal are being developed by companies like Boeing, SpaceX, and ViaSat (Amos, 2017). Public and private sectors share an interest in promoting portable and non-portable ICT.

![Global Digital Snapshot](image)

*Figure 23 - (As of Jan 2017) Global Digital Trends*

With sustained growth in digital technologies, it is likely that portable electronic devices will continue to aid in data-driven research and development in LMIC.

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