Global Partnership for Sustainable Development Data

TRENDS
Thematic Research Network on Data and Statistics

Data Sharing via SMS Strengthens Uganda's Health System

A Case Study of mTRAC, Uganda

Prepared by SDSN TReNDS

The health system in Uganda is highly decentralized and geographically dispersed, with thousands of health facilities spread across 112 districts. Low capacity for information sharing between distant health facilities and the centralized health ministry resulted in low stocks of life-saving medication for malaria, slow or inadequate responses to disease outbreaks, and misappropriated funds, among other issues. The Ugandan government, with the support of UNICEF, began leapfrogging this outmoded system in 2011 by introducing an SMS-based health reporting program called mTRAC. This program has supported significant improvements in Uganda's health system, including halving of response time to disease outbreaks and reducing medication stockouts, the latter of which resulted in fewer malaria-related deaths. mTRAC has cost-effectively enhanced the quality and exchange of health data and strengthened the capacity of practitioners to use this data to improve health outcomes. The recurrent costs of the program are being taken on by the Government of Uganda and its success is being replicated in other low-income countries, testifying to the value of investing in quality data and efficient data sharing enabled by mobile technology.

Context

Lack of access to quality healthcare in Uganda is an endemic challenge. Maternal and infant mortality rates are some of the worst in the world, at 343 per 100,000 live births and 38 per 1,000 live births respectively (WHO et al. 2015; UNICEF et al. 2017). Malaria kills some 70,000 people in Uganda annually, accounting for 20 percent of all deaths in the country (DFID 2014). The WHO-recommended treatment for malaria is artemisinin-based combination therapy (ACT) (WHO 2018), but Uganda has struggled with ACT stockouts, meaning that health facilities would regularly run out of medicine supplies (DFID 2014).

The mTRAC program required an initial three-year investment of approximately US$4.5 million, with costs going towards capacity development, technology, and staff training. The UK Department for International Development (DFID) was the primary donor (DFID 2014).

These problems were historically compounded by the lack of a comprehensive health management information system. Health facilities have to provide district health offices with weekly surveillance forms, which report on disease incidents, treatments and other health issues (Muhereza and Mukasa 2018). Under the previous, paper-based system, surveillance forms had to be physically delivered over distances as far as 100 kilometers (Nabunya 2013). Given the great expense and poor infrastructure, facilities would routinely fail to provide weekly health reports in a timely manner.

With support from DFID, WHO, and UNICEF, Uganda's Ministry of Health (MoH) implemented an innovative package of interventions to overcome these obstacles and build on unprecedented rates of growth in telecommunications infrastructure and high rates of mobile phone penetration in Nigeria (DFID 2014). The package, mTRAC, aimed to use mobile phones that already existed in health facilities and communities to track health service quality, drug access, and disease patterns, with a particular focus on malaria (DFID 2014).

Description of Data Solution

The mTRAC program—short for "mobile tracking"—is a phone-based information sharing system that enables timely transfer of health data among beneficiaries, health professionals, and the Ugandan MoH (Yoweri 2018). It is based on RapidSMS, an open-source platform from the UNICEF Innovation Unit (Huang, Blaschke, and Lucas 2017).The application was specifically designed to integrate with the national health system, with the format of SMS reports matching the structure of existing health surveillance forms. Although initial priority was given to malaria, mTRAC collects data on 17 different diseases, as well as public health emergencies (DFID 2014). It also monitors 64 key medicines, including HIV treatments, drugs for tuberculosis patients, and vitamins for children (Muhereza and Mukasa 2018).

> **"We don't have to spend money on fuel to drive to national medical stores just to inquire about drugs. We simply SMS and this triggers an immediate response that culminates in delivery of medicines to the health facility."**
> **— Cathy Mugisha, Medical Records Officer at Mukono Health Center (UNICEF 2014)**

The mTRAC program consists of three data collection techniques: an SMS-based health facility tracking mechanism; an anonymous hotline that allows members of the general public to submit complaints by SMS to the government about local health facilities; and U-Report, an SMS service for registered stakeholders to share feedback on developmental issues (DFID 2014; UNICEF 2018). The program has also enlisted the support of Village Health Teams (VHTs), groups of volunteers that serve as links between communities and health facilities (The Republic of Uganda Ministry of Health 2018). In addition to collecting health data, mTRAC facilitates two-way communication between district offices or other central units and local health workers (Berman 2012; Huang, Blaschke, and Lucas 2017). The exchange of information is managed by the District Health Information System

(DHIS) (Muhereza and Mukasa 2018), an open-source platform that has been deployed in 60 countries ("DHIS2 (District Health Information System 2)" 2018). DHIS data warehouse collects between 10,000 and 16,000 SMS messages every week (Muhereza and Mukasa 2018).

Implementation

The mTRAC program was launched in 2009 by the nonprofit Foundation for Innovative New Diagnostics in two of Uganda's 112 districts (Huang, Blaschke, and Lucas 2017). UNICEF approached the Foundation in 2011 and proposed scaling the program to the entire country in a single year. Implementation was not as rapid as first suggested; by March 2012, mTRAC was extended to approximately 1,000 facilities in 28 districts, and by March 2013, it reached every public health facility in all 112 districts. Statisticians and health officers were trained on form completion, SMS reporting, and data analysis (Blaschke 2013). By June 2015, mTRAC had also reached most nonprofit and non-government health facilities (Huang, Blaschke, and Lucas 2017). As of 2018, 52,946 health facility workers had been trained on mTRAC, representing 5,684 health facilities across Uganda (Muhereza and Mukasa 2018).

As of 2018, 52,946 health workers at 5,684 health centers across the country were using mTRAC (Muhereza and Mukasa 2018).

The Ugandan MoH has taken on additional responsibility, with ongoing support from UNICEF (Muhereza and Mukasa 2018). Among other tasks, the government trains health facility workers on procedures for reporting data. The system produces a dashboard that helps districts monitor the reporting status of facilities and provide guidance to local health workers (Muhereza and Mukasa 2018). The MoH also publishes weekly reports that include maps of recent health data and descriptions of trends across the country (National Malaria Control Program, WHO Uganda Country Office, and Uganda Malaria

Surveillance Project 2018). Weekly data outputs include counts of deaths resulting from identifiable conditions, maternal mortality, and infant mortality, as well as testing and treatment rates for the National Malaria Control Program (Muhereza and Mukasa 2018).

Funding

Initial funding came from DFID, which was particularly eager to see the program used to tackle malaria (DFID 2014). Over its three years of involvement, DFID invested £3,005,919 (US$4,582,194) towards mTRAC development and implementation. Costs included technical equipment, personnel training, and mobile phone bills. Additionally, £556,682 (US$848,601) was used to purchase 10 million doses of ACT. £65,908 (US$100,470) was spent on monitoring and evaluation. Following the close of DFID funding for the project in 2014, the Government of Uganda has provided financial support for mTRAC and now covers approximately 70 percent of project costs, with UNICEF and the WHO responsible for the remaining 30 percent (Muhereza and Mukasa 2018). Based on figures provided in 2018 (Muhereza and Mukasa 2018), the annual budget for mTRAC is estimated to be between $800,000 to $850,000. Ongoing negotiations are ensuring that the government will be able to assume complete financial responsibility in the future.

The Government of Uganda now covers 70 percent of the estimated $800,000 to $850,000 in annual costs, with the remainder covered by UNICEF and the WHO (Muhereza and Mukasa 2018).

Impact

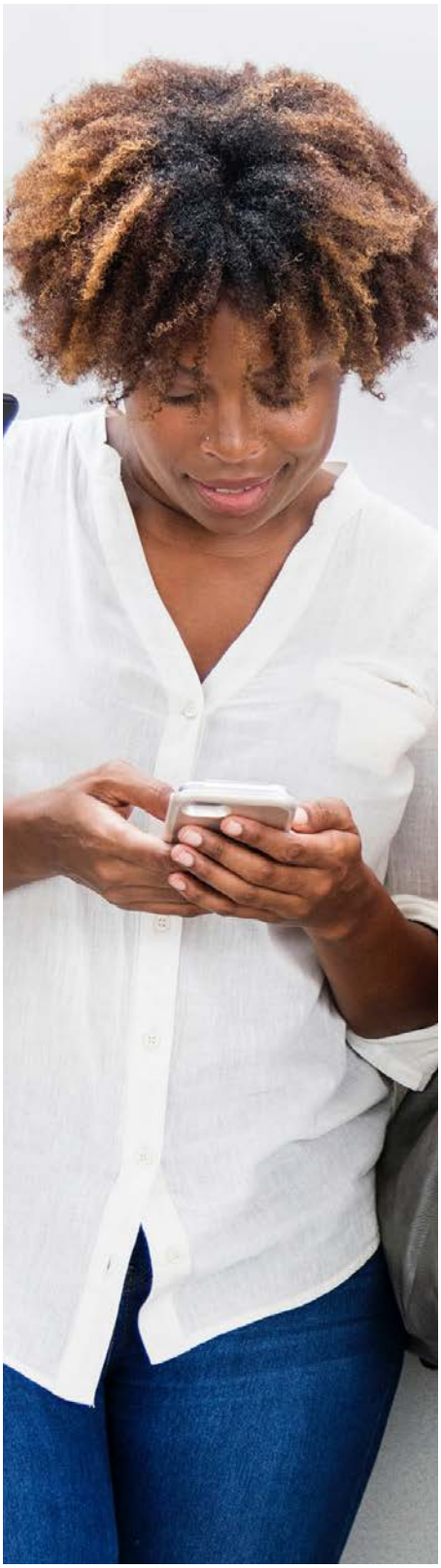
DFID evaluated the efficacy of the mTRAC program after each of its first three years of operations and identified a number of positive impacts. DFID's first-year evaluation found that mTRAC was improving transparency and accountability of health services, enabling more informed responses to drug shortages and medical

issues, and improving overall communications in the health system. The second-year evaluation concluded that the program was on track to achieve results without overspending (Department for International Development 2013). DFID's 2014 Project Completion report scored the mTRAC intervention with an "A" grade and determined that several expectations had been exceeded (DFID 2014). Successes included the use of mTRAC for emergency response, improved reporting, and efficient health center drug stocking. It has also served as inspiration for health programs in other countries.

> **"My proudest moments have been seeing community health workers [...] get excited about learning a new function for their personal phones: positively impacting the health of their families and neighbors."**
> **— Health systems consultant Dr. Davis Musinguzi (Musinguzi 2012)**

Emergency Response

UNICEF credits mTRAC with nearly halving the response time to disease outbreak. According to local UNICEF officials, tracking and responding to a disease outbreak previously took five to six days but can now take just two to three days with the support of mTRAC data (Muhereza and Mukasa 2018). With the system's near-real-time data, health professionals and institutions can implement quarantines and other protective measures more quickly. In particular, mTRAC aided the response to the 2012 Ebola outbreak in Kibaale District (Berman 2012). Likewise, during the 2012 Marburg outbreak, some 9,900 SMS messages sent to 825 health workers across five districts through mTRAC provided immediate exchange of outbreak details and response guidance. MoH epidemiologists also used the program's disease reporting functions to actively respond to cholera, measles, meningitis, and other diseases (DFID 2014). The MoH and district health teams were able to respond to a typhoid outbreak in 2015



within hours of its emergence through near-real-time reporting in mTRAC (The Republic of Uganda Ministry of Health 2018).

Reporting

Two related measures of success are the completeness and timeliness of weekly health facility reports (Muhereza and Mukasa 2018). Replacing paper-based health surveillance systems with mTRAC has enabled a number of districts to reach reporting levels never previously achieved. For example, Koboko District received mTRAC in March 2013 (Charason 2013); three weeks later, the district achieved a 93 percent reporting rate and, by the following week, all district health facilities were reporting. Moreover, the completion rate of surveillance forms has increased nationally, rising from 50 percent in January 2015 to 68 percent by December 2015 (Huang, Blaschke, and Lucas 2017). As of 2018, Uganda has reached a 78 percent completion rate (Muhereza and Mukasa 2018). Furthermore, 65 percent of facilities are submitting surveillance forms on time, although there has been difficulty surpassing this level (Muhereza and Mukasa 2018).

Malaria Treatment Stocks and Outcomes

Along with improving general health surveillance, mTRAC provided a platform for districts to share real-time reports on the availability of the malaria treatment ACT. None of the 112 districts were able to report ACT levels in June 2011 but by August 2013, there were 89 districts (79 percent) reporting ACT levels (DFID 2014). By March 2014, all 112 districts were reporting stock levels. As of 2018, districts are instead reporting ACT stock balances on a weekly basis, while reports on most other medicines are given on a monthly basis (Muhereza and Mukasa 2018).

A stated goal of DFID's support was to reduce the number of malaria-related deaths through swift identification and improved availability of treatments (DFID 2014), and this objective was supported by the production of data on ACT supplies. A key indicator was the proportion of health facilities reporting no stockouts of ACTs (DFID 2014). The project set a target of 50 percent, compared to a baseline of 21 percent.

Surpassing expectations, 84.6 percent of facilities reported no ACT stockouts by March 2014 (DFID 2014). All district officials interviewed by the project evaluators testified this success was due to the mTRAC program, because ACT could be distributed from facilities with an oversupply to facilities with a shortage. The testing rates of suspected malaria cases also increased from 82 percent to 95 percent between 2011 and 2016 (UNICEF, DFID, and WHO 2016). Previously, the malaria morbidity rate was at 40 percent but by 2016, it was being maintained at 17 percent (UNICEF, DFID, and WHO 2016).

However, the data also suggests that there is continued ACT wastage and that communication between districts could be improved (DFID 2014). The national medicine supply chain struggled to keep up with demands for reallocating ACT resources, and this service was temporarily halted (Huang, Blaschke, and Lucas 2017). Exchanges have renewed, but the government now requires that a select set of drugs receive national-level approval before being redistributed (Muhereza and Mukasa 2018). Concerns about navigating the new regulations has resulted in only 35 percent of districts internally redistributing drugs between health facilities (Muhereza and Mukasa 2018).

The anonymous hotline helped save $400,000 in misappropriated funds in 2013 as a result of citizens reporting concerns about health facilities (DFID 2014).

Cost Savings

A formal evaluation of cost savings has not been performed. According to UNICEF officials, the project developed more "organically," so the costs of the previous reporting system were not calculated (Muhereza and Mukasa 2018). Instead, resources have been concentrated towards creating a stable platform that integrates with the national statistical system. Yet the same officials point out that the value of mTRAC is underscored by the fact that the Ugandan government has

decided to take responsibility for continuing and funding the program (Muhereza and Mukasa 2018).

Program consultants say that, although this cannot be easily quantified, health facilities are saving on the expenses of transportation and staffing that were required to submit paper reports (Musinguzi 2012). The anonymous hotline has also helped realize other efficiencies. In 2014 alone, information provided by concerned citizens saved $400,000 in misappropriated funds (DFID 2014), and the service has continued to help save resources (Muhereza and Mukasa 2018). Most notably, there has been an increase in health facility working hours, along with a 12 percent reduction in absenteeism, and the government has been better able to fight against illegal institutions offering health services (Muhereza and Mukasa 2018).

Additionally, mTRAC allows for rapid surveys of the medical system. For $150, an effective survey can be conducted in 48 hours via SMS (DFID 2014). The MoH is able to receive responses from 95 percent of facilities within 24 hours, and the feedback informs the distribution of supplies (UNICEF, DFID, and WHO 2016). This approach was used to survey the availability of refrigerators and vaccines at health facilities, and vaccine stockouts were then significantly reduced (DFID 2014).

These outcomes have been supported by the U-Report campaign, which has engaged over 250,000 volunteers representing every community in the country (DFID 2014). U-Reporters have aided verification of anonymous complaints, are polled about local health and developmental issues, and have become resources for parliamentarians.

mTRAC, due to its success, has served as a template for other mobile-based health data reporting systems, including Liberia's mHero program (Blaschke and Alinaitwe 2015).

Replication

mTRAC has also served as a template for Liberia's mHero program (Blaschke and Alinaitwe 2015). IntraHealth International and UNICEF collaborated on mHero in response to Liberia's 2014 Ebola crisis, creating a platform that could provide training, surveys, and other communication via SMS (BenDor 2015). By August 2016, over 8,000 health workers were connected to the mHero system and Liberia formed a multi-year plan for its extension (Oaiya 2016).

Ongoing Challenges

Although mTRAC has improved disease response and the accountability of health facilities, the program has experienced challenges with achieving universal reporting and extracting the full value from available data:

- All 112 districts are participating in mTRAC, but surveillance completion is not evenly distributed. Out of the 112 districts, 70 are above the suggested DHIS reporting rates and 35 districts are between 60 percent and 70 percent, but 17 more remote districts continue to experience difficulty (Muhereza and Mukasa 2018).

- mTRAC is more convenient than prior reporting procedures, but data still needs to be collected from source documents. It is a supplement to—not a replacement of—the existing system, and reporting can still be time-consuming (DFID 2014). Also, there is sometimes network interference, and this can negatively impact SMS reporting (Yoweri 2018).

- Facility reporting may have improved, but VHTs have experienced less success. Starting with no VHTs submitting timely reports, mTRAC helped 60 percent do so on time by March 2013. However, this number fell to 40 percent by August 2013 and 9 percent by March 2014 (DFID 2014).

- The decrease in ACT stockouts exceeded expectations, but the use of mTRAC for redistributing doses has been described as suboptimal (DFID 2014). The exchange of ACT doses has not

been systematically recorded, so it is challenging to demonstrate exactly how data has informed decision-making.

» Although the anonymous hotline has recovered value for the health system, additional improvements are needed. Sometimes, anonymous tips provide insufficient details for follow-up, but more cases also need to be properly analyzed by relevant authorities (Muhereza and Mukasa 2018).

» Capacity development is a recognized priority. Ongoing MoH budget gaps have resulted in inadequate availability of data tools and limited resources to train facilities (Yoweri 2018). Additionally, the leadership bodies have been overwhelmed at times, and some participants have lost motivation, in part because of a failure to communicate the impact of community data (DFID 2014). Currently, the available support supervision is not robust enough to follow up with all issues raised in data reports, and additional capacity-building is required for the surveillance team in mTRAC (Muhereza and Mukasa 2018). In particular, there is a need for stronger data summaries, and the program wants to follow up with non-reporting facilities. Data verification at the district level is still weak, and the MoH needs to create greater uniformity with data collection.

UNICEF officials explained that plans have been made to update mTRAC (Muhereza and Mukasa 2018). The MoH created a Health Sector Development Plan for Uganda's health system for 2015/2016 through 2019/2020 with the stated objectives of improving staffing levels, infrastructure, and equipment (UNICEF, DFID, and WHO 2016). These issues extend beyond mTRAC but relate to core difficulties that the program has faced.

BOX 1: A District Perspective

The Gulu District in Northern Uganda piloted mTRAC in 2009 and has continued using the program to positive

effect. The district has a population of 301,286 across 248 villages and is served by 62 health facilities, including four hospitals. The local health system employs 1,560 but has 13 percent of staff positions unfilled. Regular health issues include cholera, flu, malaria, measles, meningitis, pneumonia, and respiratory tract infections.

Mr. Idiba Yoweri is the Gulu District health department biostatistician, and he is responsible for receiving weekly mTRAC reports and managing administrative data. Yoweri presents an analysis of the data to the district's Epidemic Preparedness Committee, which brings together district government leaders along with representatives from hospitals, health facilities, and prison services. The committee reviews trends in different diseases and determines what actions may be required to mitigate them.

Yoweri says that the Gulu District is better prepared in multiple ways with mTRAC, explaining that "[...] it's a good software which helps with service delivery, which helps with reporting, which helps with communicating." Before mTRAC, Yoweri says, the health reporting process in Gulu was very poor. Some health facilities would have to travel 70 kilometers to physically submit paperwork to the district office. 48 percent of facilities were submitting reports and just 30 percent were submitting on time. Now, 80 percent of facilities are submitting on time and the district regularly has 100 percent completion. The district also has three to four VHT workers per community, and the district plans to begin paying volunteers to improve their participation.

Gulu uses mTRAC data to monitor the use of medicines and request additional supplies for the district. Officials can also communicate more easily with individual facilities and organize the redistribution of medicine stocks. "You

don't need to waste resources when mTRAC is available," Yoweri explained.

If a disease outbreak is reported, nearby communities are quickly alerted and can now respond with precautionary measures. Data also informs the timing of targeted health education campaigns. For example, if the district observes an increase in malaria, radio messages can be broadcast to remind the public about ways to protect themselves. Furthermore, the district has integrated mTRAC with family planning and antenatal services. Yoweri was positive in his assessment of the program, saying, "mTRAC is efficient in terms of resource utilization. Therefore, it must be scaled up in other countries. [...] It works everywhere."

Source: (Yoweri 2018)

Testimonies

» "My proudest moments have been seeing community health workers [...] get excited about learning a new function for their personal phones: positively impacting the health of their families and neighbors." Dr. Davis Musinguzi (Musinguzi 2012).

» "I used to cry whenever it came to submitting weekly surveillance data to the District Health Office because I had no information records from which I could get the information. I wasn't collecting that information because I knew I couldn't be able to transport it to the district and neither did I have airtime to call the district every week." A nursing assistant at Rwantaaha HC II (Nabunya 2013).

» "We don't have to spend money on fuel to drive to National Medical Stores just to inquire about drugs. We simply SMS and this triggers an immediate response that culminates in delivery of medicines to the health facility." Cathy Mugisha, a Medical Records Officer at Mukono Health Center (UNICEF 2014).

Conclusion

The mTRAC system was designed as a technical platform to improve the exchange of health administrative data in Uganda between local health facilities and the Ministry of Health. DFID provided initial funding with the hope of improving the availability of malaria treatments. The system has led to an increase in the complete and timely submission of health surveillance forms, and all districts in Uganda can now report on levels of malaria treatment supplies. mTRAC has since contributed to better emergency response times for endemics, improved distribution of resources, and more efficient health system operations. It has also been shown to be cost-effective, saving local health officials transportation costs and time when submitting detailed health information. The Ugandan government has demonstrated strong support for the initiative, assuming 70 percent of the program's annual operating costs. mTRAC has also inspired innovation in other sub-Saharan African countries, such as the mHero program in Liberia.

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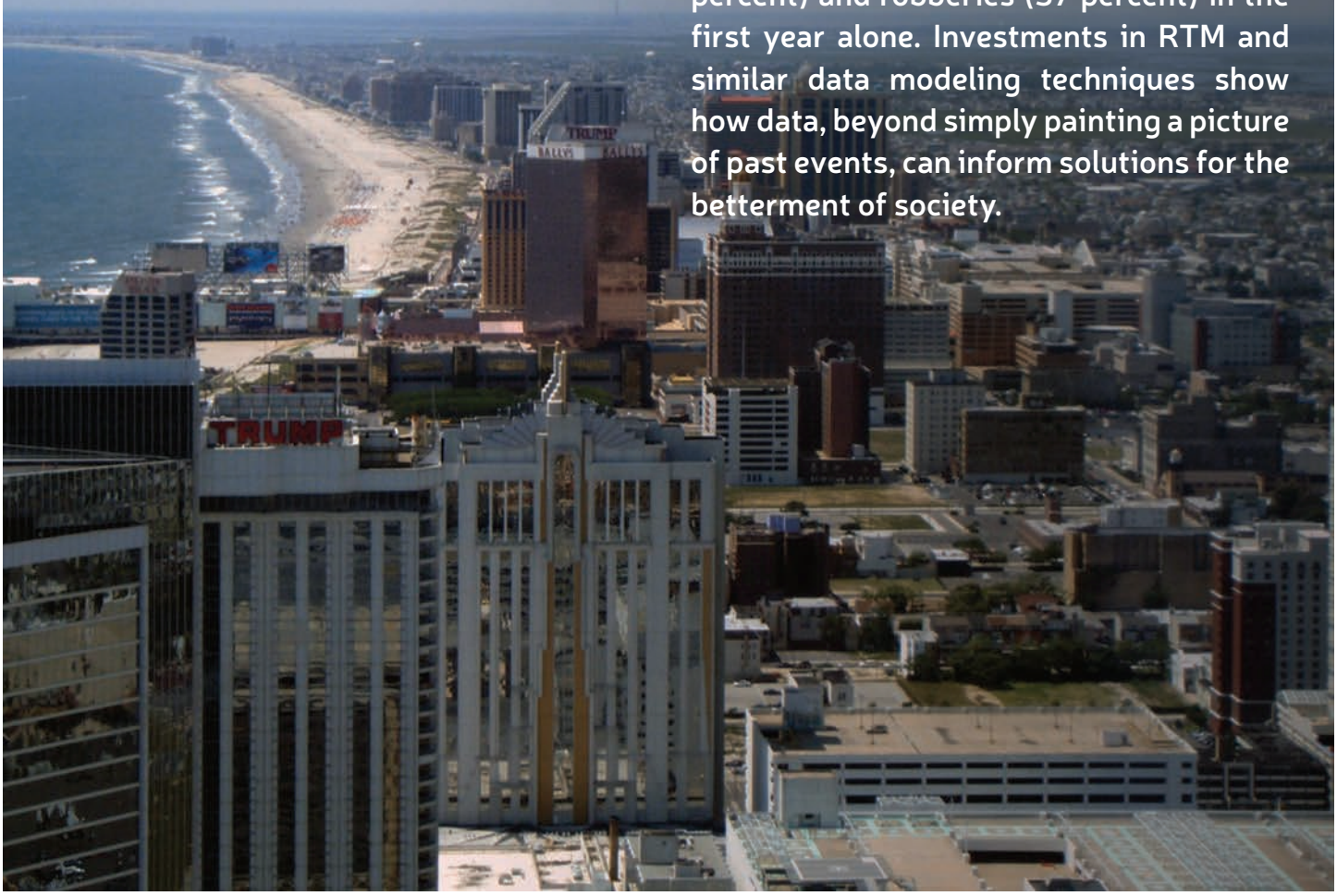
Data Modeling Helps Reduce Risk of Violent Crime in Atlantic City

A Case Study of Risk Terrain Modeling, Atlantic City

Prepared by SDSN TReNDS

High rates of violent crime dealt a blow to Atlantic City's citizens and businesses in the late 2000s and early 2010s. Hamstrung by a reduced force, the Atlantic City Police Department turned to new solutions to optimize resources for predicting and preventing crime. This included risk terrain modeling (RTM), an analytical technique combining crime data and environmental risk factors to identify high-risk areas. This data informed new approaches to their patrolling, community engagement, and other activities, and police saw reductions in homicides and shooting injuries (26 percent) and robberies (37 percent) in the first year alone. Investments in RTM and similar data modeling techniques show how data, beyond simply painting a picture of past events, can inform solutions for the betterment of society.



Context

Atlantic City, New Jersey is a coastal U.S. city of approximately 39,000 people (United States Census Bureau, n.d.). It has historically been a center for tourism and gambling, but new casinos in neighboring Pennsylvania have absorbed significant revenues in the region and, as of 2016, five of the city's 12 casinos closed since 2014 (Glenza 2016). With Atlantic City facing potential bankruptcy, New Jersey formally took control of the city in November 2016, granting the state authority to manage the city's finances and contracts (McGeehan 2016).

In addition to financial difficulties, Atlantic City is recognized as one of the most dangerous cities in New Jersey (Reuters 2016). A 2015 survey ranked Atlantic City as the eighth most dangerous city in the entire United States, with 9.29 violent crimes per 1,000 residents and 28.45 property crimes per 1,000 residents annually (NeighborhoodScout 2015).

Homicides and shooting injuries in Atlantic City reduced by 26 percent over 2017 compared to 2016 (Caplan, Kennedy, and Drawve 2018).

Authorities have made efforts to counter urban blight and have cracked down on drug-related gang activity (Reuters 2016). Meanwhile, the Atlantic City Police Department (ACPD) has made community relations a focus of its mission, with stated goals including to build public confidence in the department, to support cultural diversity training, and diverting youths from crime (Atlantic City Police Department 2018). Community outreach activities have included a homework completion club, community walks, and public meetings with complementary coffee (Sarkos 2018).

Crime overall fell 9.3 percent in Atlantic City during 2015 (Reuters 2016). Yet a noticeable increase in robberies in 2016 caused concern, and media coverage described shop owners as feeling frustrated that there was not a greater police presence (Serpico 2016). Furthermore,

between 2010 and 2017 the police force was cut from 374 to 267 officers due to financial constraints (Melamed 2017).

Description of Data Solution

Since the 1990s, a number of police departments have used Geographic Information System (GIS) technology to map out hotspots, the areas in a community where crimes tend to concentrate. In 1994, the New York Police Department launched the now widely-replicated CompStat model, which led to hotspots being flooded with additional officers (Walton 2014). CompStat has been credited with significant crime reductions. But the strategy minimized the role of community engagement, and the associated "zero tolerance" approach was found to disproportionately impact racial minorities in urban areas such as New York City (Walton 2014).

The ACPD realized the need for an evidence-based policing strategy, but it wanted a technique that would align with the community outreach program better than CompStat. Deputy Chief James Sarkos, commander of the ACPD's investigations division, explained that "[…] There was a lot of push for us to go to a CompStat model of policing. […] We saw that there were some negatives associated with that style of policing. […] We had done a lot of effort with community relations, and we felt like we had made great strides in the community, and we didn't want to go to a policing style that just focused on hot spots and attacking everyone who happened to be in the hot spot" (Sarkos 2018).

The Rutgers Center on Public Security at Rutgers University developed an alternative, data-driven policing strategy called risk terrain modeling (RTM) (Caplan, Kennedy, and Drawve 2018). RTM is an analytical approach that helps police departments learn from crime data without targeting individuals or demographic groups. It is founded on the principle that location matters to human behavior, and it asserts that certain environmental factors—such as the presence of parks or certain types of retail—can create natural opportunities for crime. As described by Joel Caplan, the Center's deputy director, "Past crimes aren't used to predict future crimes, but past crimes are analyzed to identify the environmental correlates that tend to attract

criminal behavior" (Caplan 2018). Police can use RTM results to form targeted interventions that modify environmental conditions and mitigate the risk of crime. Sarkos explained that Atlantic City chose to implement RTM because they "thought it fit in a lot better with [their] philosophy of policing in Atlantic City, and [their] community partnership" (Caplan 2018).

RTM maps the location of past crimes along with local environmental factors and then identifies what combinations of factors are associated with increased risk of crimes. The Center on Public Security has published free tutorials on how to perform the calculations (Caplan 2018) and it has made its RTM analysis and mapping software, RTMDx, available for purchase (Rutgers University Center on Public Security, n.d.). The process requires three key inputs: the study area boundary, the list of potential risk factors to test, and the outcome events (Caplan 2018). The model uses Bayesian statistics to consider the spatial influence of a potential risk factor within a threshold. A series of regressions are then calculated to determine the aggregated risk in different locations. The result is a forecast of crime for the upcoming period displayed in map and tabular forms. Crime patterns can be highly dynamic, so models are regularly updated and only consider recent crime data (Caplan 2018).

Although crimes tend to cluster, the underlying risk factors can be dynamic and vary by city, so researchers must analyze local data to determine what factors are most relevant. Police departments then need to devise risk-prevention strategies that address relevant factors and disrupt crime patterns. As Caplan explained, "The answer wouldn't be, say, to stop and frisk passersby, but to do things to make the environment less attractive to crime. That's how we can reduce crime, and we can do it without arrests" (Melamed 2017).

RTM applications in multiple cities have demonstrated the predictive accuracy of the technique (Kennedy, Caplan, and Piza 2015). Previous work funded by the Department of Justice introduced RTM in five other U.S. cities according to a quasi-experimental design (Kennedy, Caplan, and Piza 2015); similar high-risk areas in the same city were compared, but only one area would receive targeted police

interventions according to insights from RTM. The results showed a causal linkage between RTM and crime reductions, and the impacts were greatest when authorities responded to the identified spatial factors behind crime. For example, in Colorado Springs, Colorado, the police used RTM to target vehicle theft. The study identified six significant risk factors (calls for service, multifamily housing units, foreclosures, parks, sit-down restaurants, and commercial zoning), and determined that the highest risk settings covered only 4 percent of the city but accounted for 43 percent of thefts. The police responded to these findings with code inspections, license plate recognition technology, and other targeted interventions in high-risk locations. Vehicle thefts fell by 33 percent in target areas relative to control areas. Within the United States, RTM has been applied from Glendale, Arizona to Newark, New Jersey, and the technique has now been used in 45 countries (Rutgers University Center on Public Security, n.d.). Researchers have expanded RTM beyond its initial conception of addressing criminal behavior to consider issues ranging from epidemiology to maritime shipping (Rutgers University Center on Public Security, n.d.).

Implementation

ACPD Chief of Police Henry White, Jr. and command staff have led the implementation of risk-based strategies in Atlantic City. The department learned about RTM through a criminal justice board meeting and then contacted Caplan directly (Sarkos 2018). A researcher-practitioner collaboration was officially launched on October 15, 2015 between the ACPD and the Rutgers Center on Public Security, along with the Atlantic County Prosecutor's Office and other local government agencies (Caplan, Kennedy, and Drawve 2018).

During a pilot project that began on January 1, 2016, Rutgers researchers collected necessary data and tested the validity of predictive models (Caplan, Kennedy, and Drawve 2018).

The police department prioritized homicides, shootings, and robberies, and separate models were defined for each type of crime. Administrative data from the ACPD and other city offices were used as model inputs. Statistics from the Federal Bureau of Investigation's

Uniform Crime Report may double count crimes, so researchers rigorously reviewed police records to confirm that incidences were appropriately categorized (Caplan 2018). Testing determined that analyzing crime data from the two most recent months gave statistically significant predictions (Caplan 2018). The software can then produce maps that highlight the key areas of risk.

The ACPD also worked during the pilot phase to strengthen procedures for data management and access (Caplan, Kennedy, and Drawve 2018). Researchers provided in-house training on RTM, GIS technology, and data management. The police also began to develop new strategies informed by data, though these strategies were not implemented during the pilot phase (Caplan, Kennedy, and Drawve 2018).

Full implementation of risk-based policing started on January 1, 2017 (Caplan, Kennedy, and Drawve 2018). Every month, the list of environmental factors was updated and revised models forecasted high-risk areas of the city based on crimes from the past two months (Caplan 2018). These forecasts informed priorities for police interventions for the upcoming month. From January to May 2017, the Rutgers Center on Public Security worked closely with Police Department commanders, providing ongoing assistance in running models and communicating results (Caplan, Kennedy, and Drawve 2018). In June 2017, the ACPD assumed responsibility for maintaining models and developing prevention strategies.

Police officers were advised not only on what risk features to address, but also how best to respond to those risks. These strategies are updated according to new model results. The entire city has continued to receive police support, but areas that present the greatest risk are prioritized. The police hold monthly community action meetings, inviting select community members to discuss the validity of risk-based models and responses (Caplan, Kennedy, and Drawve 2018). Other Atlantic City departments have also collaborated with the ACPD to address risk factors.

Parallel Policing Strategies

The data intervention did not occur in isolation. While Atlantic City was implementing RTM, the Police Department initiated additional strategies for combatting crime. In 2017, the ACPD launched the Atlantic City Headquarters for Intelligence Logistics Electronic Surveillance (ACHILES) (Atlantic City Police Department 2018). A surveillance team at ACHILES monitors security camera feeds from around the city (Sarkos 2018). As part of the project Protecting Atlantic City Together (PACT), businesses in the area have granted police remote access to 971 security cameras. Through this access, the surveillance team can conduct virtual patrols, support responding officers, and view historical footage. Additionally, the platform Mutual Link allows the police to immediately connect with security systems in casinos, schools, and hospitals (Atlantic City Police Department 2018).

Financing

The 2016 pilot program involved a startup cost of $73,000 that covered initial research on Atlantic City crime, including funding for a postdoctoral fellow (Caplan 2018). These costs were paid for by forfeiture funds, which are collected from criminal assets (Atlantic Country Prosecutor's O 2015). There is also an ongoing subscription fee for RTMDx of $4,990 per year (Caplan 2018). An ACPD detective updates models and analyzes results but the associated expense is limited as these tasks only take a few hours each month (Sarkos 2018).

Impact

Model Outcomes and Accuracy

RTM identified a number of environmental factors that increase the risk of crime in Atlantic City (Caplan, Kennedy, and Drawve 2018). Analysis of recent crime data highlighted the risk of both shooting and robbery crimes in proximity to convenience stores, laundromats, vacant properties, and schools. Additionally, the density of residences of parolees is associated with increased risk of shootings, while the risk of robbery increases with proximity to amenities such as restaurants, hotels, and retail clothing. The predictive ability of RTM in Atlantic

City was tested using a predictive accuracy index, which compares the risk score for an area with the observed crime count, and model accuracy exceeded expectations (Caplan, Kennedy, and Drawve 2018). Consistently, the 1 percent of the study area that was identified as high risk would account for over 30 percent—sometimes over 50 percent—of the un-prevented crimes in the subsequent month (Caplan 2018). The model has also predicted the displacement of crimes. There have been instances where crimes have increased in areas where crime had not historically occurred, but that were identified as high-risk areas by RTM (Caplan 2018). For example, parking lots have recently emerged as a priority in RTM, so the police have given them added emphasis in their regular patrols (Sarkos 2018). The concentration of crimes may shift a couple blocks from month to month, but the police are more aware of emerging crime patterns and can anticipate the response to interventions (Caplan, Kennedy, and Drawve 2018).

Robberies in Atlantic City reduced by 3 percent over 2017 compared to 2016 (Caplan, Kennedy, and Drawve 2018).

Responding to RTM Outputs

Working with community members, the ACPD forms risk narratives that explain why crimes are associated with particular locations (Caplan, Kennedy, and Drawve 2018). For example, one narrative posits that drug deals were solicited at convenience stores, transactions then took place at unsupervised laundromats, and drug supplies were kept at vacant properties (Melamed 2017). These activities could then increase the risk for violent crime. At the same time, RTM helped refute the assumption that crimes are associated with housing projects (Melamed 2017).

The ACPD has worked to disrupt risk narratives and limit opportunities for crime (Caplan 2018). Patrol routes were revised, and the police conducted over 1,000 checks at businesses in high-risk areas in

2017 (Caplan, Kennedy, and Drawve 2018). Updated business check procedures required officers to get out of their vehicles, sign a log book, interact with store owners and customers, and establish an active police presence (Atlantic City Police Department 2018). Other city departments also worked to address risk factors by installing brighter street lights and modifying or demolishing 17 abandoned buildings in high-risk areas (Caplan, Kennedy, and Drawve 2018).

Crime Reductions

The crimes prioritized in RTM analysis declined in Atlantic City following the full implementation of risk-based strategies (Caplan, Kennedy, and Drawve 2018). During the first five months of 2017, violent crimes decreased by 20 percent compared to the same period in 2016:

- The combined measure of homicides and shooting injuries fell 26 percent from 39 in 2016 to 29 in 2017, excluding June (Caplan, Kennedy and Drawve, Risk-Based Policing in Atlantic City: 2017 Report 2017).

- Robberies fell 37 percent from 231 in 2016 to 145 in 2017, excluding June and July.

- Combining homicides, shooting injuries, and robberies, the prioritized violent crimes declined 36 percent between 2016 and 2017, excluding June and July.

[Full-year comparisons are unfortunately unavailable; some data from the pilot phase was lost after the department's digital storage system experienced technical issues in 2016 (Caplan 2018).]

According to Caplan, an upcoming journal publication highlights significant month-by-month reductions in crime following the introduction of RTM (Caplan 2018). These reductions also correlate with the intensity of the intervention, as measured by police presence in high-risk areas (Caplan 2018). Atlantic City observed a 10 percent improvement in its case clearance rate—the proportion of crime

cases solved—in 2017 compared to 2016 (Caplan, Kennedy, and Drawve 2018). Due to the overall reduction in crimes, total arrests did not increase. As a result of the reduction in violent crimes, the researchers estimated an annual cost savings to the local criminal justice system of $1.6 million. According to Sarkos, RTM has enabled the department's reduced number of officers to be placed where they will be most effective (Sarkos 2018).

> **"Before, we would clean up an area temporarily but all we were doing was displacing crime. […] We're getting there before the crime does to make sure that now it is not the next hot spot. We're no longer playing Whack-a-mole."**
> **– Atlantic City Chief of Police Henry White, Jr. (Melamed 2017)**

While the Rutgers Center on Public Security did not provide verification and analysis, available data from the Uniform Crime Report shows a continued decline in crime in the early part of 2018 (Caplan 2018). According to this data, there were 62 robberies and five homicides as of mid-year 2018, compared to 100 robberies and nine homicides over the same period in 2017 (Atlantic City Police Department 2018).

Impact of Multiple Policing Strategies

The use of crime data and RTM have been part of a wider policing strategy. As Caplan explained, "Risk Terrain Modeling itself did not reduce crime. The police did. […] This was an agency that tried to make it work and tried to bring multiple technologies and multiple policing practices together holistically that were going to be efficient and effective" (Caplan 2018). The surveillance system at ACHILES has been important in its own right, with security cameras aiding 138 arrests in 2017 (Atlantic City Police Department 2018), but the technology has also been integrated with the RTM strategy. The

ACPD prioritized access to cameras in high-risk locations, and the surveillance team dedicates downtime to monitoring areas identified as problematic by RTM (Sarkos 2018). Sarkos said, "It's all part of a large picture. Each one has a lot of merit and has contributed to this. I think they all work in conjunction" (Sarkos 2018).

Testimonies

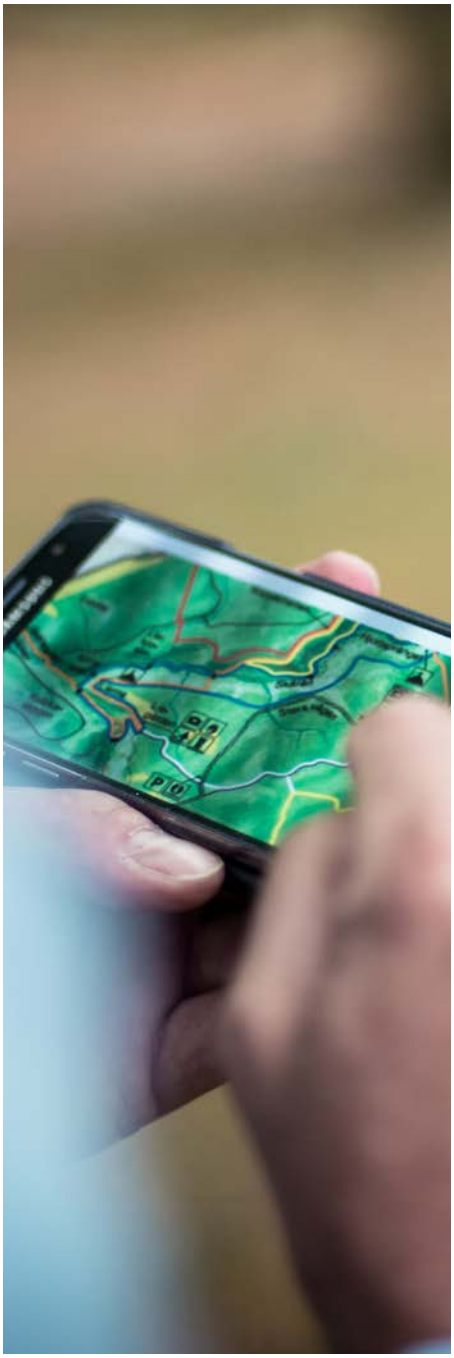
Police Chief White's perspective on how the risk-based approach improved Atlantic City policing: "We've had certain neighborhoods in town that have been hot spots since I was on patrol. We made a ton of arrests. But, you know what? They were still hot spots until recently. [...] Before, we would clean up an area temporarily but all we were doing was displacing crime. [...] We're getting there before the crime does to make sure that now it is not the next hot spot. We're no longer playing Whack-a-mole" (Melamed 2017).

Sammy Nammour, the manager of an Atlantic City store that has witnessed multiple robberies and a murder, has testified to the effectiveness of the risk-based intervention. He told reporters that "Whatever they're doing, it's working. They've been coming around. You can see more police presence" (Serpico 2018).

Challenges

The ACPD received technical and analytical support from the Rutgers Center on Public Security but, according to Sarkos, "The biggest challenge at the beginning was gathering all the data together" (Sarkos 2018). A list of all mercantile licenses was obtained from the city, but the available information did not indicate establishment type. Consequently, police officers had to manually categorize approximately 1,000 businesses to have sufficient data for the RTM analysis. As mentioned, ACPD's previous digital storage system also encountered technical issues, "crashing" and erasing some crime data (Caplan 2018). This issue and subsequent loss of data underscored the need for more advanced data management.

The program has faced issues in gaining support among officers and enabling trust within the community. During the first year of implementation, Chief White explained: "The biggest challenge we're



having here is getting the rank-and-file to buy in. We're trained to focus on the bad guys, and it's hard for them to make that shift" (Melamed 2017). In 2018 Sarkos reflected, "Buy-in from the officers was a little challenging at the beginning. I think when we first implemented it, we didn't do the best job of explaining exactly what it was to the officers, so we had to go back and explain to them. [...] Once that was done, it was more well received" (Sarkos 2018).

There is also ongoing concern in the community about crime and police relations. Kellie Cors-Atherly, who runs a memorializing and activist group against gun violence called Peace Amongst Youth, told reporters, "We're having active shootings in Atlantic City once a week. That doesn't seem to be changing so much. And it's still a division between the police and the community. There's still a big trust factor" (Melamed 2017). Similarly, a 2016 joint statement from 16 civil rights, racial justice, privacy, and technology organizations in the United States expressed concern about the impact of predictive policing (The Leadership Conference on Civil and Human Rights et al. 2016). The statement claimed that predictive methods may appear impartial but can strengthen biases inherent to police data, and that many predictive programs ignore community needs.

The Rutgers team believes their approach of focusing on location mitigates these concerns (Melamed 2017). The ACPD has worked to create transparency around RTM by regularly consulting community members and incorporating their understandings of criminal activity into risk strategies. Sarkos explained that the monthly community meetings have been integral to the RTM program. Community members are helpful in identifying why particular locations may be susceptible to crime, and keeping the community informed has created a positive reception and reduced suspicions about predictive analytics (Sarkos 2018).

Conclusion

The use of RTM in Atlantic City is associated with notable reductions in crime. Models have analyzed data to identify local factors that contribute to the risk of crime, and these insights have led to new policing strategies. Moreover, the approach is effective without

profiling person-specific characteristics or increasing total arrests. The potential implications of predictive strategies deserve scrutiny and additional efforts may be needed to ensure community trust, but initial results from Atlantic City suggest the thoughtful application of data can save lives, property, and public resources. When asked if he would recommend RTM to other police departments, Deputy Chief Sarkos replied, "I would, most definitely" (Sarkos 2018).

Written by Hayden Dahmm (Analyst, SDSN TReNDS) with inputs from and thanks to Atlantic City Deputy Chief of Police James Sarkos and Jay Neuner (Communications Manager, SDSN TReNDS).

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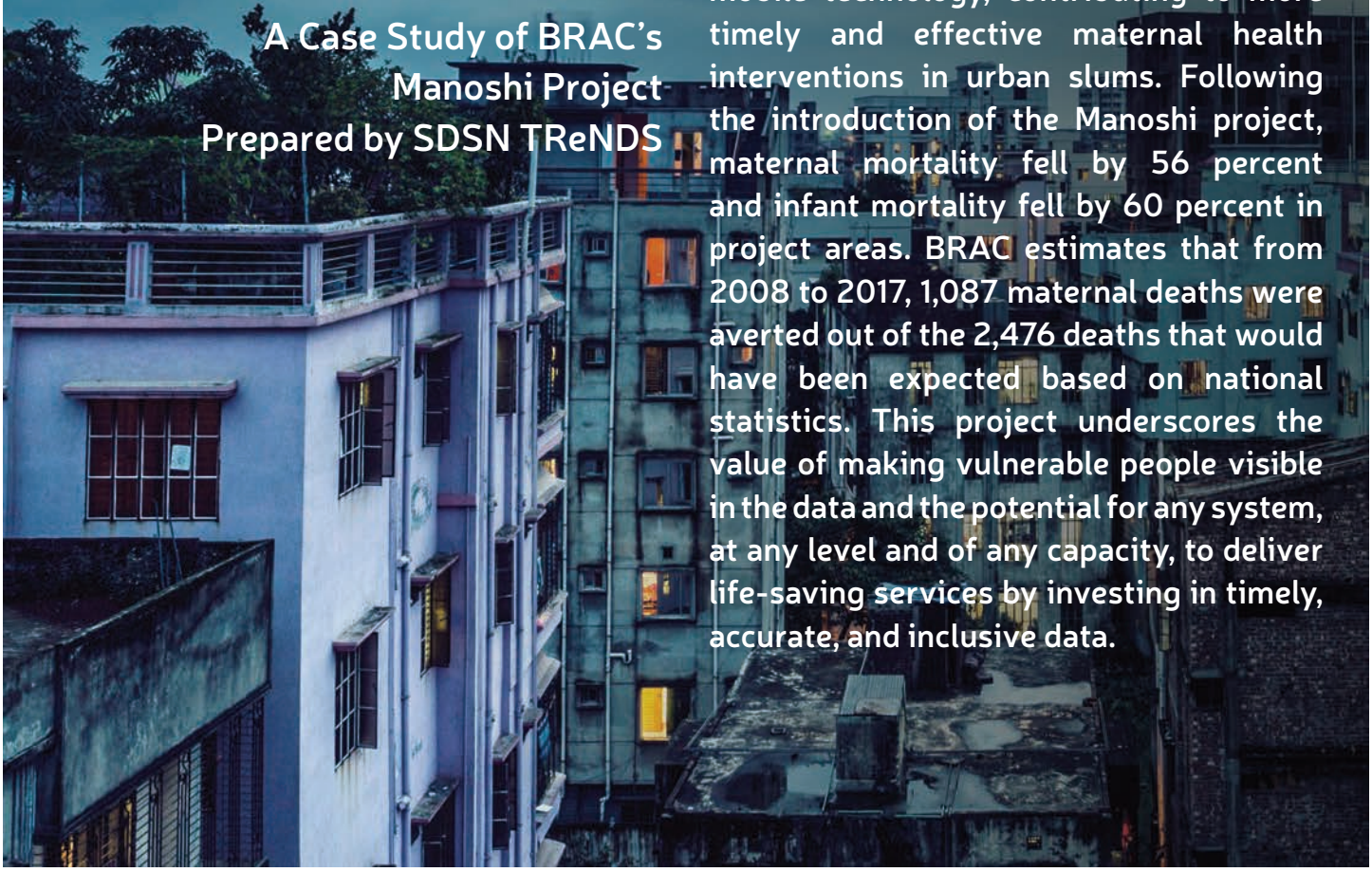
Bangladeshi Slums Reduce Maternal and Infant Mortality with the Help of Innovative Health Data

A Case Study of BRAC's Manoshi Project

Prepared by SDSN TReNDS



Nearly one billion people worldwide live in slums—unplanned communities that are overcrowded, highly impoverished, and hazardous to their residents. These people are at high risk of being left behind not only in official statistics, but also in receiving essential services like healthcare. International nonprofit BRAC developed a data-driven approach to account and care for mothers and young children in these communities through healthcare initiative Manoshi. Manoshi built the capacity of local health workers in Bangladesh to derive actionable data from social mapping, local censuses, and real-time data-sharing via mobile technology, contributing to more timely and effective maternal health interventions in urban slums. Following the introduction of the Manoshi project, maternal mortality fell by 56 percent and infant mortality fell by 60 percent in project areas. BRAC estimates that from 2008 to 2017, 1,087 maternal deaths were averted out of the 2,476 deaths that would have been expected based on national statistics. This project underscores the value of making vulnerable people visible in the data and the potential for any system, at any level and of any capacity, to deliver life-saving services by investing in timely, accurate, and inclusive data.

Context

According to UN-Habitat, approximately 1 billion people live in urban slums globally (UN-Habitat 2016), and slum conditions are particularly acute in developing countries. Poverty and limited sanitation in slums contribute to health issues, and the unorganized layout of slum communities also makes individual patients difficult to identify and monitor (Marcil, Afsana, and Perry 2016). In Bangladesh, slums have grown as people migrate from rural areas in search of economic opportunities.

According to 2017 estimates, Bangladesh has been urbanizing at an annual rate of 3.17 percent, with 36.6 percent of the country's 158 million population now living in urban areas (Central Intelligence Agency, n.d.). Slums have grown at a disproportionate rate (Adams, Nababan, and Manzoor Ahmed Hanifi 2015) and they struggle with sanitation, water access, and waste disposal services (Uddin 2018).

In the project areas, maternal mortality rates fell by 56 percent and infant mortality fell by 60 percent between 2007 and 2013 (Roy et al, 2014).

Although Bangladesh has made progress in the provision of healthcare, with national neonatal mortality rates cut by more than half between 1990 and 2010 (Hoope-Bender et al. 2014), significant challenges persist. Health outcomes are historically worse in slums, where fewer women receive antenatal care and many give birth at home (Hoope-Bender et al. 2014). In 2007, around 86 percent of slum births took place at home, where multiple families might share a confined space in unhygienic conditions (Afsana 2018). At this time, calculations found Bangladeshi slums had a maternal mortality rate of 294 deaths per 100,000 live births and a neonatal mortality rate of 43 deaths per 1,000 live births (Marcil, Afsana, and Perry 2016).

BRAC—the world's largest non-governmental development organization as measured by number of employees—developed an intervention to improve maternal and neonatal health in Bangladeshi

slums (Hoope-Bender et al. 2014). The Manoshi project created a network of health workers armed with information about the communities they serve.

Description of Data Solution

The Manoshi project developed a multimodal data solution to address the unique challenges faced by women in slum conditions. BRAC had existing maternity programs in rural Bangladesh, but this model could not translate directly to the urban context (Afsana 2018). A comprehensive map of slum communities was created to locate pregnant women, mothers, and their children. This information was then used to guide healthcare workers and increase the availability of health services. Additional data was collected on individual patients using mobile technology.

Social Mapping and Census

Data collection began with a social mapping exercise that located significant landmarks, including mosques, schools, markets, and bridges (Afsana, 2018). Community surveyors received specialized training and then systematically assigned a number to every house in the slum, using identified landmarks for reference (Hoope-Bender et al. 2014). Numbers were marked both on a hand-drawn map and on the front of the actual house. Different households sharing the same house were also assigned a letter code to distinguish them.

Following the social mapping, a local census was performed to understand the demographics and economic condition of all households (Roy et al. 2014). Households were randomly selected to be resurveyed as a check for census accuracy (Hoope-Bender et al. 2014). The census is updated every six months, enabling health workers to track households in the slum communities and identify pregnant women (Afsana 2018).

Mobile Data Collection

In addition to census data, health workers were provided with mobile phones for near-real-time reporting of standardized patient data.

Prior to the mobile intervention, the centralized Manoshi management team could only access data after manual submission at the end of the month, so resources were not optimally allocated (Alam, Khanam, and Khan 2010). Click Diagnostics (later renamed MPower-Health) developed a mobile module in Java for the Nokia 3110c. This allowed workers to view schedules, receive feedback, and automatically display data in a companion web module (Alam, Khanam, and Khan 2010). The tool was developed to improve the reporting process, perform remote risk screening, and better allocate staff according to advanced algorithms (Center for Health Market Innovations 2018). BRAC conducted a pilot of the application between July 2009 and January 2010 and found that health workers were able to use the application effectively to conduct the household census and submit data (Rahman 2018). Following on initial successes, BRAC continued to roll out the platform, and mobile phones were connected with a central support center at BRAC offices (Roy et al. 2014).

Implementation

The project was first piloted in a single slum community of Dhaka, the capital of Bangladesh, in 2007. It expanded to all Dhaka slums by the end of the year (Alam, Khanam, and Khan 2010). By 2012, the project covered 5.7 million Bangladeshi slum inhabitants (Afsana, 2018). As of 2014 it had extended to 6.9 million slum inhabitants, including 1.8 million women of reproductive age and over 191,000 newly pregnant women (Hoope-Bender et al. 2014).

The project operates in slums in ten city corporations and one municipality across Bangladesh, covering approximately 6.9 million inhabitants (Rahman 2018).

BRAC formed a package of interventions informed by the data collection. Pregnant and lactating women, as well as children under five, receive healthcare services through a community-based system managed by BRAC (Roy et al. 2014). The program works to ensure all pregnant women receive a comprehensive prenatal checkup focusing

on basic health concerns, including abdominal tests and blood pressure exams (Afsana 2018). Services are administered by a network of community health workers (CHWs) (Roy et al. 2014). Shasthya shebikas each visit an assigned group of 150 to 200 households every month, and they provide a range of basic services. Shashthya shebikas receive incentives based on the number of pregnancies they identify and deliveries they support, and they can sell medical and sanitation supplies to make a small profit. Shasthya kormis supervise the shashthya shebikas, visiting all 10,000 households they oversee at least once every three months (Roy et al. 2014).

BRAC developed trust within slum communities by incorporating traditional practices into the Manoshi program (Marcil, Afsana, and Perry 2016). Traditional birth attendants are women who lack formal training but have considerable experience with deliveries. BRAC provided these familiar community members with additional training and incorporated them as urban birth attendants. At the start of implementation, urban birth attendants were based at birthing huts—minimalist facilities located in slum communities, where women can deliver babies with privacy and support. Informed by the social maps, birthing huts were situated so that each would cover a population of around 10,000 and attend to one birth per day on average (Afsana 2018).

Yet the huts could not properly address bleeding and other serious complications, and the hospital delivery rate was increasing, especially in regard to the need for caesarean sections (Afsana 2018). As a result, BRAC created Maternity Centers, which are more advanced facilities staffed by trained paramedics. There are now 45 Maternity Centers operating in 10 city corporations and one municipality throughout Bangladesh (Afsana 2018). Accordingly, the number of birthing huts was reduced from a peak of 426 to approximately 45. As of 2018, Manoshi employs 4,500 shasthya shebikas and 450 shasthya kormis, along with 180 midwives across Bangladesh (Afsana 2018).

BRAC has also developed partnerships with local government hospitals, but these are not committed to under formal agreements (Afsana 2018). Urban primary healthcare in Bangladesh is provided by

a combination of government and NGO services, but the government does not officially recognize slums, and slum communities are not specifically addressed in health policies (Afsana 2018). BRAC has stationed referral staff at partner hospitals to assist Manoshi patients with navigating admission and treatment (Hoope-Bender et al. 2014), and women below a determined income level can be reimbursed for emergency care (Roy et al. 2014).

The collection of data and the clear assignment of CHWs to specific households allows BRAC to assess an individual's performance and iteratively improve the program. BRAC is alerted when a pregnant woman or child under five dies, and a Manoshi program officer visits the household to interview the family and conduct an autopsy (Roy et al. 2014). Manoshi then holds a community meeting to identify potential service issues and works to avoid similar fatalities.

Funding

BRAC received initial funding for the Manoshi project from the Bill & Melinda Gates Foundation, which provided $25 million from 2007 to 2012 (Afsana 2018). Since the close of this funding, the UK Department for International Development (DFID) and the Australian Government have provided combined funds of $3 to $4 million annually (Afsana 2018).

The Bill & Melinda Gates Foundation provided US$25 million in funding from 2007 to 2012. The UK and Australian governments have subsequently provided $3 to 4 million annually.

Additionally, the Maternity Centers initiated fees in 2011 for services including antenatal care, delivery services, and various tests (Rahman 2018), supporting costs such as staffing (Afsana 2018). The fees are minimal in comparison to the wider competitive market, and BRAC provides free services for the ultra-poor (Rahman 2018), defined as those with a household monthly income under 5,000 taka (US$64)

(Roy et al. 2014). Through this fee structure, a Maternity Center can become self-sustaining within 15 to 18 months (Afsana 2018).

Impact

The Manoshi project areas have observed an uptake of available health care services and an improvement in health outcomes for slum residents.

Logistical Improvements

The social mapping exercises provided accurate information about the community, allowing birthing facilities to be placed in more central and accessible locations. For example, overlaying population distributions with landmarks led to designs that reduced the need to cross a bamboo bridge when traveling to a birthing facility, which pregnant women in the community prefer to avoid (Roy et al. 2014). Also, BRAC was able to allocate an appropriate number of health workers to serve the local population, and women could be more easily directed to their nearest facility (Hoope-Bender et al. 2014). Social maps were of particular importance as BRAC established a presence in slums, but these maps became less significant as workers grew familiar with the communities (Afsana 2018).

Increased Institutional Deliveries

In 2007, an estimated 86 percent of women from slums in Bangladesh gave birth at home, and only one-quarter received antenatal and postnatal care (Marcil, Afsana, and Perry 2016). A survey of women from Manoshi project areas in Dhaka showed that of the 15 percent who chose to deliver at a healthcare facility in 2007, only one percent used a BRAC facility. A repeat survey in 2011 found that 23 percent of women delivered at BRAC facilities, and 59 percent delivered at either a BRAC facility or a hospital. The surveyors concluded that Manoshi was successful at improving practices and reducing inequalities (Alam, Khanam, and Khan 2010). Although not all additional, institutional births occurred at BRAC facilities, BRAC had provided prenatal services, raised public awareness, and referred emergency cases to

hospitals. By 2013, 87 percent of women delivered at either a BRAC or hospital facility (Marcil, Afsana, and Perry 2016).

Improved Health Outcomes

Maternal mortality rates declined by 40 percent nationwide between 2001 and 2010, but Manoshi communities exceeded this trend (Marcil, Afsana, and Perry 2016). At the start of implementation, the project area was experiencing high mortality and limited access to health services. Between 2007 and 2013, the maternal mortality rate in the Manoshi service area fell 56 percent from 294 deaths per 100,000 live births to 130 deaths per 100,000 live births (Marcil, Afsana, and Perry 2016). Over the same period, the neonatal mortality rate in the service area fell 60 percent from 43 deaths per 1,000 live births to 17 per 1,000 live births (Marcil, Afsana, and Perry 2016). In 2010, the national maternal mortality rate was 170 deaths per 100,000 live births, and the national neonatal mortality rate was 36 deaths per live births. The mortality rates in Manoshi service areas were lower than these national figures when next measured in 2011, suggesting that the interventions have helped to reverse historic health inequities. As of 2016, similar progress has not been observed across Bangladesh; national neonatal mortality rates have declined to 28 deaths per 1,000, but national mortality rates have reportedly increased to 196 deaths per 100,000 live births (Afsana, 2016). BRAC has estimated that between 2008 and 2017, the Manoshi program averted 1,087 maternal deaths out of an estimated 2,476 deaths that otherwise would have occurred based on national statistics (Afsana 2018).

An additional proxy for overall quality of care is the fresh stillbirth rate, which divides the number of stillbirths by the combined number of still and live births (WHO 2018). The rate correlates with access to maternal services, and nearly half of stillbirths occur during labor. In 2016, the fresh stillbirth rate for home deliveries was 1.9 percent; in hospitals, 1.8 percent; and in BRAC Maternity Centers, 1.3 percent (Afsana 2018). This is further evidence that BRAC centers support better health outcomes.

The Importance of Community Health Workers

A social network analysis suggests that CHWs were important to realizing these health benefits. Adams et al. surveyed 993 women from Dhaka slums who had recently given birth (Adams, Nababan, and Manzoor Ahmed Hanifi 2015). Women who accepted Manoshi membership by default were compared against those who had opted out of the program. For Manoshi members, CHWs served as the main source of informational, instrumental, and emotional support during pregnancy, while non-members relied more on mothers-in-law and other family. Furthermore, women who included Manoshi CHWs in their social networks were far more likely to use maternal and postnatal services. Women who listed a CHW in their network were twice as likely to deliver with a trained attendant, and Manoshi members in particular were three times as likely to receive postnatal care. Conversely, relying solely on a mother-in-law and family was associated with negative outcomes. These results demonstrate how CHWs have successfully integrated into support networks, and underscore the importance of making women known to the health system.

Mobile Data Sharing

BRAC's seven-month pilot evaluation of the mobile data collection system from Click Diagnostics showed success (Rahman 2018), but issues were later realized (Afsana 2018). Follow up interviews with nine shasthya kormis suggested that the module could shorten patient appointments from 30 minutes to within a range of four to six minutes, and the data could be processed immediately (Alam, Khanam, and Khan 2010). The module reduced the potential for errors in comparison to manual reports, and questions could be updated at no expense. However, a BRAC review in 2018 found that the mobile application had several issues and was no longer fit for purpose (Afsana 2018). Identified problems include missing records, misreporting, and the lack of a dashboard for analyzing data (Rahman 2018). Maternity Centers have been simultaneously maintaining complete records, so potential disruptions were minimized (Afsana 2018). BRAC is now planning an overhaul of its mobile health program (Rahman

2018). The Bangladeshi government has recently adopted the DHIS2 and OpenSRP health reporting platforms to support the national exchange of health data, and BRAC intends for the revised application to be interoperable with the government's system (Rahman 2018). A new application would not only improve the collection of data but would also allow for maternal and neonatal mortalities from slum communities to be officially reported (Rahman 2018).

Challenges

Overall access to maternal health care services has improved in Bangladeshi slums, but health facilities still struggle with limited staff and medical supplies (Hoope-Bender et al. 2014). At the start of Manoshi implementation, CHWs faced difficulties in identifying all households because the operation was logistically complex (Afsana 2018). The slum communities are also in constant flux, with 20 to 40 percent of the slum population moving annually (Roy et al. 2014). As a result, BRAC has to perform an update every six months of all the information from the communities where they work (Afsana 2018).

Additionally, Bangladeshi slum communities face the constant risk of being forcibly removed by the government from the land they informally occupy, making way for other forms of development (Islam and Mungai 2016). When a community supported by Manoshi is evicted, BRAC attempts to follow up with displaced mothers and children, but this is unavoidably difficult (Afsana 2018). Slums are also being forced further into flood-prone river banks, compromising the health and safety of residents (Roy et al. 2014).

Replication

In 2013, BRAC received a Healthcare Innovation Award from pharmaceutical company GSK and nonprofit Save the Children in recognition of Manoshi (GSK 2013). The prize money of $300,000 was invested in replicating the Manoshi program in the slums of Freetown, Sierra Leone (BRAC 2013). These slums experience some of the highest under-five and maternal mortality rates in the world. The investment is part of a larger initiative in the area with funding from UNICEF and the UK's foreign aid efforts, and BRAC has developed a series of interventions that address microfinancing, advocacy, and

health (Sesay 2015). BRAC adapted Manoshi's operations to the local community in Freetown, where the government is more active in the delivery of slum health services (Afsana 2018). The Manoshi expansion has involved creating Maternity Centers, developing CHW capacity, and identifying pregnancies (Sesay 2015). The program started a few health facilities that are continuing under government operation (Afsana 2018).

Conclusion

The complex layout of Bangladeshi slum communities has long made it difficult for residents to access healthcare services. Combining data from social mapping, a local census, and continual e-record sharing provided a detailed understanding of these communities and their individual healthcare needs. Empowered by this data, BRAC has trained a team of community healthcare workers that can use information to monitor pregnant women, mothers, and young children. The ability to identify and support individuals has expanded the availability of health facilities and dramatically improved maternal and neonatal health outcomes. The informed application of data has saved lives and protected the most vulnerable members of Bangladeshi society. Wider applications of social maps and household level demographic and economic data could realize even greater benefits for these historically marginalized communities.

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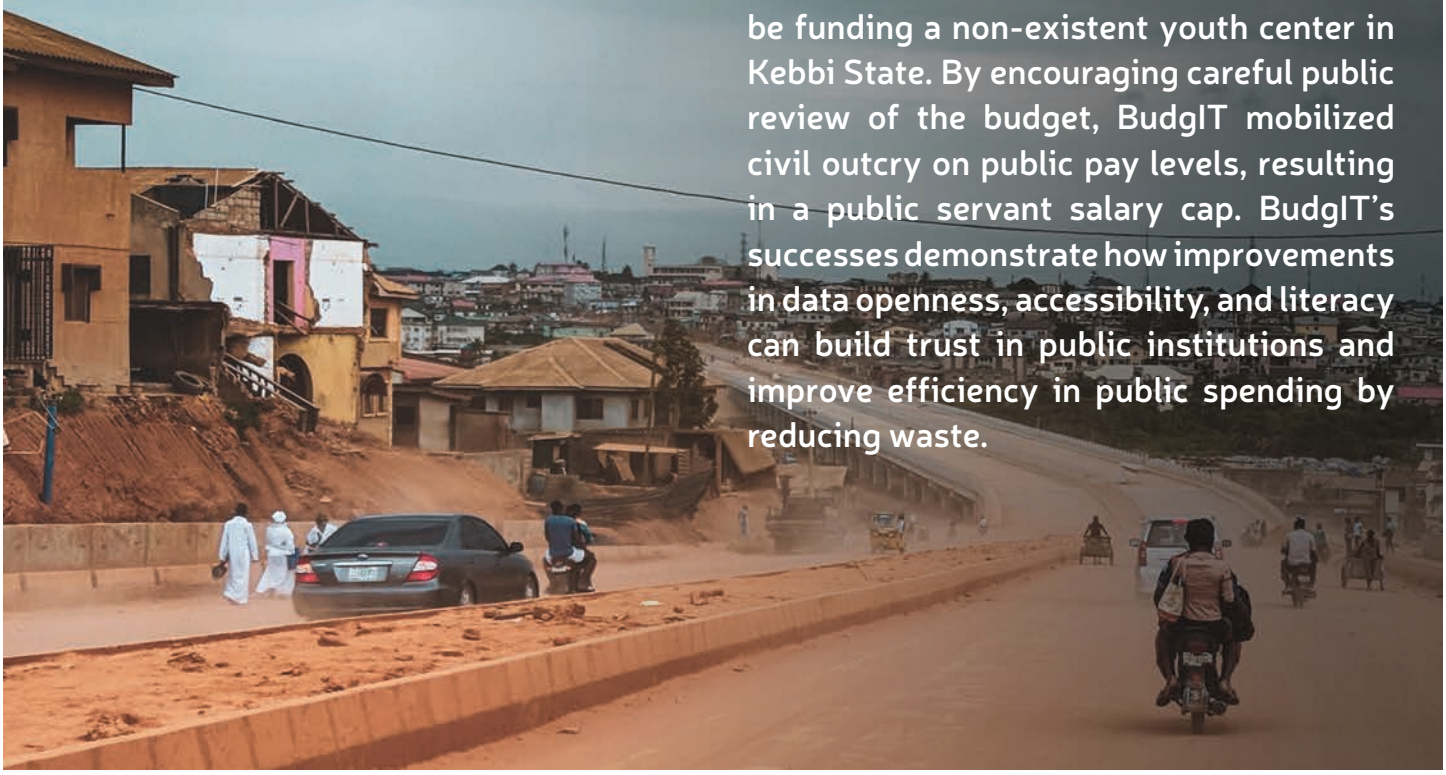
Global Partnership for Sustainable Development Data

TRENDS
Thematic Research Network on Data and Statistics

BudgIT Empowers Nigerian Citizens Through Open Data

A Case Study of BudgIT, Nigeria
Prepared by SDSN TReNDS

Frivolous spending and opaque processes plague Nigeria's federal budget. Civic startup BudgIT launched in 2011 to take on this challenge. The organization aims to make budgetary data from Nigeria's Federal Government more accessible and understandable through digital technologies, including making PDFs machine-readable and designing visual representations of the data for those with low data literacy. Their campaign to drive awareness and analysis of the 2017 federal budget successfully reached 2.5 million Nigerians via online and offline platforms and engaged 25,000 citizens in the review process. This led to action on unnecessary budgetary items and "fake" projects. In one example, BudgIT exposed a 41 million naira (US$113,575) investment that claimed to be funding a non-existent youth center in Kebbi State. By encouraging careful public review of the budget, BudgIT mobilized civil outcry on public pay levels, resulting in a public servant salary cap. BudgIT's successes demonstrate how improvements in data openness, accessibility, and literacy can build trust in public institutions and improve efficiency in public spending by reducing waste.



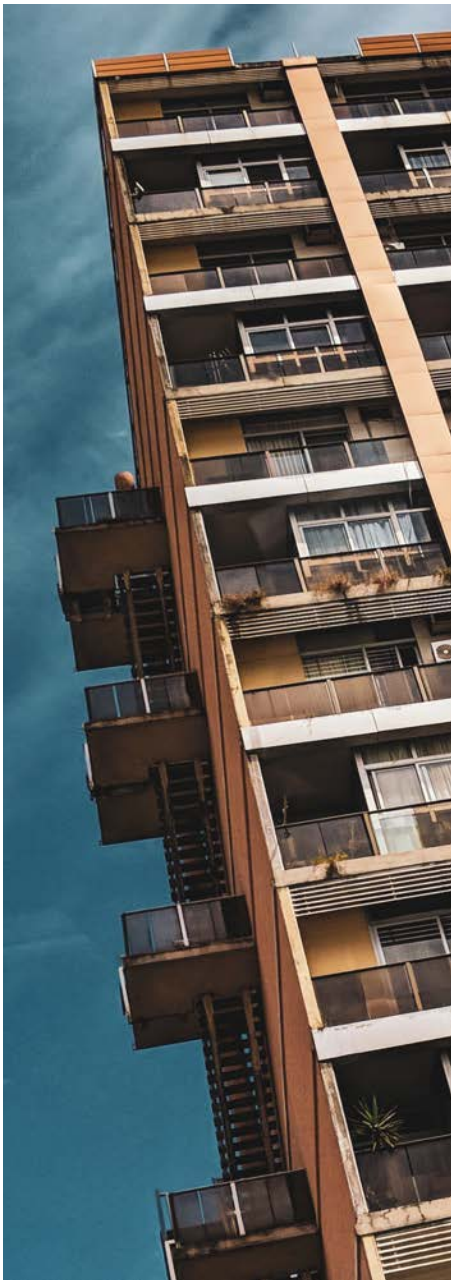
Context

Nigeria is sub-Saharan African's richest economy, with a nominal GDP of $404 billion as of 2016 and an annual GDP growth rate of 2.47 percent as of 2018 (World Bank n.d.). However, its competitive economic growth and social development is undermined by widespread corruption. The country was ranked 148 out of 180 countries featured in Transparency International's 2017 Corruption Perceptions Index with a score of 27 out of 100, classifying it as "Highly Corrupt" (Transparency International 2017). The exact scale of corruption in Nigeria is unknown but estimated to have a large impact; according to one estimate from PwC, Nigeria's economy could have been 22 percent bigger in 2016 if its levels of corruption had been closer to those of its neighbor, Ghana (PwC 2016). In one instance, a 2016 government audit identified and resulted in the removal of 50,000 "ghost workers" from the government's payroll, with savings estimated at 630 million euros (approximately US$734.6 million) (Agence France Presse 2016). PwC claimed in its report that if the country's leadership does nothing about this corruption, the cost could amount to almost $2,000 per person per year by 2030 (PwC 2016).

According to BudgIT's 2017 annual report, their 2017 Budget Review actively engaged 25,000 people and reached close to 2.5 million Nigerians via online and offline channels.

As a result, BudgIT exposed and called for action on frivolous budgetary items and "fake" projects. In one example, BudgIT exposed a 41 million naira (US$113,575) investment that claimed to be funding a non-existent youth center in Kebbi State.

Civil outcry on public pay levels, exposed through careful review of the budget, also resulted in a public servant salary cap.



The inaccessibility of budgetary information across the Nigerian Government aids financial corruption among public sector workers. Although the Nigerian federal budget is published annually, it is provided in PDFs that are not machine-readable, making searches difficult. Furthermore, Nigeria does not have a legal framework defining the format of the budget's publication or the extent to which public participation in the budget is required, nor is there a requirement to release annual in-year spending, procurement, public assets, and liabilities [as highlighted by the Technical Committee on Budget Reforms established in 2016 ("Budget Reform Takes Front Burner As NILS Host Influencers" 2018)]. In response to the inaccessibility of Nigeria's budgetary information, a civic nongovernmental organization called BudgIT was established in 2011. It aims to make government budgets more accessible and understandable to all Nigerians. The founders of BudgIT believe that open data and information can help foster debate and tackle corruption, stating:

> **"Opening up information throws up more debate within a society, and reveals the patches of corruption. If no one knows what goes on in government and citizens are handed a fuzzy narrative, the incentive to steal funds is high. When we open up information about the flow of public funds, we strengthen the social contract, and deepen the trust between the electorate and the leader."**
> **— Oluseun Onigbinde, Founder of BudgIT (Open Knowledge International, n.d.)**

Description of Data Solution

BudgIT uses a range of online and offline communications tools to make budgetary information more accessible to the general public, with the aim of raising transparency and accountability within government. BudgIT's method is to undertake data mining and then creatively represent data (e.g. through infographics) to empower citizens to use the resulting information in demanding improved

service delivery. They also communicate their findings through radio and television.

Beyond budget access, BudgIT creates tools for citizens to do their own budgetary tracking. One such tool is Tracka, created in 2014. It is an e-platform that allows Nigerians who are "online" (with access to the internet and/or mobile phones) to share updates and photos on development projects in their areas. BudgIT's project officers also facilitate engagement "offline," consulting with local communities to gather information for the platform and by using information from the platform and other sources to help citizens provide feedback to their elected representatives about the status of local projects. According to Onigbinde, Tracka is operational in 30 states across Nigeria and over 600 communities (Onigbinde 2018). It also has a media and TV component, with a radio program broadcast across six states.

BudgIT also advocates to influence a national debate on public spending. It generates policy papers; analyzes existing open government, transparency and anti-corruption activities; and works with international organizations such as CIVICUS, Open Government Partnership, and the OPEN Alliance to encourage the Nigerian government to adhere to international standards of transparency and accountability (Open Alliance Nigeria n.d.).

Implementation

BudgIT was conceptualized at the Tech-In Governance event, a 48-hour hackathon organized by Lagos, Nigera's Co-Creation Hub in March 2011. The platform launched on September 13, 2011 (Washtell 2014).

In 2013, BudgIT's total revenue from grants, consulting, and competitions was 34.9 million Nigerian naira (US$96,600). In that year, personnel were its biggest outgoing expense, accounting for 33 percent of total expenses and 18 percent of their revenue. In 2017, the organization's total revenue had grown to 495.7 million Nigerian naira (US$1.4 million). In that year expansion projects were the biggest outgoing expense with personnel coming in second, accounting for 19 percent of total expenses and 24 percent of total revenue (BudgIT,

n.d.; Guay 2017). As of 2017, BudgIT has expanded its work to Sierra Leone and Ghana.

> **"In Nigeria, it's a big challenge to access information, which is what we're trying to solve. A lot of public resources are really hidden. We wanted to make it simpler and more accessible for people to understand government budgeting."**
> **— Oluseun Onigbinde, founder of BudgIT**

As highlighted in the 2012 to 2017 annual reports, BudgIT facilitates much of its work through partnerships (BudgIT, n.d.; Guay 2017). According to Onigbinde, "for our work to scale we cannot do it without broad range of partners and [civil society organization] engagement" (Onigbinde 2018). In 2013, BudgIT worked with 28 civil society organizations and participated in or made presentations on the Nigerian budget at 32 civil society sessions. As of 2017, the organization has 55 civil society partners and was employing a broad range of new public communications tools, including e-tools, SMS, a regular radio program, and social media. BudgIT also has partnerships with official national institutions including the National Assembly of the Federal Republic of Nigeria ("National Assembly"), the National Assembly Budget and Research Office, the Budget Office of the Federation, and the Kaduna State Government. BudgIT has also provided support upon request to the Nigerian Extractives Industries Transparency Initiative (NEITI), the Federal Ministry of Budget and National Planning, and the Lagos State Ministry of Economic Planning and Budget (BudgIT, n.d.; Guay 2017).

Funding

As noted above, BudgIT's 2017 operating budget was US $1.4 million, with personnel and project expansion expenses taking up more than half of all outgoings. As of 2018, Onigbinde estimates it to be closer to $1.8 million USD (Onigbinde 2018). The Bill & Melinda Gates Foundation and the Ford Foundation were BudgIT's largest

donors in 2017, contributing $285,495 and $250,000 respectively in that year. The Bill & Melinda Gates Foundation website characterizes itself as a "long-time supporter," having contributed a total of $1.4 million as of November 2016 (Bill & Melinda Gates Foundation, n.d.). Other funding comes from the John D. and Catherine T. MacArthur Foundation, the Open Society Initiative for West Africa, the Natural Resource Governance Institute, Oxfam International, the U.S. Embassies in Lagos and Abuja, the Indigo Trust, and the Omidyar Network (BudgIT, n.d.; Guay 2017). International donors provide 90 percent of the organization's core operational funding (Onigbinde 2018).

Impact

According to Onigbinde, "it can be difficult to show social impact as it's not a sprint, it's a marathon," and giving people more information won't lead to changes in policies and programs overnight. It requires understanding and use of the data, then engagement with elected officials, and long-term advocacy and influencing in partnership with a broad range of other actors such as journalists and civil society organizations. As such, "[BudgIT is] not solely responsible for impact, but [the organization does] try to show [its] contribution" (Onigbinde 2018). In spite of these caveats, there is demonstrable evidence of BudgIT making budgetary data more open and accessible and instigating conversations on public financial flows in Nigeria.

Public engagement in the national budgeting process:

BudgIT has engaged millions of citizens in what was a complex, opaque, and inaccessible government process. According to the organization's 2017 annual report, in the preceding year BudgIT reached approximately 2.5 million people–1.5 million Nigerians offline, as well as 1 million more via digital spaces. The Tracka program was particularly successful in promoting offline engagement by using BudgIT project officers to share the feedback of "offline" communities or individuals through the platform or with local representatives. Engagement occurred in more than 600 separate communities, monitoring 5,273 public projects. For example, BudgIT organized

more than 4,271 town hall meetings to sensitize citizens across the country (BudgIT 2018).

The depth of the organization's engagement is illustrated through its 2017 campaign to analyze the Nigerian federal budget. Working with citizens, BudgIT compiled a 2,210-page document of searchable budgetary data. It was then translated into simplified budgetary documents for public distribution. BudgIT distributed 20,000 copies of these simplified budget documents and sent out approximately 480 budget-related SMS messages to Nigerians in urban and rural areas, encouraging citizens to review the budget. It also produced over 210 infographics highlighting insights from the budget; these were curated and distributed on social media with over 1.6 million impressions. Over 25,000 citizens actively participated in the process and the full, simplified report was subsequently submitted to the National Assembly and the Federal Budget Office. This outreach set a new precedent for public engagement in the Nigerian federal budget process via online and offline channels, despite this engagement not being required by law.

> **"Our key goal is to democratize – to fight against corruption with transparency and trust in public resources."**
> **— Oluseun Onigbinde, founder of BudgIT**

According to Onigbinde, the value of this engagement is not just about giving citizens information to engage with their public officers, but also about changing local conversations. He considers the Tracka project to be their most successful activity as "it's not just about getting something done or built, it's about the strength of the conversations at the grassroots [...] and about challenging the psychology of society and that of its public officers" (Onigbinde 2018).

Identifying misuse of funds:

As a result of BudgIT's and citizens' analysis, BudgIT identified a number of suspicious or frivolous planned expenses in the 2017 federal budget — including a 656 percent spending increase over 2016 levels on the legal aid council's "office stationeries and computer consumables" (Guay 2017).

Careful review of sub-national budgetary documents also exposed corruption at different levels of government. In one instance, identified by the Tracka project, the Honorable Muhammad Umar Jega– a National Assembly representative for Gwandu, Aliero, and Jega in Kebbi State–facilitated the allotment of 41 million Nigerian naira (US$113,575) for a youth center that did not exist ("Tracka Uncovers a N41 Million Non-Existent Youth Centre in Jega Community, Kebbi State" 2018). This and other non-existent projects were highlighted via media and press–for example, in the Premium Times (Adebowale, Katty, and Adebowale 2018)–resulting in citizen advocacy and, in some cases, dialogue between citizens and local officials on revisions to their local budgets.

More transparent review of government budgets has also opened a discourse between the government and citizens on allocation of resources and compensation. In 2016, the government made a controversial call to remove fuel subsidies. The policy was very unpopular as demonstrated by widespread riots (Mark 2012), and was made all the more so when, due to the communication efforts of groups such as BudgIT, citizens saw how much of the national budget was being spent on government workers' compensation. The government responded by offering concessions, including a 25 percent cut in the salary of several high-ranking officials (Firth 2013).

Serving as a data intermediary:

BudgIT's work has highlighted the complexity of the budgetary process in Nigeria and its inaccessibility not only for citizens, but also for companies and development entities. The organization has therefore tried to position itself as a financial intermediary that can

help individuals, corporations, and development organizations sift through dense budgetary information and answer specific budgetary queries. In 2017, BudgIT received over 2,000 unique data requests monthly from corporate and organizational users.

According to Onigbinde, one of the most important roles BudgIT can play is making budgetary information machine-readable. This allows analysts and ordinary citizens to rapidly and easily search and analyze large amounts of budget data to better understand government actions and allocations, and advocate for change where it is needed.

BudgIT does this by sourcing relevant budgets from the federal and local budget offices in their standard PDF form. They submit the documents to an online software conversion service and then go through a rigorous data cleaning and validation exercise to ensure the official PDFs have been accurately translated. Once the documents are in a searchable format, BudgIT works on "drawing out insights, building designs, media strategy and building connections" (Onigbinde 2018).

One user of BudgIT's data professed, "planning for my business is easier because of the understanding gotten from BudgIT's interpretation of the budget" (Omidyar Network 2017). Said another, "My quality of life/work has improved because of access to adequate information of which I harness in my job-related activities (finance and treasury) and intellectual development in personal dealings" (Omidyar Network 2017).

In spite of their initial success, BudgIT faces a number of ongoing challenges. First and foremost is outreach to those who are "offline," given that many of BudgIT's tools require access to mobile phones or the internet. Across Nigeria there is limited cell service and poor connectivity in many rural areas (OpenSignal n.d.). Tracka's primary

Ongoing Challenges

function—allowing online users to enter information about local projects—is one such example, though BudgIT has attempted to bridge this digital divide in its programming through offline engagement by its project officers.

Second, BudgIT has challenges reaching a large proportion of the population who are illiterate—approximately 49 percent as of 2008 (UNESCO n.d.)—and/or innumerate and therefore struggle to understand budgetary information even when it is converted into a visual format such as infographics. BudgIT's end users are therefore limited to those who are digitally literate and, for the most part, those who are not living in poverty. According to a survey conducted among users of BudgIT in 2017, only 9 percent are living in poverty, compared to 50 percent of the national population (Omidyar Network 2017).

> **"Technology might not be the entire solution to the multifaceted problems but it is an enabler for improvement."**
> **— Oluseun Onigbinde, founder of BudgIT**

Third, access to budgetary information is highly dependent upon BudgIT's relationships with government officials. According to Onigbinde, "BudgIT staff spend a lot of time chasing officials for budgetary documents and many don't feel obliged to respond to you, in spite [sic] the Freedom of Information Act. This is useful but we don't have a punitive structure so if people don't respond there is no recourse." Further exacerbating the problem, members of the National Assembly have expressed their distrust of the project, not least of all as BudgIT has also launched various campaigns calling for public officials' salaries to be made public (Kazeem 2017).

Finally, there is the ongoing challenge of financial sustainability. BudgIT is currently 90 percent funded by international donors as, according to Onigbinde, "Nigeria doesn't have a large elite likely to

fund that kind of work" (Onigbinde 2018). He attributes this to the smaller pool of well-endowed philanthropists in Nigeria and the fact that the organization holds "many of the wealthiest to account."

Conclusion

In the seven years since its inception, BudgIT has helped thousands of Nigerian citizens better understand budgetary data from Nigeria's Federal Government. It has promoted more open dialogue between citizens and government officials on spending and project implementation, fostering a culture of accountability which has led to various national and local budgetary changes. There is a clear case for replicability of the project in other countries with opaque governmental processes. However, given the often-adversarial nature of the work, it is unlikely that local public resources will support these efforts, and local private philanthropy options are limited. Replication will therefore be dependent on international donor investment in similar data sharing platforms, but also in local human capacity to engage citizens offline, help them interpret findings, and to facilitate engagement opportunities with local officials.

Written by Jessica Espey (SDSN TReNDS Director) with input from and thanks to Oluseun Onigbinde (Founder of BudgIT), Eric Swanson (SDSN TReNDS member and Director of Open Data Watch) and Jay Neuner (SDSN TReNDS Communications Manager).

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Landsat's Earth Observation Data Support Disease Prediction, Solutions to Pollution, and More

A Case Study of Landsat
Prepared by SDSN TReNDS

How can open access to Earth imagery help predict disease spread or identify solutions to toxic waterways? The Landsat program—the longest-standing continuous global record of the Earth's surface through satellite imagery—has enabled these and other solutions in support of people, planet, and prosperity since its launch in the 1970s. Beyond its social and environmental impacts, Landsat is also an economic boon; it has produced annual cost savings in the United States ranging from US$350 million to $436 million for federal and state governments, nongovernmental organizations, and the private sector, as well as an estimated worldwide economic benefit as high as $2.19 billion as of 2011. Landsat is a powerful example of the benefits of long-term investing to build robust data systems for sustained, longitudinal monitoring of environmental, social, and economic conditions.

Context

There are approximately 150 million square kilometers of land worldwide, of which humans occupy or use roughly 80 percent. 40 percent of that is used for the purposes of agriculture, feeding our rapidly growing population; in 2011, the global population reached 7 billion, and it is projected to increase to more than 9 billion by 2050 (United Nations Population Division 2017). As demand grows, our planet's capacity to sustain needed food and fiber production and fresh water supply diminishes (NASA, n.d.). Close monitoring of environmental change is therefore required.

Images of the Earth taken at moderate resolution (each pixel representing an area of about 30 meters by 30 meters) by Earth-orbiting satellites such as Landsat offer the critical capability to observe land use and land use change over time and to compare changes in different parts of the world. Furthermore, this Earth observation data can inform a wide variety of applications "including tracking biodiversity and wildlife trends; measuring land use change such as deforestation; mitigating, and managing the impact of natural disasters, including fires, floods earthquakes, and tsunamis; sustainably managing natural resources, such as energy, freshwater, and agriculture, address emerging diseases and other health risks; and predicting, adapting to, and mitigating climate change" (Anderson et al. 2017).

For policymakers, satellite data better equip them to make policy decisions across geographic scales and to consider the environmental impacts of seemingly local decisions. Keeratikasikorn and Bonafoni describe an example from Bangkok, Thailand in the anthropogenic phenomenon of increasing temperatures in urban areas. Maps of this phenomenon were developed using data from Landsat 8 and then "[supplied] a scientific support for the urban planning policy aimed to integrate urban development and landscape ecosystems"(Keeratikasikorn and Bonafoni 2018).

In 2015, 193 countries committed to an ambitious global agenda to eradicate poverty and achieve sustainable development. The 2030 Agenda for Sustainable Development and its 17 accompanying Sustainable Development Goals (SDGs) acknowledge the importance

of considering the local, regional, and global impacts of our land use decisions, if we are to chart a more sustainable development path. For example, five targets (under Goals 2,6,11, 13, 14, and 15) specifically relate to ecosystem management, and tracking their progress will rely heavily on access to time-series Earth observation and land imaging data (Anderson et al., 2017).

Table 1. Earth observation and geospatial information linkages to SDG goals, targets, and indicators

Target Contribute to progress on the Target, not necessarily the Indicator									Goal	Indicator Direct measure or indirect support to the Indicator					
							1.4	1.5	1 No poverty	1.4.2					
						2.3	2.4	2.c	2 Zero hunger	2.4.1					
					3.3	3.4	3.9	3.d	3 Good health and well-being	3.9.1					
									4 Quality education						
								5.a	5 Gender equality	5.a.1					
		6.1	6.3	6.4	6.5	6.6	6.a	6.b	6 Clean water and sanitation	6.3.1	6.3.2	6.4.2	6.5.1	6.6.1	
					7.2	7.3	7.a	7.b	7 Affordable and clean energy	7.1.1					
								8.4	8 Decent work and economic growth						
					9.1	9.4	9.5	9.a	9 Industry, innovation and infrastructure	9.1.1	9.4.1				
						10.6	10.7	10.a	10 Reduced inequalities						
	11.1	11.3	11.4	11.5	11.6	11.7	11.b	11.c	11 Sustainable cities and communities	11.1.1	11.2.1	11.3.1	11.6.2	11.7.1	
				12.2	12.4	12.8	12.a	12.b	12 Responsible consumption and production	12.a.1					
					13.1	13.2	13.3	13.b	13 Climate action	13.1.1					
		14.1	14.2	14.3	14.4	14.6	14.7	14.a	14 Life below water	14.3.1	14.4.1	14.5.1			
	15.1	15.2	15.3	15.4	15.5	15.7	15.8	15.9	15 Life on land	15.1.1	15.2.1	15.3.1	15.4.1	15.4.2	
								16.8	16 Peace, justice and strong institutions						
17.2	17.3	17.6	17.7	17.8	17.9	17.16	17.17	17.18	17 Partnerships for the goals	17.6.1	17.18.1				

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Description of the Data Solution

The Landsat program consists of a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. To date there have been eight Landsat satellite missions, and a ninth launch is planned for 2020 (U.S. Geological Survey, n.d.).

The sensors on the Landsat satellites generate images with individual pixels that each represent an area of 30 meters by 30 meters. You cannot see individual houses in a Landsat image, but you can detect large, built infrastructure like highways, dams, and office buildings. From a scientific perspective, the 30-meter spatial resolution and 185-kilometer breadth of Landsat imagery fills an important scientific niche because the resulting data provide global coverage every season of the year, yet are detailed enough to characterize human-scale processes such as urban growth, agricultural irrigation, and deforestation. By establishing baseline knowledge of Earth's land areas throughout the last half-century, Landsat allows scientists to evaluate environmental change over time, to better understand the drivers and impacts of change, to model and predict future changes, and to chart these changes in the form of maps.

> **"The foresighted acquisition and maintenance of a global image archive has proven to be of unmatched value, providing a window into the past and fueling the monitoring and modeling of global land cover and ecological change" (Wulder et al. 2012).**

The two most recent Landsat satellites—Landsat 7 and Landsat 8—orbit the Earth at an altitude of 705 kilometers (438 miles), collecting data for a 185-kilometer (115-mile) swath that moves from north to south over the sunlit side of the Earth in a sun-synchronous orbit. Each satellite makes a complete orbit every 99 minutes, completes about 14 full orbits each day, and crosses every point on Earth once every 16 days. The satellites' orbits are offset to allow eight-day repeat coverage of any Landsat scene area on the globe. Between the two

satellites, more than 1,000 scenes are added to the USGS archive each day (U.S. Geological Survey, n.d.).

Landsat data are received and downlinked to ground stations worldwide, and are archived at the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, South Dakota. Landsat data products are processed and made available for download to all users at no cost via EarthExplorer, GloVis, and the LandsatLook Viewer.

Implementation

In a 1966 press release, U.S. Secretary of the Interior Stewart L. Udall announced the start of "Project EROS," a program "aimed at gathering facts about the natural resources of the Earth from Earth-observing satellites carrying sophisticated remote sensing observation instruments" (United States Department of the Interior 1966). Secretary Udall named Dr. Pecora to lead the EROS program. USGS's Dr. Pecora stated that the program was "conceived in 1966 largely as a direct result of the demonstrated utility of the Mercury and Gemini orbital photography to Earth resource studies." Although weather satellites had monitored Earth's atmosphere since 1960, prior to the Mercury and Gemini missions there was no appreciation of land imagery taken from space (Baumann 2010).

"It was the granddaddy of them all, as far as starting the trend of repetitive, calibrated observations of the Earth at a spatial resolution where one can detect man's interaction with the environment" (NASA, n.d.).

In cooperation with NASA, the Earth Resources Technology Satellite (later renamed Landsat 1) was launched on July 23, 1972. Additional Landsat satellites were launched in the following decades. Launched in 1984, Landsat 5 collected data for more than 28 years, more than 23 years beyond its original design lifetime. Landsat 7 was launched in 1999 and also continues to operate well past its design lifetime, though in 2003 it experienced an instrument failure that leads to

gaps in about 22 percent of its imagery. The most recent satellite – then Landsat Data Continuity Mission, now Landsat 8 – launched on February 11, 2013. Landsat 9 is in development, with launch scheduled for late 2020 (U.S. Geological Survey, n.d.).

Today, Landsat continues to be administered by the USGS in partnership with NASA.

Funding

The United States Government has funded Landsat since its inception. But the relationship between NASA and the institution that legislates that funding (the U.S. Congress) has been turbulent, with ongoing disagreement over the amount of resources required for the Landsat program and available through the U.S. federal budget. The¬Landsat 9 mission is no exception.

"Appropriators [for the Federal Government's FY2014 budget] chided NASA for unrealistic expectations that a Landsat 9 would cost $1 billion, and capped spending at $650 million," according to a report by the Congressional Research Service (Folger 2014). By contrast, $850 million was the approximate cost of building and launching Landsat 8, its predecessor.

Even with funding constraints, NASA and the USGS announced in April 2015 that work on Landsat 9 had commenced, with funding allocated for the satellite in the president's FY2016 budget. At the time of this announcement, they stated that launch was planned for 2023, but was subsequently expedited to December 2020 (Singh 2016). As of April 2018, the launch plan appears on track and a Mission Critical Design Review characterized a 2020 launch as "an aggressive but achievable launch date" (NASA 2018).

Return on Investment

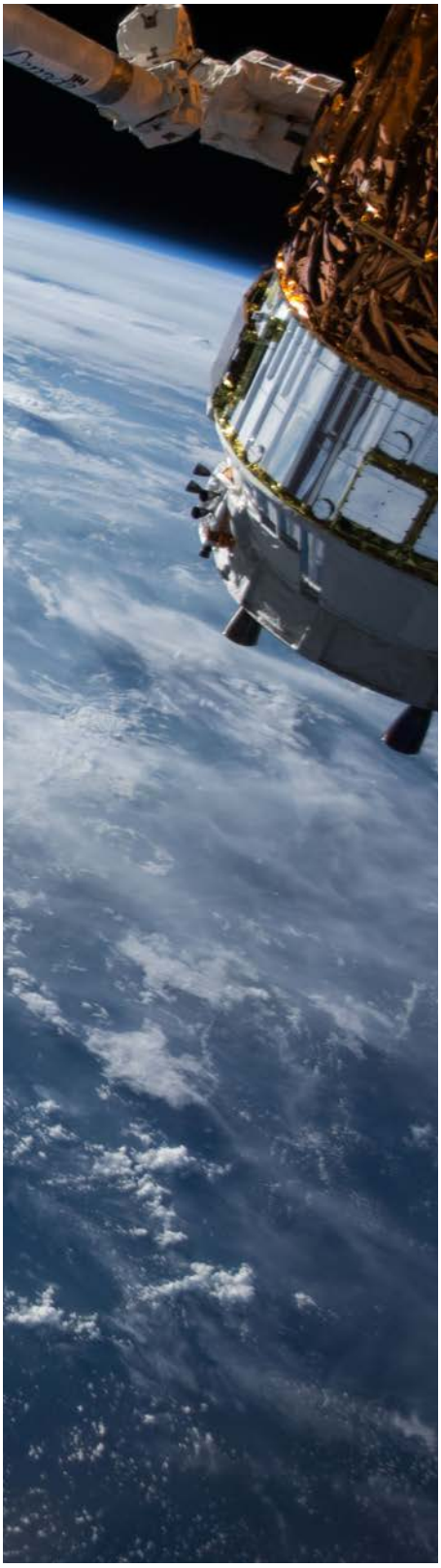
Since 2007, multiple analyses have quantified the economic value of the Landsat program, including studies by the American Society of Photogrammetry and Remote Sensing (National Science and Technology Council 2007) and by Booz Allen Hamilton, which was commissioned to undertake an economic returns study for the USGS

(Adams and Pindilli 2012). In 2013, another analysis by the National Research Council concluded "the economic and scientific benefits to the United States of Landsat imagery far exceed the investment in the system" (National Research Council 2013).

The USGS also published its own analysis in 2013. It included a survey of 11,275 Landsat users on the uses and value of Landsat satellite imagery, 77 percent of whom stated they were dependent on Landsat imagery to do their job. The study also estimated the economic benefit of Landsat data for the year 2011 was an estimated $1.70 billion for U.S. users and $400 million for international users, resulting in a total annual value of $2.19 billion (Miller et al. 2013).

"Satellite imagery has significant potential to provide more timely statistical outputs, to reduce the frequency of surveys, to reduce respondent burden and other costs and to provide data at a more disaggregated level for informed decision making" (Global Working Group on Big Data for Official Statistics, n.d.).

In 2015, the Landsat Advisory Group of the National Geospatial Advisory Committee undertook a critical review of the value of the Landsat information. The committee consisted of commercial entities such as Google and Esri; federal, state and local government entities; and NGO geospatial information experts. The review considered both past studies and broader applications of Landsat data, such as government mapping, monitoring consumptive agricultural water use, forest change detection, flood mitigation, coastal change, and wildfire risk assessment. The analysis examined 16 decision processes and attempted to quantify the cost of using Landsat to inform these processes versus other methods (National Geospatial Advisory Committee – Landsat Advisory Group 2014; Mitchell 2012). The study found that 16 Landsat applications alone produced savings of $350 million to over $436 million per year for federal and state governments, NGOs, and the private sector (National Geospatial



Advisory Committee – Landsat Advisory Group 2014). The study notes that these savings and others not addressed by the paper will continue to accelerate. The Advisory Committee found that "the economic value of just one year of Landsat data far exceeds the multi-year total cost of building, launching and managing Landsat satellites and sensors" (National Geospatial Advisory Committee – Landsat Advisory Group 2014).

Other assessments estimate the value of Landsat to be far higher. A 2015 report by economists from Colorado State University and the USGS Fort Collins Science Center estimated that the 2.38 million Landsat images freely downloaded in 2011 benefited the U.S. economy by $1.8 billion in that year—almost double the cost of building and launching Landsat 8, as noted by the study authors (Loomis et al. 2015). Their study was based on a Contingent Valuation Method, which estimates users' willingness to pay for non-market goods. For this study, the economists analyzed a 2012 survey with a sample of 13,473 data users. Users were asked if they would purchase Landsat data at a given price. This price was then incrementally revised upwards or downwards depending on if the user said "yes" or "no" to the initial amount. The prices ranged from $10 to $20,000 per Landsat scene. The study found a mean value for established Landsat users of $912 per scene and $367 per scene for new users, whom—one would assume—gave a lower value as they had yet to understand its potential application. Based on these prices, the annual economic benefit for the Landsat scenes obtained in 2011 was calculated at $2.19 billion worldwide (for both U.S. and international data users). This estimate was considered conservative because it did not include downstream users of Landsat data, i.e. data users who did not directly download Landsat data from the USGS but used data or derived products obtained from others.

There have also been attempts to quantify the value of Landsat data for specific industrial sectors; for example, Abhishek Nagaraj at the Massachusetts Institute of Technology looked at how Landsat imagery has contributed to the discovery of new deposits in the gold exploration industry (Nagaraj 2015). Nagaraj finds that between the 1950s and 1990 information from Landsat nearly doubled the

rate of significant gold discoveries from the industry. Furthermore, affordable access to the imagery encouraged entrepreneurship as junior firms had lower costs for early-stage experimentation.

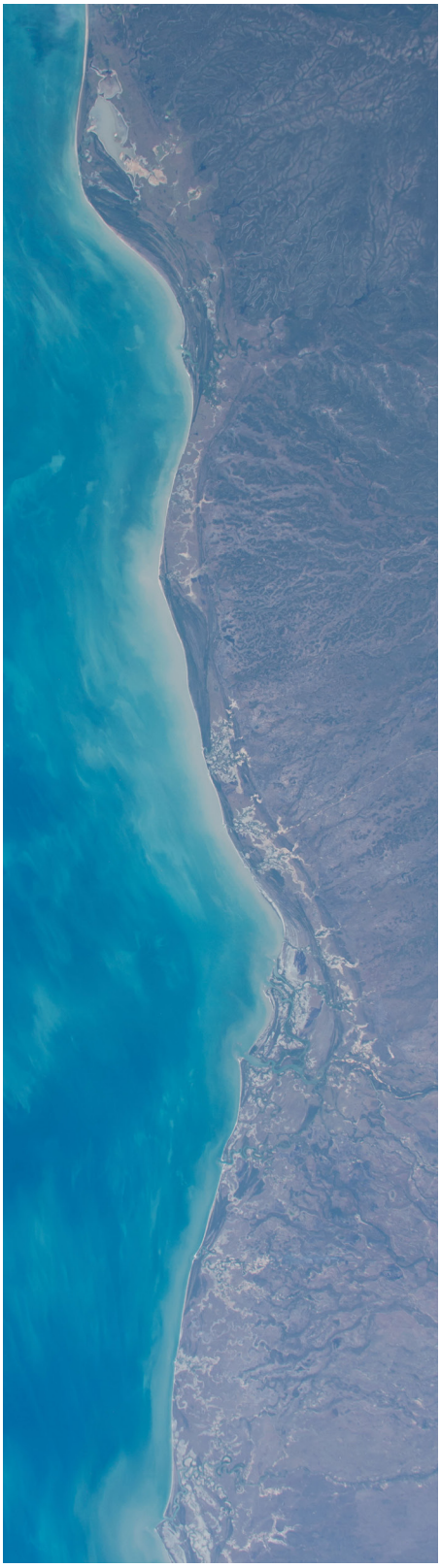
Social and Environmental Impacts

Since Landsat's inception in 1970, data from its missions have had considerable impact on research and science and on resultant policy. The same 2012 survey analyzed by Loomis et al. asked about perceived environmental and societal benefits and impacts from projects that used Landsat. It found that "[…] more than 80 percent of users saw environmental benefits, including improving or enabling long-term planning or monitoring, protecting or improving environmental conditions, and maintaining or improving ecosystem services. Almost 90 percent saw improvements in decision-making through better communication of concepts using Landsat imagery. More than three-quarters cited supporting enforcement of regulations or policies and reducing human risk or increasing human safety as benefits. Close to 70 percent of users also saw some resolution of disputes or reduction in conflicts as a result of projects using Landsat" (Miller et al. 2013). The following section considers just three applications of Landsat and the associated benefits.

1. Implications for human health

Landsat measurements can help decision-makers pinpoint and minimize environmental health risk. For example, they can highlight agriculture or urbanization trends that might pollute waterways or show changes in vegetation growth that might affect habitats for disease-carrying animals and insects.

By way of example in September 2000, the Yemen Ministries of Agriculture and Irrigation and of Health reported an outbreak of Rift Valley fever (RVF) disease in humans and livestock in the El Zuhra district, located on the western coastal plain of Yemen. Experts from across Yemen, the WHO, and the U.S. Naval Medical Research Unit 3 (based in Cairo) subsequently confirmed this (Balkhy and Memish 2003). Large-scale flooding in semi-arid areas and the pooling of water in shallow depressions on the Earth's surface (and resultant



changes in vegetation) can illustrate areas at high risk for the spread of RVF; the disease spreads through bites from infected mosquitos, and these areas are appropriate habitats in which mosquitos can thrive (Centers for Disease Control and Prevention, n.d.). Other spatial monitoring and reporting tools—such as ground-based sensors and radiometers—can capture these kinds of depressions, but the terrain in Yemen was too complex for these tools. Landsat 7 data was therefore used to compare changes in vegetation between May and September 2000. As reported by NASA, "Landsat data in combination with aerial surveys revealed numerous areas along the coastal plain and neighboring areas that were conducive to the transmission of the RVF virus. This enabled the surveillance teams to much better target disease control operations to areas at highest risk of disease than would have been possible using ground surveillance methods in this region of complex topography" (NASA, n.d.).

2. Enabling environmental management

In the United States, scientists from the Carnegie Institute for Science used Landsat 5 imagery to better understand the causes of toxic freshwater algal blooms in Lake Erie—which borders the U.S. states of Ohio, Pennsylvania, and New York—and the Canadian province of Ontario. According to lead researcher Jeff Ho, Lake Erie provides drinking water for 11 million people, and yet the quality of the water supply has been steadily declining (Carnegie Institution for Science 2017). This is generally attributed to phosphorus run-off from fertilizers and as such in 2016 the bi-national International Joint Commission set new phosphorus targets, but as Ho and Michalak's 2017 study (Ho and Michalak 2017) set out to demonstrate, that is only part of the problem. Ho and Michalak's study used historical Landsat imagery to trace changes in algal blooms since 1984, more than doubling the historical record and dramatically boosting their ability to understand trends and causes. These new data have strong policy implications as they clearly highlight the extent to which phosphorus run-off needs to be curtailed and the length of time it will take for the lake to recover. According to Michalak, "The path ahead for Lake Erie is clear—we have to reduce the amount of phosphorus flowing into the lake. And we will need to be patient to give the lake time to recover."

(Ho and Michalak 2017) The Landsat data have enabled scientists, conservationists, and policymakers to see the extent of the problem and the scale of the solution required.

3. Creating a culture of open access to data

Another important impact of the Landsat program is its contribution to open data and open science. In 2008, the U.S. Government made all Landsat data openly available for purchase. After this decision, an average of 53 Landsat scenes per day were being downloaded, with users charged approximately $500 per scene (Anderson et al. 2017). In 2012, the government agreed to make all of the data openly available and free of charge. Since this revised data policy, an average of 5,700 scenes per day are downloaded and, as of 2016, more than 40 million Landsat scenes had been downloaded in total (Anderson et al. 2017). As a direct result of the policy shift, one study estimates that the use of Landsat data within academic and scientific articles has increased by 69 percent (Mishra 2015).

Landsat imagery is an essential "national asset" which has made and continues to make critical "contributions to U.S. economic, environmental, and national security interests" (Marburger 2005).

According to Miller et al.'s 2013 survey of Landsat users, the average number of scenes obtained from all sources annually per user more than doubled after the policy change, whereas the average amount spent annually on Landsat imagery per user decreased by 78 percent (Miller et al. 2013). Although the policy did render Landsat imagery free through the USGS, some users continued to purchase imagery from other providers, "possibly to obtain imagery which has been processed beyond what is provided by the USGS" (Miller et al. 2013).

Like Landsat, other geospatial data providers around the world are sharing data free of charge, including the European Commission's

Copernicus program (FDC, n.d.) and Geoscience Australia (Foong 2012). The Landsat example has also helped drive efforts to promote more open and free data access under the auspices of the Group on Earth Observations (GEO), a voluntary intergovernmental network of Earth observation data providers and other participating organizations established in 2005 (Group on Earth Observations, n.d.).

Ongoing Challenges

Operating costs and political support

In spite of its immense value to research, science, and policy, Landsat faces a number of challenges to its ongoing operation and replication. As satellites are highly specialized technology, the Landsat satellite missions are costly. Although the satellite design and engineering is constantly improving, the lifespan of a satellite is limited by fuel capacity and maintenance issues (NASA, n.d.). (This issue has decreased in significance over time; since the 1970s, the average operational lifetime of an Earth observation mission has tripled to today's average mission length of 8.6 years, which enables more stable and continuous observations from the same sensor over many years (Belward and Skøien 2015).) Several of the Landsat missions have operated well past their baseline design lifetimes. Nevertheless, securing budget for Landsat 9 has been a tense political battle, with the return on investment for this program and its further iterations perhaps viewed less favorably by some politicians in comparison to other proposed programs for the U.S. federal budget. This hurdle has jeopardized the current Landsat open data policy. U.S. Government officials are reportedly considering whether to reverse the policy to allow recovery of Landsat's operational costs from users (Popkin 2018).

Access to and interpretation of the imagery

Although Landsat has seen a surge in use since 2008, especially the open data policy was fully implemented, there are still considerable barriers to the use of the imagery, including the lack of availability of technical expertise to understand and interpret the results. According to Miller et al.'s 2013 survey, many users still purchase the data in

a more interpretable format than the USGS provides, in part due to the lack of technical expertise to process the data. These technical issues may also hinder the use of Landsat for a range of simple SDG-relevant measurements; for example. For example, only in 2018 has the Government of Colombia (which has high statistical capacity) started to use Landsat imagery to monitor urban sprawl and urban land use, even though the imagery has been publicly available for more than a decade.

To help countries access and interpret Earth observation and related geospatial data for SDG monitoring, the United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM) is leading the Working Group on Geospatial Information, under the Inter-Agency and Expert Group on SDG Indicators. The Working Group has agreed to provide in-depth analysis, recommendations, and advice on the development of methodologies for a subset of indicators. It will also undertake methodological work in a variety of cross-cutting themes including data disaggregation, national and sub-national reporting, and other data issues (e.g. citizen science, crowdsourcing data, and volunteered geographic data) to facilitate countries' better use and interpretation of Earth observation data (Anderson et al. 2017). To ensure more widespread uptake and use of these data, particularly in countries with limited resources, additional international investments are needed in statistical capacity with a specific focus on geospatial monitoring and Earth observation.

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