



# Improving Immunisation Coverage and Equity through the Effective Use of Geospatial Technologies and Data

A Landscape Analysis & Theory of Change September 2020

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# Acronyms

|        |  |
|--------|--|
| AFP    | Acute flaccid paralysis  |
| CDC    | U.S. Centers for Disease Control and Prevention                    |
| DHIS2  | District Health Information Systems 2                              |
| DHIS2  | District Health Information Software 2                             |
| DHS    | Demographic and Health Surveys                                     |
| DOPH   | Department of Public Health (Myanmar)                              |
| EPI    | Expanded Programme of Immunisation                                 |
| Gavi   | Gavi, the Vaccine Alliance   |
| GIS    | Geographic Information System                                      |
| GNSS   | Global Navigation Satellite System                                 |
| GPEI   | Global Polio Eradication Initiative                                |
| GPS    | Global Positioning System  |
| GRID3  | Geo-Referenced Infrastructure and Demographic Data for Development |
| HIS    | Health Information System  |
| IHRIS  | Electronic human resource information system                       |
| LMIC   | Low- and middle-income country                                     |
| LQAS   | Lot Quality Assurance Sample                                       |
| MFL    | Master facility list   |
| MOH    | Ministry of Health   |
| MOHS   | Ministry of Health and Sport                                       |
| ODK    | Open Data Kit software   |
| SDG    | Sustainable Development Goal                                       |
| SIA    | Supplemental immunisation activities                               |
| UHC    | Universal Health Coverage  |
| UNICEF | United Nations Children's Fund                                     |
| VTS    | Vaccination tracking system  |
| WHO    | World Health Organization  |
| WPV    | Wild poliovirus  |



# Glossary of Terms

|  |   |
|--|---|
| <b>Geographic Information System (GIS)</b>       | A collection of computer software and data used to view and manage information about geographic objects, analyse spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analysed. |
| <b>Geospatial data</b>                           | Information about the location and shape of objects, geographic features and the relationships between them   |
| <b>Geospatial technologies</b>                   | A set of equipment, computer applications and systems to visualise, measure, and analyse Earth's features, typically involving such systems as Global Navigation Satellite System (GNSS), Geographical Information Systems (GIS), and remote sensing (RS)   |
| <b>Global Navigation Satellite System (GNSS)</b> | Any satellite navigation system with global coverage—a system of orbiting satellites that transmit signals received by devices on the ground to determine the position of the receiver on Earth   |
| <b>Global Positioning System (GPS)</b>           | One of the global navigation satellite systems managed by the United States   |
| <b>Health system map</b>                         | A map containing the spatial distribution of the geographic features pertaining to the health system, in general, and the delivery of health service, in particular (e.g. health facilities, health districts, catchment areas)   |
| <b>Master facility list</b>                      | A complete, up-to-date, authoritative listing of the health facilities in a particular country  |
| <b>Microplan</b>                                 | An operational workplan that identifies communities, immunisation resources, and geographic features relevant to local-level immunisation service delivery  |
| <b>Modelled geographic accessibility</b>         | The measurement of the physical distance or travel time that quantifies the movement opportunity for people to reach existing health services   |
| <b>Population Estimation</b>                     | The use of statistical models, remote sensing datasets and sampled census information to create spatially accurate and precise estimates of human density and distribution  |
| <b>Remote sensing</b>                            | Collecting and interpreting information about the environment and the surface of the Earth from a distance through the use of methods such as aerial photography, radar and satellite imaging   |

## Executive Summary

The effective use of geospatial technologies, including geographic information systems (GIS), to collect, manage, analyse, model and visualise geographic data has the potential to improve data-driven decision-making for immunisation programme delivery. Digital maps displaying programme resources, population distribution, immunisation coverage indicators and other geographic data can effectively uncover patterns in space and over time to facilitate better use of information and decision-making. Despite recent advances in technologies and data collection devices, the use of geospatial technologies for immunisation programme delivery and other public sector health applications is still underdeveloped in most low- and middle-income countries (LMICs). This is due to the fact that effective use of geospatial technologies requires a long-term commitment, resources, policies and procedures for systematic collection and use of geospatial data. The aim of this report is to assess the state of the art and to document current approaches for leveraging geospatial technologies, including GIS, to improve immunisation coverage and equity in low- and middle-income countries.

A review of the state of the art on geospatial technologies for immunisation programming reveals the potential for digitally produced maps with accurate geospatial data to reduce the number of missed settlements and to contribute to other programmatic improvements when applied to microplanning activities for routine immunisation and immunisation campaigns. Analysis of the geographic distribution of populations in relation to service delivery points and key programmatic indicators can help identify areas that need additional outreach or targeted improvements in service delivery. Additional studies are needed to strengthen the evidence and understanding of how geospatial data and technologies can impact immunisation programme outcomes in addition to enhancing equity, accessibility, cost-effectiveness and uptake of immunisation services.

Through document review and key informant interviews the potential for geospatial data and technologies to impact immunisation programming is described in eight use cases: health system mapping, population estimation/spatial distribution, microplanning, disease surveillance, vaccinator tracking, campaign monitoring, geographic accessibility modelling and vaccination coverage modelling.



Credit: The Bill & Melinda Gates Foundation and Vincent Seaman



These examples demonstrate how the visualisation of geospatial data, spatial analysis and geospatial modelling can help service delivery teams identify zero-dose children (children who have never been immunised) and improve service delivery to achieve equity in vaccine coverage. Additionally, country-focused case studies describe the experiences in Nigeria, Myanmar and Cameroon, demonstrating the achievements, investments and enabling environments that can contribute to the successful and cost-effective management and use of geospatial data and technologies in support of immunisation programs.

The lessons and challenges that accompany the programmatic use of geospatial data and technologies

for immunisation service delivery highlight the need for a clear enabling environment that covers aspects such as governance and leadership, policies, data specifications and protocols, technical capacities and resources to support the sustainable use of geography as a unifying dimension in a national health information system (HIS). These foundations form the basis for powerful changes that can impact immunisation programme implementation and contribute to increasing in the number of fully-immunised children globally. In the context of the Covid-19 pandemic, the accelerated development of tools for data sharing and collaboration between remote locations using the common language of geography is more important than ever to advance the delivery of immunisation services.



Mapping activities in Sindh, Pakistan. Credit: Frank Salet

# Introduction and Background

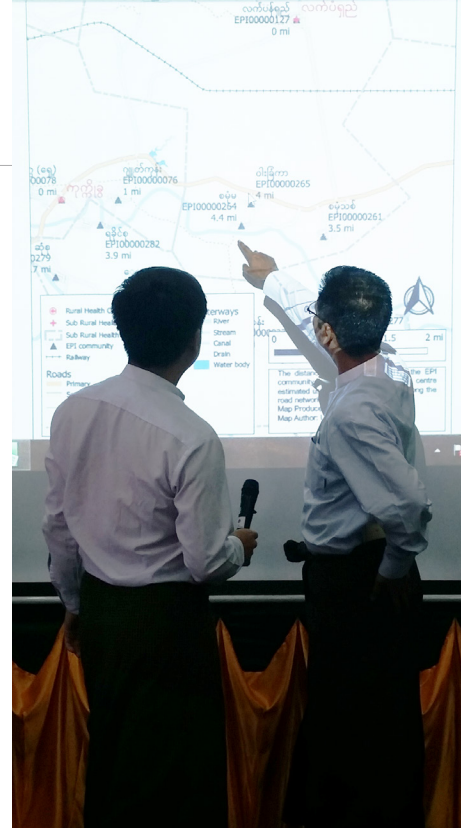
The effective use of digital innovations has the potential to improve data-driven decision-making, planning and evaluation of immunisation programmes. In this context, geospatial technologies, which includes global navigation satellite system (GNSS), geographic information systems (GIS) and remote sensing, are helping immunisation programme implementation through the visualisation and analytical power of maps, geospatial analysis and modelling.

Advances in recent decades have increased the scope and use of geospatial technologies due to (1) increasing availability of large volumes of freely accessible geospatial data, (2) the availability of easy to use devices to collect geographic coordinates in the field, (3) increasing availability of user-friendly tools for the visualisation and analysis of geospatial data and (4) increased computing power made widely available.

A geographic information system (GIS) is a collection of computer software and data used to view and manage information about geographic objects, analyse spatial relationships and model spatial processes. A Global Navigation Satellite System (GNSS) is composed of satellite and ground segments that can determine the geographic coordinates of any location on the surface of the Earth. The acquisition and analysis of information captured by remote sensors, including satellites from space, are collectively known as remote sensing. All of these technologies use the unifying science of geography to collect data and enable advanced analysis and modelling to support the understanding of real-life operations and situations on the ground.

Despite the potential and recent developments in geospatial technologies, many low- and middle-income countries (LMICs) most in need of immunisation programme improvements are not yet fully benefiting from what they have to offer. The comprehensive use of geospatial technologies requires a long-term commitment supported by policies, data quality and data-use culture, supervision and systems in place to support the digital interventions. When these systems are in place, geospatial technologies have the potential to improve programming and impact through improved data-use, decision-making and programme implementation.

Advancements and applications in the field of geospatial data and technologies for health sectors are championed by regional centres of excellence such as the WHO-AFRO regional Geographic Information



Credit: UNICEF





Mapping activities in Chad. Credit: The Bill & Melinda Gates Foundation and Vincent Seaman

System Centre<sup>1</sup> in Brazzaville, Congo and the Health GeoLab Collaborative in the Asia/Pacific region.<sup>2</sup> Both provide technical support for the management and use of geospatial data and technologies in health programming and opportunities to share experiences and expertise. Recent workshops for regional sharing of experiences and best practices in using geospatial technologies for immunisation and other health programmes have resulted in important guidance, capacity assessments and case studies (UNICEF, 2017; UNICEF, 2018a; AeHIN, 2017).

In support of Gavi's Data Strategy Review this report aims to provide an overview of lessons learned and recommendations for the use of geospatial data and technologies in immunisation programming in LMICs. Through resource review and key informant interviews

this landscape analysis documents the current state of implementation and provides a Theory of Change on how the effective use of geospatial data and technologies can result in improved immunisation coverage through routine and supplemental immunisation service delivery, programme planning and monitoring. This landscape analysis aims to understand the state of the art and document challenges, capacity building experiences and enabling environments to inform programming that promotes equity with a particular focus on zero dose and under-immunised children.

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1 WHO Regional GIS Center in Brazzaville, Congo  
[www.afro.who.int](http://www.afro.who.int)

2 The Health GeoLab Collaborative [www.healthgeolab.net](http://www.healthgeolab.net)

## State of the Art Review

A rapid review of published studies, research and literature was conducted to examine the current “state of the art” on the use of geospatial technologies for immunisation programming in LMICs. The review was intended to contextualize current applications, experiences, successful approaches and research gaps; it is outside the scope of this review to make definitive statements about evidence or effectiveness. Documents were identified for review from a broad systematic database search using standardised inclusion criteria. Thirty-eight publications concerning the use of geospatial technologies to implement, monitor or improve immunisation programme service delivery were included for the state of the art review. The remaining documents, project reports and research articles concerning the use of geospatial technologies for broad health and development applications, modelling, statistical analysis, vaccine efficacy research and epidemiology were not included in the state of the art review but contributed to the overall background and development of this landscape analysis.

The state of the art review provides an overview of how geospatial technologies have been explored and used for immunisation programming over the past two decades. The operational use of these technologies focuses on efforts applied through the Global Polio Eradication Initiative (GPEI). **Routine immunisation programmes** and mass campaigns for measles-rubella vaccination are discussed in selected references, showing promising results on cost-effectiveness of geospatial technology approaches and helping to define catchment area boundaries, but also highlighting challenges around coordination, capacity development and datasets that contain conflicting information; the challenges stem from a lack of governance systems and policies to guide the systematic collection and use of data (Dougherty et al., 2019; Ali et al., 2020; Pradhan et al., 2012). Utilizing maps to visualize inequities in coverage and underperforming facilities can inform planning for improved service delivery and increase vaccine coverage, as seen in a study in Kenya demonstrating that a targeted door-to-door strategy based on indicator visualization resulted in a 33.5% increase in fully-immunised children in one year (Shikuku et al., 2019).

**Modelled estimates of multi-national vaccination coverage** are explored and described in a number of publications, using geolocated Demographic and Health Survey (DHS) clusters of vaccination indicators with covariates such as population density, poverty, or climate to create geospatial models of immunisation coverage (Utazi et al., 2018; Utazi et al., 2019; Takahashi et al., 2017; Takahashi et al., 2015; Mosser et al., 2019). While these modelled estimates contain inherent uncertainties, they are useful



Cameroon monitoring activities  
Credit: The Bill & Melinda Gates  
Foundation and Vincent Seaman



for global monitoring, advocacy and generating recommendations to improve programme strategies. In contrast to large-area aggregate coverage data, these high-resolution modelled estimates can provide fine details of coverage heterogeneities to maximise programme investments at subnational levels and even pinpoint clusters of low vaccination that cross administrative or national boundaries for coordinated action. Modelled immunisation coverage can be used to estimate vaccination coverage in conflict areas where immunisation services are limited, demonstrating the relationship between areas of insecurity and low coverage (Higgins et al., 2019, Mashal et al., 2007).

The use of geospatial technology for **microplanning** activities demonstrates that a geo-enabled approach can increase the identification of previously missed settlements and help delineate health area boundaries (Barau et al., 2014; Dougherty et al., 2019; Kamadjeu et al., 2009; Rosencrans et al., 2017). The combination of geospatial technologies for immunisation service delivery planning within a suite of other interventions contributed to doubling the routine immunisation coverage in urban Patna, India and to reducing the incidence of wild polio virus infections in Nigeria (Pradhan et al., 2012; Barau et al. 2014). In a cost-effectiveness analysis on the use of geo-enabled microplanning for routine immunisation in Nigeria, the enhanced microplanning approach cost between 58%-73% more than traditional microplanning but covered a greater target population estimate, accounted for more cases of measles and pertussis averted and was determined overall to be a cost-effective investment (Ali et al., 2020).

The relationship between **geographic accessibility** and vaccine coverage demonstrates how geospatial tools can be used to optimize vaccination service distribution and logistics. Despite multiple citations examining the association between vaccine coverage and distance to nearest vaccination centres, there are no clear published results demonstrating the impact of accessibility modelling on immunisation services or vaccination coverage. A study in Zambia measured an increase in vaccination coverage four years after the opening of twelve outreach posts, but the outreach service locations were not determined by geo-enabled accessibility modelling but based on available locations within the catchment area (Sasaki et al., 2011).

Descriptions of geospatial technologies for **immunisation**

**campaign activities** demonstrate benefits for day-to-day monitoring of activities. Descriptions of pilot programmes and feasibility studies report improvements in accountability and supervision, standardisation of data and the ability to provide real-time feedback to field staff for follow-up on missed settlements (Bawa et al., 2018; Teng et al., 2014; Haskew et al., 2015; Oh et al., 2016). Post-campaign coverage survey activities also benefit from the ability to collect geospatial data on areas that did not reach target coverage levels (Kazi et al. 2017; Oh et al., 2016). Vaccinator teams equipped with automated tracking devices can provide an extra level of security for teams operating in areas with security concerns (Kazi et al., 2017). Programmes that have implemented real-time tracking of vaccinator teams see improvements in attendance and the ability to ensure that all assigned catchment areas are covered, resulting in a reduced number of missed settlements (Chandir et al., 2017; Gammino et al., 2014; Touray et al., 2016). All of these publications give promising indications that GNSS-enabled campaign monitoring can benefit supplemental immunisation activities (SIAs), but there is a need for studies that demonstrate quantifiable effects on the identification of missed settlements and improved coverage rates.

Lastly, the review identified examples of using geospatial tools for **disease tracking and risk mapping**. Descriptive studies show the benefit of mapping measles cases to understand clustering of cases and the relationship to coverage indicators (Ulugtekin et al., 2007). Community- and local-level engagement through electronic surveillance and reporting tools can increase detection of indicators such as acute flaccid paralysis (AFP) case reports (Clarke et al., 2019). Geo-statistical models can predict areas at risk of cholera infection (You et al., 2013), and remote sensing measurements serve as a proxy for population density to predict seasonal measles outbreaks (Bharti et al. 2011; Bharti & Tatem, 2018).

This state of the art review highlights how the field of geospatial technologies is increasingly being applied to immunisation programmes and service delivery. There is a need for additional assessments, studies, and sharing of results from implementation experiences highlighting the range of events within the complex environment of service delivery that can be supported by the effective use of geospatial technologies. These include acceptability, feasibility, equity, cost-effectiveness, access to and uptake of services in addition to improved vaccination coverage.

## Use Cases

The state of the art review suggests that geospatial technologies have the potential to impact immunisation coverage, programme planning and outcomes. These findings, along with the key informant interviews conducted as part of this landscape analysis, point to eight areas or use cases where geospatial technologies have the greatest potential to shape immunisation outcomes as part of a comprehensive immunisation programme strategy. The first two use cases, health system mapping and population estimation/spatial distribution, are the essential foundations required for any subsequent application of GIS in immunisation programming. The next six use cases provide opportunities to use geospatial technologies in immunisation programming for improved decision-making and monitoring (microplanning, disease surveillance, vaccinator tracking, campaign monitoring) while the last two describe the analytics supported by geospatial technologies (geographic accessibility modelling, vaccination coverage modelling). These applications of geospatial data and technologies work together to contribute to improved identification of zero dose and under-immunised children, improved planning and allocation of resources and improved immunisation service delivery.

### Health system mapping

- Population estimation and spatial distribution with geospatial technologies
- Microplanning with geospatial technologies
- Disease surveillance with geospatial technologies
- Vaccinator tracking
- Campaign monitoring with geospatial technologies
- Geographic accessibility modelling
- Vaccination coverage modelling

### Health system mapping

Any application of GIS in health, including the other use cases for a geo-enabled immunisation programme described here, requires geo-spatial data to be available, of high quality and accessible. Among these essential geospatial data are those covering the geographic features of objects under the curation mandate of the health sector: health related infrastructures (health facilities, vaccination sites, warehouses, pharmacies,

## Health System Mapping

The creation of maps containing the spatial distribution of the geographic features pertaining to the health system, in general, and health service delivery, in particular (e.g health facilities, health districts, catchment areas)

### How can it improve immunisation outcomes?

Health system maps benefit the overall geo-enabled immunisation programme by providing an overview of the geography of the health system, in general, and of the available health services, in particular. The geospatial data contained in the health system map form the basis for the implementation of the other use cases.

**What do you need?** A coordinated effort to define, maintain, regularly update and share the master lists as well as associated geospatial data of relevant ge-ographic features; the master lists and geospatial data must be curated, stored and made accessible to stakeholders in a user-friendly system or database.

**Main challenges:** Bringing stakeholders together to establish the necessary governance mechanism and agree on the structure and content of the master lists and the data specifications to ensure the quality of the associated geospatial data; securing resources and commitment for long-term maintenance and regular updating of the lists and data in a system that is usable and accessible.

**Evidence/resource base:** Although some tools and guidance exist (see Ebener et al. 2017), there is a need for more guidance on immunisation programme planning and best practices for implementing a sustainable data collection, storage and management programme.

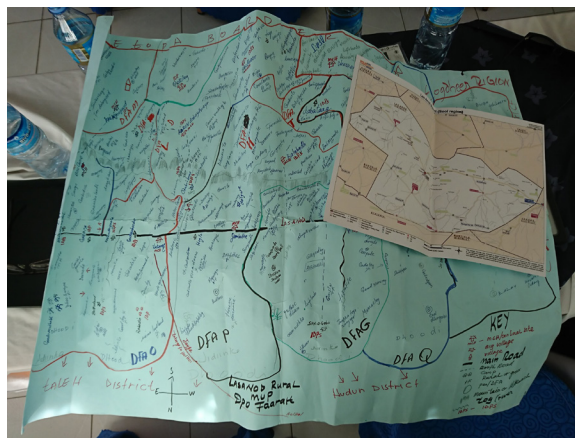


distribution centres) and health boundaries (EPI communities, health districts, catchment areas). Additional data such as administrative boundaries and the geographic locations of inhabited settlements can be included when this information is available and useful for the intended purpose of the maps. Ideally a master list, a complete, up-to-date and uniquely coded list of all the records for a given type of geographic feature, are available and used as reference.

Master lists and the spatial distribution of these features are consistently cited as the most critical need for LMICs to begin using geographic data for better programme planning. An assessment conducted by the WHO-AFRO GIS team in 2019 found that only a quarter of countries in the African region have a complete dataset of health district boundaries and less than half with complete health facility and road infrastructure data. In Asia and the Pacific, 13 countries surveyed in 2017 reported that the master lists of health facilities, administrative divisions and villages were often unavailable and, when available, they were either incomplete or out-of-date (Ebener et al., 2018).

In the past few years Cameroon and Somalia have created health system maps efficiently and in a short amount of time, motivated by polio outbreaks and the need for better maps to manage vaccination campaigns and outreach efforts. Thanks to the support of volunteers, updated lists of health facilities and settlements list, information on roads, catchment areas, populations, households, landmarks, and schools have been collected by teams of data collectors with GNSS-enabled devices and supplemented with pre-existing data from other partners (key informant interview).

Health facilities are often the first health-related feature for which a master list, or Master Facility list (MFL), is established in a country. This represents an opportunity for government stakeholders, national and international partners from the health sectors to work together on defining the content and structure of the list, the governance mechanism and process that will support the content of the list, including the geographic coordinates of each health facility, to be collected, maintained, regularly updated and shared to ensure its authoritativeness and usefulness. The governance mechanism established for the health facilities master list and the process that has been followed, can then be reused for other health-related features (e.g. vaccination posts, supply distribution points). The MFL may be accessed through an online interface to facilitate its use and updating mechanisms as is the case with National



Hand-drawn and digital health map in Somalia  
Credit: Frank Salet

Health Facility Registry in the Philippines.<sup>3</sup> As an essential link to brick-and-mortar health facilities, data on community health worker (CHW) location in communities can be included to strengthen health system planning.

The maintenance of the geospatial data used to create the health system map presents a number of challenges. These include disagreement in definitions between stakeholders; inconsistency between data sources; the fluid nature of data as administrative boundaries, built infrastructures and the catchment areas associated with them change over time; health-related boundaries not the same as administrative ones and different spelling and codes used in data and lists from different sources (Dougherty et al., 2019).

These challenges demonstrate the need for more capacity to be built within countries' governments to develop, manage, share and use their master lists and associated geospatial data and to look at solutions to supplement field-based data collection. Among these, mapathons allow volunteers anywhere in the world to augment digital maps and have been employed for polio vaccination and measles-rubella campaign planning in a number of programmes (GISCorps, 2018; Eros & Schmeltzer, 2017; Cole, 2019). This use of crowdsourcing can streamline the initial mapping process, but the quality and consistency of information must still be validated for use in programme planning on the ground (Dougherty et al., 2019).

<sup>3</sup> National Health Facility Registry in the Philippines  
[nhfr.doh.gov.ph/rfacilities2list.php](http://nhfr.doh.gov.ph/rfacilities2list.php)

## Population estimation and spatial distribution with geospatial technologies

An accurate count or reliable estimation of the total target population number and of its spatial distribution is an essential component to reaching effective vaccination coverage for all children. In the best case-scenario, national census data are collected every ten years but are often outdated due to significant changes in population movement over the course of a decade or more. In order to fulfil the promise to reach every child with routine immunisation, reliable population counts for defined catchment areas are essential for programme planning, resource allocation, monitoring and evaluation, especially at the local (district and subdistrict) levels. Inaccurate target population estimates can have a significant impact on immunisation programming. Overestimation leads to wasted resources while underestimation means not every child is reached with the intended intervention and creates risk for outbreaks in areas where coverage is believed to be higher than it actually is.

Geospatial technologies are used to estimate the distribution and number of people for use in programme planning with statistical models that estimate populations; including unreached, nomadic, marginalized or remote communities. These approaches are sometimes referred to as “bottom-up” since micro-census data collected from households is combined with the identification of buildings and settlement features from satellite imagery to create an estimate of the number of people in a given area. Other “top-down” approaches use a variety of covariate datasets such as night-time lights, mobile phone use, analysis of built infrastructure and topography from high resolution satellite images to disaggregate census information and create gridded population estimates that can reach 100 meters and even 30 meters of resolution.

Modelled population estimates have been shown to closely match real numbers on the ground and can create more accurate programme targets. A study in two states in Nigeria found that immunisation population estimates using geospatial models were 62% higher than the traditional estimates calculated by applying a standard growth rate to the latest census data (Ali et al., 2020). Precise door-to-door enumeration compared to modelled population estimates and population projections based on the latest census in Nigeria showed that the modelled estimate was within 1% of the actual count whereas the

## Population estimation and spatial distribution with geospatial technologies

The use of statistical models, remote sensing datasets and sampled census information to create spatially accurate and precise estimates of population density and distribution.

### How can it improve immunisation outcomes?

Improved population denominator estimation at sub-district levels supports the measurement of programme targets and coverage in a geo-enabled immunisation programme; improves programme planning for more accurate allocation of resources and reduced waste.

**What do you need?** Many existing gridded population datasets are freely available for download along with guidance on intrinsic uncertainties and recommendations for use. Effective use of existing datasets or the creation of new model estimates requires technical capacity in geospatial statistics, database systems and computer application technology.

**Main challenges:** Inherent uncertainties in modelling must be carefully considered. Confidence, awareness and understanding of methods used for estimation are still developing in many national statistical offices and ministries. There is a need for more capacity building and opportunities for national health workforce.

**Evidence/resource base:** Practical guidance on how to use existing spatially distributed population estimates for immunisation programme planning is needed. Evidence is also needed on how denominators from modelled population estimates and spatial distribution can impact immunisation programme delivery and coverage outcomes.



census-based projection was 50% higher (Ghiselli et al., 2019). Geo-located household surveys can provide a source of population and demographic data in areas that have not had a recent national census. Using multiple survey datasets, the most recent available census information, data from satellite images and a geostatistical model, a study in Nigeria was able to show that the number of children under five was under-estimated in national statistics (Alegana et al., 2015).

Although these geostatistical estimation models show great potential to improve immunisation programme planning, they do not yet have the level of confidence and awareness that traditional statistics and census data carry. Even though modelled population estimates are not meant to replace national census activities, resistance to drastically changed population numbers and coverage data is not uncommon. A recent guidance report from the Popgrid Data Collaborative aims to narrow the gap between geostatistical experts and users of gridded population estimates by addressing misconceptions and clarifying appropriate use and validation of population datasets (TReNDS, 2020). Despite initial indications of their accuracy, additional evidence is needed to validate the use of modelled population estimates for immunisation programming especially in areas with high population mobility, high population density and areas affected by conflicts.

### Microplanning with geospatial technologies

Since UNICEF and WHO's first guidance on creating and using immunisation-specific microplans for the Reach Every District (RED) strategy, the maps used for health facility-level operational planning have been predominantly hand-drawn sketches based on local knowledge. These sketch maps are often not to scale, not accurate, incomplete and do not contain additional crucial information for microplanning such as socially and geographically hard to reach areas, seasonal barriers to movements (e.g. floods), immunisation coverage rates or population demographics. The combination of health system maps with spatial-distributed population data for microplanning can unlock the potential to improve the efficiency and reach of immunisation services.

## Microplanning with geospatial technologies

The process of identifying communities, immunisation resources, and geographic features to create operational workplans for immunisation service delivery based on spatially accurate maps.

### How can it improve immunisation outcomes?

Spatially accurate maps for local-level service delivery planning can improve coverage and reach of services by identifying all settlements in a given catchment area and ensuring that vaccinator work assignments are realistic and efficient.

**What do you need?** The validated geospatial data from health systems mapping and spatially distributed population estimates must be combined with local-level settlement names and landmarks to create maps for improved microplanning. Data collection must include stakeholders and leaders at the local level to inform the process.

**Main challenges:** Initial time and cost to build the capacity and systems for creating digitally enhanced maps for microplanning requires commitment and sustainable resources. Data must be updated regularly to maintain the validity and usefulness of the maps.

**Evidence/resource base:** Practical guidance is needed for implementing a digitally-enhanced microplanning process. Evidence is needed of the impact on routine immunisation coverage.



Credit: UNICEF

Evidence from Nigeria shows that microplanning for polio vaccination with GIS technology in eight states resulted in more than 3,000 new settlements included in the operational microplans, reducing the number of missed children and thereby increasing coverage (Barau et al., 2014). A cost-effectiveness analysis of traditional and GIS-enhanced microplanning for routine childhood immunisation in two states in Nigeria found that even though the initial implementation of the technology incurs a higher cost, the approach also accounts for a higher number of children vaccinated based on the modelled population estimates, resulting in between 47,000 and 190,000 additional vaccinations delivered and therefore higher coverage made possible (Ali et al., 2020). In Somalia the combination of GIS database layers allows for the creation of detailed digital microplans showing the path that each vaccinator will cover for polio campaign days to maximise coverage (key informant interviews).

Microplanning with digital maps for routine immunisation has shown promising results as well. In urban Patna, India, the use of satellite images and geolocated vaccination sites to define catchment area boundaries improved geographic coverage in all neighbourhoods through coordinated logistics distribution for routine immunisation

outreach (Pradhan et al., 2012). In Nigeria, the lessons and resources from polio vaccination campaigns have begun to be applied to other SIAs. During the national measles campaign in 2017-2018, geospatial technologies were used to create microplans for fixed-point vaccination posts, ensuring that posts were located no more than 1km from the target population and helping calculate the number of days and team members for each post to vaccinate all of the children in each catchment area (key informant interview). States that used the GIS tools for planning had fewer zero-dose results recorded in the post-campaign coverage survey.

The creation of a comprehensive geo-enabled microplanning process allows for live, interactive and accurate maps that reflect the current situation of immunisation programming on the ground. To realise this potential the infrastructure, technology and capacity must be in place at the local level where microplanning takes place and the sub-national levels where the microplanning process is coordinated (key informant interviews). In many situations where GIS is used to create microplanning maps, the maps are printed and provided as a static hard copy to local planners who will continue to use them for planning and monitoring.



Even with a printed copy of a spatial accurate and detailed microplanning map, local place names may vary or may be absent. In Nigeria computer-assigned names for mapped hamlets were reported to create challenges for vaccination teams on the ground (Barau et al., 2014). Even the most accurate map based on recent satellite images and geolocated landmarks can be challenging for vaccination campaign teams to follow on the ground.

### Disease surveillance with geospatial technologies

Geography and time are at the origin of epidemiology and are relevant to vaccination programmes for monitoring, reporting and responding to vaccine-preventable disease case reports, an area that requires better visualisation and data-use for timely decision-making and response (SAGE, 2019).

Geospatial data linked to disease reporting can be combined with an HIS such as the District Health Information System (DHIS2) for both aggregate and case-based surveillance of diseases or events. The electronic Integrated Disease Surveillance and Response (eIDSR) in Sierra Leone is fully integrated with DHIS2 and allows district managers to submit disease or event reports, including AFP and adverse events following immunisation, directly to the DHIS2 (eHealth Africa, 2019b). The system has been scaled-up for all health facilities country-wide and has achieved 99% compliance with routine weekly reporting (WHO, 2019).

Auto-Visual Acute Flaccid Paralysis Detection and Reporting (AVADAR) is a mobile-phone app developed to facilitate reporting of AFP in hard-to-reach areas and supplements the traditional reporting system by engaging community informants to expand the reach of AFP surveillance. In this app, the geographic location of a suspected case of AFP identified by a community informant is automatically sent to the area surveillance officer's mobile phone with details of the case, including geographic coordinates of the location for trained health workers to follow-up with the patient. The system was piloted in Nigeria in 2016 and is now implemented by over 6,000 community informants in eight countries in sub-Saharan Africa (key informant interviews). The system has demonstrated improvements in case detection

### Disease surveillance with geospatial technologies

The collection and analysis of geolocated data on disease incidence to identify and respond to outbreaks of vaccine-preventable disease or adverse events following immunisation.

#### How can it improve immunisation outcomes?

Disease surveillance systems with standardised data collection can improve information sharing and coordination for targeted action in response to outbreaks and contribute to optimised distribution of immunisation program re-sources and services.

**What do you need?** Beside the technical capacity to develop, maintain and report into a digital platform, the digital data collection must operate within an established system of investigation and response that empowers managers to effectively utilise real-time geospatial data on disease incidence.

**Main challenges:** Establishing roles and responsibilities for effective data use, outbreak investigation and response; digital data collection should fit into the data reporting workflow and not create parallel reporting systems.

**Evidence/resource base:** Evidence is needed to understand how integrated geospatial technologies can improve outbreak detection and response.

and reporting, timeliness of reports and effectiveness in security-compromised areas and hard-to-reach communities as evidenced in the Lake Chad area where 36% more cases of AFP were reported through AVADAR than the traditional system during the same 12-month period (Shuaib et al., 2018; eHealth Africa, 2019a). The automatic collection of the geographic locations of case reports helps identify outbreaks for emergency response.

The systematic detection of disease outbreaks using GIS builds on a foundation of geo-enabled health system geospatial datasets. Although single applications focused on one disease like AVADAR can function independently, stand-alone digital disease reporting systems may create a reporting burden (Ope et al., 2013). Reporting systems should ideally be integrated with the country's existing HIS to optimise the comprehensive use of geolocated disease reporting across geography and over time.

### Vaccinator tracking

GNSS-enabled devices such as mobile phones or tablets allow for an entirely new level of monitoring by enabling real-time tracking of immunisation staff during campaign activities, regular outreach or supervisory visits. Combined with an accurate health system map and microplans integrated into a web-based dashboard, vaccination team movements are accessible by all levels of supervisors to facilitate rapid corrective action, feedback on missed settlements and areas with poor coverage.

The Vaccination Tracking System (VTS) in Nigeria<sup>4</sup> publishes data on vaccination campaign activities on a publicly-available website with reports on missed settlements, coverage and team activities. The system was implemented as part of the suite of mapping activities in the northern states to address challenges and inconsistencies around polio vaccinator performance during SIAs (see Nigeria Case Study for more information). The digital immunisation registry system in Pakistan's Sindh Province includes real-time tracking for vaccinators in the entire province during working hours. What began as a pilot project for polio campaign monitoring has now been scaled-up and incorporated into the wider routine immunisation registry system, Zindagi Mehfooz (ZM). In combination with geographic coordinates for every registered child, the vaccinator tracking system can provide managers with daily reports on the number of children reached and has been used

## Vaccinator tracking

The use of global positioning devices to monitor the movement of vaccination outreach teams during campaign or outreach vaccination activities.

### How can it improve immunisation outcomes?

In combination with validated digital health resource maps and operational microplans, it can help programme managers identify missed settlements and provide rapid corrective action to improve coverage.

**What do you need?** A vaccinator tracking system must feed into an established database and user interface containing the health system map and micro-plans with complete settlement lists. Vaccinator tracking builds on top of an established and sustainable system of geo-enabled immunisation programming.

**Main challenges:** Mobility tracking can not guarantee that vaccines are delivered. Supportive supervision is required to maintain quality and accountability during campaign and outreach activities. Vaccinator resistance and privacy concerns must be addressed within a system of trust and transparency.

**Evidence/resource base:** Evidence shows that vaccinator tracking combined with operational microplans can reduce missed settlements.

4 Nigeria Vaccination Tracking System [vts.eocng.org](https://vts.eocng.org)



**“ Everything that happens,  
happens in time and space.**

In most cases when we analyze data outside of the spatial component, we are only presenting half of the story. ”

GIS expert/key informant

during campaign activities to rapidly correct missed settlements or neighbourhoods (Key informant interviews; Chandir et al., 2017). Also in Pakistan, the EVACCS smart-phone based vaccinator monitoring application enables community vaccinators in Punjab Province to record all community visits with geo-coordinate data that serves as both a management and an accountability tool (Collins & Eldon, 2019). The system has contributed to the improved vaccination coverage in the Province and has promoted more supportive supervision relationships between community-based vaccinators and district managers.

Systematic, timely and accurate reporting at the local facility level is an on-going problem. Although mobility tracking of

vaccination activities can ameliorate some reporting pitfalls by creating automatic data feedback, geographic coverage does not necessarily translate into vaccine coverage (Barau et al., 2014). The effective use of a vaccinator tracking system requires good supervisory roles to monitor vaccinator performance and implement corrective action to cover all settlements in respective catchment areas. These challenges can only be addressed through capacity building and human relationships, not by a technological solution. The intent of the tracking system, data security measures and corrective action should be made clear for all stakeholders involved in the tracking system. All of these issues require clear governance policies on the use of GIS-enabled tools, data sharing and privacy.

## Campaign monitoring with geospatial technologies

Rapid convenience monitoring (RCM) is used to provide internal feedback during or immediately after immunisation campaign activities while Lot Quality Assurance Sample (LQAS) surveys provide vaccination coverage estimates following campaign activities. These and other SIA monitoring tools can benefit from rapid data transfer linked to geographic coordinates to help locate pockets of poor coverage or to help direct teams for mop-up activities. Real-time monitoring dashboards linked to geospatial data collection can improve timeliness and completeness of campaign monitoring reports (Oh et al., 2016).

In Somalia, GNSS-enabled devices accompany survey teams on post-campaign monitoring and LQAS surveys to create a visual representation of polio coverage after an SIA. Using an Open Data Kit (ODK) form, data for children in the target age-group with finger marks in the sampled households are compiled in the GIS showing spatial distribution for rapid assessment and correction for areas with inadequate coverage (key informant interview). Mobile data transfer with geo-coordinate data has been successfully piloted in Pakistan for polio SIA monitoring and provided rapid feedback on areas of low coverage (Kazi et al., 2017).

Measles vaccination campaigns in Malawi have successfully used a geospatial data system for rapid convenience monitoring that provides real-time feedback on campaign progress as well as individual household data on reasons for refusing vaccination (Eros & Schmeltzer, 2017). The descriptions of pilot projects with GIS-enhanced campaign monitoring should be expanded to studies on larger-scale use of the technology and how real-time monitoring can improve SIA outcomes.

## Campaign monitoring with geospatial technologies

The use of real-time geo-coordinate data collection in rapid convenience monitoring, lot quality assurance sampling and other immunisation campaign monitoring practices to monitor and correct campaign activities

### How can it improve immunisation outcomes?

It improves timeliness, completeness and efficiency of monitoring data reported to managers for rapid corrective action during campaign activities and contributes to overall improved service delivery.

**What do you need?** Each monitoring team should be equipped and trained to use mobile devices to collect and record monitoring data linked to geo-coordinates and transmitted to a supervisory dashboard. Strong and supportive supervisory roles are necessary to implement the necessary corrective actions.

**Main challenges:** Technical capacity and equipment are required to integrate data into an actionable dashboard for data collection and decision-making, ideally as part of an established geo-enabled immunisation programme with a database of validated and up-to-date health system maps and boundaries.

**Evidence/resource base:** Experiences indicate improved timeliness of reporting and supervisor satisfaction, but more evidence is needed on large-scale implementation and how geospatial technology-linked monitoring can improve campaign coverage.



## Geographic accessibility modelling

As one of the complex layers that contributes to health care access, physical proximity, expressed in the form of travel time or distance to the nearest health care service, can be measured and modelled using geospatial data and specific GIS-enabled tools. Using the geographic location of health services together with other spatial-distributed information (population, land cover, ground elevation, road and hydrographic network, etc.), these tools can estimate travel time required to reach health services by different modes of transportation. The analysis can identify priority areas for health outreach services, plan resource allocation for campaigns and identify areas for new or proposed health service expansion to improve service delivery.

A powerful tool for physical accessibility modelling is AccessMod<sup>5</sup>, a free open-source software developed by the University of Geneva in collaboration with the Health GeoLab Collaborative and with the financial support of WHO and UNICEF (Ray and Ebener, 2008). Built-in features allow users to model accessibility to the existing health facility network, to calculate the population coverage of the network based on the coverage capacity of each facility, to measure referral time between service levels and to identify optimal locations for new facilities to maximise physical accessibility for the greatest portion of the population.

Modelling geographic accessibility can be a powerful tool for understanding the performance of the immunisation programme from a geographic perspective for planning and decision-making, optimizing the supply chain and outreach services. The analysis requires a database of health facilities or vaccination points with up-to-date information on infrastructure and geographic features. A high-resolution dataset of the spatial distribution of the population is also required to model the population coverage of the considered health facilities. Currently these datasets are incomplete or lacking in some LMICs, but globally available data sets can often fill that shortfall, making geographic accessibility modelling useful for many country programmes.

## Geographic accessibility modelling

The modelling of the physical distance or travel time quantifying the movement opportunity for people to reach existing health services

### How can it improve immunisation outcomes?

This can help identify areas and populations with limited geographic access to immunisation services and therefore improve coverage for expanded service outreach and contribute to improved planning and resource allocation.

**What do you need?** Validated and accurate geographic location of health service, spatial distribution of the target population and other spatial distributed information (population, land cover, ground elevation, road and hydrographic network, etc.) are required. Preparing geospatial datasets for use in AccessMod requires technical capacity in GIS.

**Main challenges:** The availability, quality and accessibility of data on health facility locations and road networks may limit use in some instances. In-country technical capacity to conduct the analysis may be lacking.

**Evidence/resource base:** Need evidence and best practices on how geographic accessibility modelling can improve immunisation programme planning, reach and delivery.

<sup>5</sup> AccessMod site: [www.accessmod.org](http://www.accessmod.org)

## Vaccination coverage modelling

New approaches using geostatistical modelling allows subnational estimates of coverage to be obtained at a granularity not possible using standard survey data, and these can provide an alternative source of information to complement coverage information from routine administrative systems. Geospatial data collected as part of national or subnational cluster surveys (such as DHS) can be used to predict the values of unsampled locations and visualise geographic differences in health or demographic indicators (Gething et al., 2015). The geographic modelling of immunisation coverage combined with socio-economic indicators can reveal areas of inequity at finer resolution than possible with national survey data, providing insights into underlying causes for low coverage and potential solutions to improve equity.

As with any sampled survey or statistical model, immunisation coverage modelling contains varying levels of uncertainty, an important aspect to consider when using these estimates for programme planning. In addition, models may not use the same spatial reference data (boundaries or population estimates, for example) and do not rely on the same covariates in different regions or countries. For example, precipitation was found to be correlated with measles vaccination coverage in Mozambique, while vegetation cover index was associated in Nigeria (Utazi et al., 2018). This not only points to the need for tailored geospatial models but also to potential underlying causes of poor vaccine coverage in different national and regional environments.

The relatively new application of geostatistical models for vaccination coverage has yet to demonstrate the validity of the results obtained through these models and how these estimates can be directly applied to national immunisation programming to improve coverage and equity. The evidence and practical tools necessary to translate these coverage estimates into action at the national and subnational level should be prioritised for the near future. UNICEF is working with a number of countries to apply triangulation methods from multiple geospatial data sources for Coverage and Equity Assessments to improve immunisation programming. The results from these efforts will form the basis of guidance and tools for broader application.

## Vaccination coverage modelling

The use of geostatistical analysis with geospatial data from cluster surveys to estimate vaccine coverage for sub-national units of measurement

### How can it improve immunisation outcomes?

This can identify communities with poor coverage to target services to those areas; when combined with socioeconomic indicators, can help identify underlying reasons for non-vaccination and suggest solutions to increase equity and contribute to overall improved planning and resource allocation.

**What do you need?** An existing geospatial system to manage and analyse datasets; technical capacity to manipulate and analyse cluster survey data, map layers and other geospatial inputs.

**Main challenges:** The technical capacity and knowledge base to perform complex geostatistical modelling may not be present in many immunisation programme settings. Modelling may be performed in a “black box” without transparent data sharing to promote replication and empower others to perform independent analysis. Promoting local partnerships between Ministries of Health and technical institutes (e.g. universities or research centres) and encouraging the publication of data and algorithms in open source software can help strengthen domestic capacity in the application of geospatial techniques to local contexts and reduce reliance on donor-driven projects and expertise.

**Evidence/resource base:** There is need for practical guidance on tools and techniques that can be applied for improved programme management and more research to estimate the validity of the results obtained through modelling.

A photograph showing a group of women in headscarves gathered around a man in a white shirt and glasses. They are looking at a tablet or document he is holding. The background shows a yellow building and a tree.

## Other Areas and Future Applications

Once the immunisation programme has been geo-enabled, new applications of geospatial data and technologies can be explored and utilised to improve immunisation programming. The geographic analysis of supportive supervision combined with coverage and service delivery indicators can be used to target resources to poorly performing areas, while customer satisfaction ratings can indicate areas that need quality improvements. Citizen-generated data from rapidly expanding smart phone use can augment health system map data in areas of accessibility, health services offered and infrastructure. Logistics management of vaccine supplies has been linked with geospatial data in a few areas but can be expanded to improve immunisation programme service delivery when digital map databases are more widely available. Pilot projects exploring the use of drones to delivery vaccines and other medical supplies will benefit from updated geospatial databases.

The most revolutionary application of geospatial data and technologies in immunisation planning will come from a change in how managers think about maps. Many stakeholders still think of a map as a paper-based resource, a static representation of a single point in time. The power of geospatial technology comes when multiple layers of data are combined with the element of time to transform a paper map into a whole new category of decision-making tools. Population movements, disease outbreaks and seasonal patterns of weather are all important factors in immunisation programming that occur over time. This quality of the technology has not been fully realised in many areas because of infrastructure but also because of a lingering mentality that maps are static. The transformation of geospatial data into a dynamic tool incorporating time and space will unlock the full potential of the technology in the future. Now more than ever, in the context of the global Covid-19 pandemic, the ability to produce and share geospatial data remotely and to analyse trends over time and space is crucial to advancing immunisation programmes in LMICs.

In order to understand how these use cases come together to geo-enable programmes for immunisation delivery, it is useful to examine in-country implementation at national and sub-national levels. The following country-specific examples provide perspectives on the recent implementation of geospatial data and technologies for immunisation in Nigeria, Myanmar and Cameroon.



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## Nigeria

Twenty years ago, Nigeria was one of the three remaining countries with wild poliovirus (WPV) transmission. The country's immunisation programme was in need of training and improvements. Some settlements were chronically missed during campaign activities and there were inconsistencies between actual and reported polio vaccination coverage. The international drive towards the elimination of polio provided the impetus to engage new technologies to address some of the programmatic weaknesses.

The use of GIS-enabled tools and geospatial mapping involves four main streams in Nigeria:

1. The creation of accurate digital maps of catchment areas with local-level details and contiguous boundaries;
2. The use of resource maps for improved microplanning activities;
3. Tracking vaccination teams during field activities to provide real-time feedback for campaign monitoring;
4. The integration of geospatial and tracking data into a web-based dashboard accessible to all stakeholders.

In 2009, polio incidence in Nigeria was the highest in the region. As part of programmatic improvements and local official's interest in monitoring programme activities, a suite of pilot projects using GIS tools were initiated in the north of the country where more than 75% of the WPV cases occurred. Creating georeferenced base maps and using these tools in microplanning were the first steps to using geospatial tools for programmatic improvements. The additional tools for tracking vaccinator activities during SIAs allowed for improved identification of chronically missed settlements and more accurate planning of campaign activities. Scale-up to eight



### Nigeria Highlights

- Nigeria provides one of the most comprehensive and long-standing examples of geospatial technologies for immunisation programming.
- The polio eradication effort has been the focus of GIS tool development and creation of health systems maps.
- The combination of accurate digital health systems maps and vaccinator tracking improved the programme's ability to reach zero-dose children by identifying chronically missed settlements.

northern states began in December 2011 in partnership with the National Government and GPEI partners with support from the Bill & Melinda Gates Foundation. Gridded population estimates are provided from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID3)<sup>6</sup> project that provides accurate and complete geospatially referenced population estimates based on micro-census data and high-resolution remote sensing datasets for all states in Nigeria.

<sup>6</sup> Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) [grid3.org](http://grid3.org).

Currently, mapping activities have expanded to reach national coverage and all State-level and Local Government Areas have geo-referenced maps. The GRID3 project is working to update and facilitate the system to validate all Ward-level boundaries. Discussions are underway to apply the groundwork and infrastructure of the geospatial mapping work to routine immunisation activities as well as primary health care services in general. Efforts to employ GIS-based maps for routine immunisation microplanning have begun in some pilot areas (Dougherty et al., 2019).

### Outcomes and results

Although it is not possible to tease out the effects of general programmatic, funding, training and monitoring improvements in the polio eradication effort from the specific effects of the GIS mapping activities and tools, the incidence of new WPV from 2012 to 2013 saw a greater reduction in the states where intensive mapping and tracking improvements were made as compared to national incidence rates (Barau et al., 2014).

To date the VTS has been used to monitor over 80 SIAs in 30 states where mapping data and GIS infrastructure is in place. Thousands of staff have been trained, including more than 60 in national agencies and local WHO offices on the use of maps and software.

### Lessons learned and future steps

The emergency situation of WPV transmission brought

together an influx of international partners, funding and experts to move the mapping activities forward and train thousands of staff on the use of the maps and tools to improve microplanning. The support of the government through the Presidential Task Force for Polio Elimination efforts and high-level steering committee for the VTS grants legitimacy to the efforts.

The combination of accurate base maps, satellite imagery and vaccinator tracking enable the identification of chronically missed settlements (see boxed text). Although this data does not provide direct evidence that vaccines were administered, it provides good monitoring of activities to ensure that all settlements are visited by vaccination teams.

The databases of georeferenced maps collected under GRID3 will be transferred to the National Space Research and Development Agency (NASRDA) for ongoing maintenance and coordination of the data. Although detailed Ward-level mapping continues, security issues in some areas do not allow for immunisation service activities, let alone detailed mapping activities. These areas will continue to be “off the map” and the children unvaccinated until health sector activities can provide services in those areas. Nigeria is still faced with the challenge of vaccine-derived poliovirus outbreaks, in addition to measles outbreaks and the need for improved routine childhood immunisation services and coverage.

## How accurate base maps + vaccinator tracking can find missed settlements

The basis of any programmatic use of GIS tools must start with an accurate health system map. In Nigeria these maps were created at the Ward level by sending local health staff on motorcycles with handheld GPS devices to trace boundary perimeters and then eventually to add in local points of reference (schools, health centres, markets etc). These geolocated points were overlaid onto the high-resolution satellite imagery. Settlements and hamlets were labelled and identified.

During SIA events select vaccinator teams are sent with GPS devices to track their routes each day. The tracks are overlaid on the base map and any settlements or houses not visited by the vaccinator team can be identified and targeted for mop-up activities.

The combination of satellite imagery with feature extraction (automatic identification of buildings and houses), on-the-ground georeferencing of landmarks and settlements and tracking door-to-door vaccinator activity can decrease the number of chronically missed settlements (Touray et al., 2016).

# Myanmar

The use of geospatial data and technologies for immunisation planning in Myanmar builds on the geo-enablement of the Health Information System as part of the implementation of the National Health Plan for 2017-2021. The process of creating a geo-enabled HIS started as an initiative of the Department of Public Health (DOPH), Ministry of Health and Sports (MOHS), with the support of the Asian Development Bank, WHO and the Health Geolab Collaborative and resulted in the development of technical capacity for the management and use of geospatial data and technologies within the Ministry (Ebener et al., 2018).

In this context, a 2016 review of the national immunisation programme by the Myanmar Central Expanded Programme of Immunisation (cEPI) found gaps in services for children in marginalised, hard-to-reach and other special populations. In response to these gaps, and in coordination with the programme's effort to digitise all vaccine logistics and service reporting, the cEPI embarked on a project aimed at using geospatial data and technologies to support the microplanning as well as monitoring and evaluation process in Myanmar. This project grew from the findings and recommendations of the 2016 meeting on improving immunisation coverage and reducing inequities: the use of GIS in Immunisations programmes (UNICEF, 2017) and the Guidance on the use of geospatial data and technologies in immunisation programmes: overview and managerial considerations for in-country strengthening (UNICEF, 2018a).

Thanks to support from UNICEF, a first pilot project for using geospatial data in the immunisation programme was completed between December 2017 and March 2018 covering the Township of Taungdwingyi in the Magway Region (UNICEF, 2018b). The objective was to illustrate the benefits of using geospatial data and technologies, build technical capacity, document the impact of such use and advocate for the MOHS to support a phased national roll-out.

Based on the experiences and success of this first pilot project, the cEPI decided to conduct a second, extended pilot covering the Region of Yangon which was already embedded as one of the key areas for Health System Strengthening Support from Gavi, the Vaccine Alliance. This extended pilot project took place between July 2018 and March 2019 with the objectives to update the master list of health facilities, establish the master list

## Myanmar Highlights

- The geo-enablement of the HIS with the Department of Health at the MOHS provided a foundational supporting environment and the technical capacity for the immunisation programme to build from.
- Phased expansion with embedded implementation research aims to ensure that the process is sustainable and aligned to national priorities and incorporates necessary changes before national roll-out.

of EPI communities and vaccination sites, identify methods to draw the boundaries of the EPI communities for five priority townships as well as develop and use an online GIS-dashboard and paper maps to support microplanning in these same priority townships.

The project has now entered the first phase of the national roll-out covering the rest of the townships in the Region of Yangon as well as expanding to the State of Kayah, building on the lessons and methods developed in the pilot phases. In parallel and with the objective of building the evidence base to inform strategies for the subsequent phases of the national roll-out, in March 2019 cEPI with the support of UNICEF and Gavi launched an implementation research project with the specific aims to: (1) assess barriers and develop strategies for the operational deployment of the technical solutions required for the geospatial data collection and map production at a national scale, (2) explore acceptability and usability of the GIS-based maps for operational immunisation microplanning by front-line health workers, and finally (3) document the impact of the use of GIS-based maps on the effectiveness of the microplanning process in the townships where these have been deployed during vaccination campaigns in late 2019. This project is still ongoing and planned to be finalised in late 2020.

## Outcomes and results from pilot phases

As a result of the township-level pilot in Taungdwingyi, the critical roles and responsibilities at the central and township levels have been established for the collection and management of geospatial data and map production, including strengthening the coordination between the cEPI programme and the DOPH on shared geospatial data requirements. The EPI programme staff at central and township levels have



improved their capacity for the management and use of geospatial data and technologies to support immunisation microplanning. The EPI management and Ministry of Health and Sports stakeholders have been introduced to the benefits that geospatial data and technologies can bring to the microplanning process and have given their political support for the process to be expanded to the rest of the country.

Based on this initial technical and political momentum, the implementation of the extended pilot project resulted in standard definitions for the different geographic objects relevant to the microplanning process (health facility, EPI community, vaccination site), including standardisation and development of clear Standard Operation Procedures for data collection. The microplanning process has benefitted from the integration of geographic and time dimensions and the fine-tuning of selected GIS solutions such as remote sensing imagery for building identification, GIS-dashboards for catchment areas delineation and the collection of data to produce online and paper-based maps. These maps were produced and made available for the planning of vaccination campaigns in five focus townships in late 2019.

Observational evidence of improvements in the microplanning process after the township and extended pilot projects demonstrated better identification of missed communities during the GIS-dashboard review of catchment areas leading to an update of catchment area boundaries. Improved locations for outreach sites were identified for areas with gaps in service made evident through the display of existing outreach locations and settlement distribution detected from satellite imagery in online GIS-dashboards.

In order to strengthen the evidence base, an implementation research design has now been embedded within the expansion project to address challenges and identify areas to improve the data collection and map production workflow, overcome barriers to the operational use of maps and assess the impact on the efficiency of the microplanning process. By building the operational research questions into the project workplans, the results feed directly into the decision-making process with each phase of implementation. This evidence-informed programming approach is led by the cEPI with support from UNICEF and Gavi, the Vaccine Alliance.

### Challenges and Future Steps

The geo-enablement of the microplanning process required the introduction of new concepts, terms, methods,

tools and Standard Operating Procedures that needed to be absorbed by the immunisation programme at all levels. Improving strategies to guarantee that all levels of staff and managers adhere to the Standard Operating Procedures for data collection, management and use is crucial and a continuing challenge. At the level of the community, some resistance has been met from midwives collecting population-level data due to the increased workload from additional communities in their catchment areas. Midwives involved in wide-scale data collection in the field as well as the manual extraction of features from satellite images (for example, during Mapathon events) require fine-tuning and data cleaning to be useful for the EPI personnel workflow. Managerial workflows are being revised and the possibility of automatic or semi-automatic feature extraction methods are being explored.

The technical capacity and skills of immunisation programme personnel to manage and use the geospatial data and technologies must be maintained and continue to progress; an over-reliance on external consultants during the pilot phases might be a challenge for national rollout if local capacity is not improved. At the same time, impact on workloads at all levels has been a barrier to regular use. Strategies to reduce the burden with better communication between managers and local health workers are being explored. Political stakeholders and decision-makers are interested in the cost-benefit of GIS interventions to inform plans for the national roll-out, including strategies for reducing costs by outsourcing some of the technical support required for the district-level training of health workers.

These challenges will be further explored through the implementation research processes and the documentation of experiences and lessons could be useful for informing approaches to implement geospatial technology for immunisation in other countries.

### Enabling factors

Both pilot projects and the first phase of the national rollout followed a well-planned and systematic process which benefited from the geo-enablement of the HIS within the MOHS as well as the use of geography as one of the foundational elements in the National Health Plan 2017-2021. Thanks to this process and the leadership demonstrated by the DOPH, decision-makers in the Ministry have been able to visualise and understand the power of geography as the science, geospatial data as the content and geospatial technologies as the tools that can support the implementation of health programmes, including immunisation.

The phased pilot projects and expansion process has made it possible for planners and designers to anticipate and address the challenges that the scale-up will face but also to improve the methods and processes used throughout the process.

# Cameroon

A 2013 outbreak of polio virus in Cameroon brought attention to the state of the health system's maps and sparked the ambitious plan to create digital health resource maps for the entire country (Rosencrans et al., 2017). The Ministry of Health (MOH) was inspired by the success of the polio initiative mapping in neighbouring Nigeria and participated in an exchange visit to Kano, Nigeria to learn first-hand from their successful GIS mapping projects (Nafundi, 2016). With support from the CDC, WHO, Nafundi, eHealth Africa and the Bill & Melinda Gates Foundation, the mapping of all 189 health districts and corresponding health areas was initiated in December 2015.

High-resolution satellite images with automated feature extraction (using artificial intelligence to identify built features in satellite images) were supplemented with field-based data collection. A central team of 14 GIS and cartography mappers coordinated district-level data collectors equipped with GPS-enabled smartphones and a standardised ODK data collection form. District-level data collectors were led by local community leaders in each health area who could guide them to health facilities, schools, settlements and places of interest to collect geo-coordinates. After a two-day pilot in one district, the bulk of the data collection took place over the entire county in five days. A total of 400 data collectors submitted more than 75,000 mobile data collection forms in one week, including updated health area borders (Rosencrans et al., 2017; Nafundi, 2016).

With the difficult step of initial data collection completed, the subsequent stages of data cleaning and creating digital maps lasted another two months (Rosencrans et al, 2017). In November 2017, the new shapefiles for all health areas were imported and integrated into the national HIS, built on the DHIS2 (Système National d'Information Sanitaire<sup>7</sup>). A cascade training system began in March 2016 on mapping immunisation data with the new system including polio coverage, routine immunisation coverage and post-campaign surveillance (Rosencrans et al, 2017). Workshops and capacity building sessions trained over 2,000 health personnel on the use of DHIS2 with integrated GIS maps by the end of 2017.

## Cameroon Highlights

- The experience in Cameroon demonstrates that core data for health system maps can be collected and stored in a short amount of time with coordination and cooperation between agencies.
- Integration of health maps and DHIS2 with an underlying Digital Health Strategy ensure long-term sustainability and optimal use for managers.

## Lessons learned and future steps

The rapid deployment of coordinated teams of field-based data collectors created the foundation necessary for a geo-enabled HIS. With the capacity building that accompanied the mapping activities, the MOH expanded and built on the GIS experience to implement mobile data collection for polio surveillance (Nafundi, 2016). Updated health area boundaries will benefit future microplanning activities for polio and routine immunisation service delivery.

This experience in Cameroon also presents some evidence on how digital mapping activities can achieve high quality with partner coordination; The Bill & Melinda Gates Foundation provided external funding while the government and local WHO and CDC partners provided the personnel, equipment and technical assistance to map over 75% of settlements (key informant interview).

Activities and systems for on-going data collection and for updating the master facility list and settlement lists are built into the 2020-2024 Digital Health Strategy along with additional training on DHIS2/GIS map integration, data management and web platform use at all health facilities. These action plans are supported by the leadership and governance that provides the legal and institutional policy framework for these digital health maps to remain useful and valid tools for the health system (Cameroon Ministry of Public Health, 2020).

<sup>7</sup> Link to the Cameroon Ministry of Health HIS with updated maps <http://cis-minsante.cm>

## Lessons Learned

The power of geospatial data and technologies applied across the immunisation cycle is amplified when layers of data are linked in a system that can provide a comprehensive overview and analysis of immunisation programming. The whole is greater than the sum of all the parts with a synergy made possible only when all of the data layers discussed in the eight use cases are linked together with geography as a unifying dimension. An integrated system allows immunisation programme managers to visualise data on programme coverage, facilitate decision-making and advocacy, prioritise and allocate resources for targeted action to improve overall programme impact. Once established, an improved and geo-enabled immunisation program has the potential to form the foundation of supply systems and increase access to other health services.

Part of the reason that geo-enabled immunisation systems are lacking in many LMICs is the required dedication and long-term investment from all stakeholders, national governments, sub-national management and international partners to develop an effective and sustainable system. The commitment to implement a national georeferenced data collection, maintenance and use initiative requires national leadership with a collaborative team of stakeholders who possess the motivation, tools and knowledge to design and manage the data collection activity. A clear policy environment, governance, action plan and sustainable resources form the foundation for the integration of geography and time into HIS. The underlying process, tools and stages necessary to achieve successful implementation of such a system are outlined in the guidance and toolkits created by the Health GeoLab Collaborative, Asian Development Bank and UNICEF (Health GeoLab Collaborative, 2018; UNICEF, 2018a).

Once established, geo-enabled HIS serve as strong advocacy tools for national level decision-makers and sub-national managers. The visual power of the map alone can make tables and lists of data come alive with spatial patterns and obvious problem areas of low coverage or missed settlements. Presenting immunisation data over space and time, showing progress and change as a result of targeted resources, can help demonstrate to policy- and decision-makers the value of investing in the management and use of geospatial data and technologies in immunisation.



Credit: The Bill & Melinda Gates Foundation and Vincent Seaman



“ [Geography] helps people with different backgrounds, different skills, and different understanding to have a common language. ” GIS expert/key informant

Maps create an approachable and easily understood entry point to discuss problem areas. Building spatial analysis, modelling and temporal data components on top of the simple spatial visualisation creates actionable and powerful decision-making tools.

Achieving goals for equity in health requires better data on the location of people and the location of health services meant to support them. Gavi’s Strategy goals, the health-related Sustainable Development Goals (SDGs) and the overall global health agenda for attaining Universal Health Coverage (UHC) all have specific targets related to equity based on geography and socio-economic status. An integrated health system with geography as the basis for data collection and analysis across sectors has the ability to ensure that geographic and socio-economic disparities are revealed and not masked by geographic aggregation. Geospatial technologies applied to immunisation programming can provide evidence of sub-national disparities to better support targeted allocation of resources and tailored strategies to improve equity in coverage.

The effective use of geospatial data and technologies in immunisation programming can promote equity

by increasing identification of zero-dose children in chronically missed settlements, hard-to-reach areas, temporary hamlets and nomadic communities. The ability to map all settlements and hamlets, including those in marginalized areas, ensures that those settlements are “on the map” and must be accounted for in outreach, campaign and routine programme planning. The use of GIS technology can help managers include every settlement in the planning process to achieve the goal of reaching every child with life-saving vaccinations.

The use of geospatial data and technologies for polio elimination represents the greatest investment and development of geo-enabled immunisation programming to-date. The political commitment and multilateral investment to eliminate WPV transmission has been a major driving force behind the introduction of GIS-enabled tools in the past decade. Implementers recognise that a crisis often presents the opportunity to introduce new systems into an established country programme. The continued maintenance of these geo-enabled information systems and the transfer of knowledge and skills to routine immunisation programmes will be a challenge for the future.

## Lessons on capacity building

**National Level:** A few GIS technical experts are needed to design and maintain the technology infrastructure and convert raw data into useful applications for national and sub-national managers. More investment in training, hiring and retaining local experts is encouraged. Colleges and universities in target countries should foster the knowledge and skills required to use GIS technology for public health and medical professionals.

**Provincial or District level:** Staff need to be able to use GPS devices and data collection forms effectively and implement standard protocols for data management, validation, and regular updating of information in the system. Sub-national staff should be able to use these tools for programme planning and monitoring.

**Local Health Facility Level:** Staff involved in geospatial data collection need to have open and trusted relationships with vulnerable, mobile and hard-to-reach communities to facilitate data collection in all settlements. The process of developing and interpreting GIS data and maps must be incorporated into the workflow and existing technology infrastructure capabilities to maximise data-driven planning and decision-making.

# What Went Wrong

From the stories and experiences of implementers and experts in the field of geospatial technologies for immunisation, the information gathered for this review can provide some examples of what not to do in these programmes.

| <b>Lack of commitment from government</b>  | <b>Authoritarian Oversight</b>   | <b>Technology First</b>  | <b>Overbuilt Technology</b>  |
|--|--|--|--|
| <p>GIS tools and technologies implemented as part of a donor-funded initiative without sincere buy-in from national decision-makers</p>  | <p>Using a vaccinator tracking system in the context of a punitive programme of shaming, singling out poor performance or in a context of corruption and data manipulation</p>   | <p>GIS is seen as an exciting quick-fix for solving all the problems in the immunisation programme</p>   | <p>User interface dashboard that is too data-heavy and not functional with current LMIC internet and IT capabilities</p>   |
| <p><b>What can go wrong?</b></p>   |  |  |  |
| <p>Data collected or estimated as part of donor-driven mapping activities are viewed as external and do not win the trust and confidence of national statistics offices or health managers. As a result, improved decision-making mechanisms made possible by the geospatial systems do not become part of the regular workflow, do not contribute to long-term planning and are not maintained and updated once donor funding ends.</p> | <p>Vaccinators who have their movements tracked during working hours may sabotage the device to avoid traveling to difficult or undesirable locations or to mask poor performance that does not meet target levels. In systems where immunisation rates have been artificially inflated to maintain performance targets, a mobility tracking system may seem like a punishment or may reveal more information than staff are ready to face.</p>                | <p>Data collection and geospatial technology systems are introduced without consensus or guidance on the intended use and maintenance. Data is collected with poor quality and not used for decision-making because staff do not have the training or experience with the system. The technology ends up amplifying gaps in the underlying programme structure rather than solving problems.</p> | <p>The time and effort that goes into the development of a user dashboard is wasted if it cannot be used in the local context. Data and analysis will not be useful for local decision-making.</p>   |
| <p><b>How to avoid this mistake?</b></p>   |  |  |  |
| <p>Guide governments interested in correcting immunisation programme gaps to consider geospatial technology as one available long-term solution within the context of an established digital strategy and vision for long-term sustainability in the country. Foster meaningful partnerships and capacity building of national stakeholders to create genuine trust and understanding of the methods involved.</p>                       | <p>The underlying supervision system needs to be built on cooperation and a team effort to improve the programme with informed consent and individual data protection measures. Incorporate best practices in privacy and security when implementing geospatial technology tracking systems (see Berman et al., 2018, UNICEF's Ethical Considerations when Using Geospatial Technologies for Evidence Generation for detailed guidance on best practices).</p> | <p>Remember that GIS is a means to an end and must be viewed as one available tool to address existing problems. The focus of any initiative to use geospatial technologies must be on the people, underlying systems and programme priorities, not on the technology itself.</p>  | <p>Design and build systems that are useful for the current state of the intended user's needs and infrastructure capacity. Build solutions with the people and communities that will use and benefit from the technology and design systems to maximize benefits within that context.</p> |

## Challenges and Gaps

Most key informants mention the immediate need for primary data collection, health resources and other core data layers that form the basis of any geospatial data programme. This effort requires long-term planning, detailed methodology and investment in human resources and equipment. Many programmes want to utilise geospatial analysis and modelling to improve programme planning and monitoring but neglect to invest in the long-term and often difficult process of building a foundation for good data management. Practical guidance is needed for countries that want to embark on mapping and health resource data collection and to incorporate geospatial data and technologies into the microplanning process.

Efforts to utilise geospatial technologies for immunisation thus far have been largely disconnected, operating in silos and often in parallel to other projects mapping other health services or programmes. International agencies may be funding different geospatial mapping projects within the same country, one for immunisation and one for maternal health, for example. Without a solid government framework to guide geospatial data management, access and use, international partners should follow common guidelines, a framework for cooperation and even develop a strategy for the long-term investment in the process.

There is often a disconnect between the polio eradication initiative, which has invested heavily in geospatial systems in places where WPV is circulating, and routine immunisation services in the same country. The resources developed and dedicated for the polio eradication effort, including geospatial data collection and tracking systems, human resources, reporting and feedback cycles, are set up to maintain the quality and track progress of polio vaccine delivery, reach, and coverage. As the polio eradication efforts make progress and near the “endgame” it will be important to have a system and a mandate in place to transfer these tools, datasets and investments to help national EPI systems benefit from geospatial data technologies in routine immunisation (Michael et al., 2017).

“ Everything stems from the need rather than the solution. ”

GIS expert/key informant

The cycle of externally driven fixed-year projects that introduce new technological solutions contributes to the common failure of programmes after funding dries up and national priorities realign. Most of the pilot projects, feasibility studies and descriptions of the programmatic use of GIS are not founded on a framework of policies, strategies and national commitment to a geo-enabled HIS. National governments often do not feel ownership of the data produced since they have not been involved in the process or the project does not align with their priorities. In order to build this ownership, successful experiences have shown that building geographic technologies into long-term MOH planning cycles (i.e. National health plans and reforms) is imperative to ensure ownership, long-term availability of dedicated resources, sharing and reuse of data across the health sector. See UNICEF's 2017 *Guidance on the Use of Geospatial Data and Technologies in Immunisation Programs* for steps and guidance on building a sustainable foundation for a geo-enabled HIS.

This review found that many project implementation experiences have not been publicly shared, documented or published. More time and resources are needed to prioritise the documentation of lessons, achievements and quantifiable research results for future geospatial data and technology implementation but also to document and share experiences from completed or on-going initiatives.



THEORY OF CHANGE

# Use of Geospatial Technologies for Immunisation Programming

|  |  |  |   |
|--|--|--|---|
| <b>Health Impact</b>   | Reduction in Childhood Disability and Mortality Due to Vaccine-Preventable Diseases  |  |   |
| <b>Immunisation Impact</b>   | ≥80% of children fully immunised in all districts and equitable coverage across population subgroups based on geographic, socio-economic and cultural differences  |  |   |
| <b>Improved immunisation campaigns and routine immunisation programmes</b> |  |  |   |
| <b>Immunisation Outcomes</b>   | Increased number of children immunised through improved target setting   | ↑ Optimised immunisation resource distribution and location of services  | ↑ Increased quality, timeliness, and perception of immunisation services with equity in coverage between communities  |
| <b>Geospatial Data and Technologies Outputs</b>                            | Improved <b>identification of zero dose and under-immunised children</b> through more accurate microplanning and identification of missed settlements to implement appropriate vaccination strategy  | Improved <b>planning and allocation</b> of immunisation resources through strengthened use of geospatial data, analysis and visualization  | Improved <b>service delivery</b> through better planning, monitoring and tracking of immunisation activities for rapid problem identification and corrective action |
| <b>Geospatial Data and Technologies Inputs</b>                             | Produce and regularly update digital maps for health area planning based on health resources mapping through a participatory process involving local health staff to map immunisation resources  | Optimize distribution of resources (workforce, funding, vaccines and supplies) based on more accurate target population distribution and identification of gaps in coverage and immunisation service accessibility based on geospatial accessibility analysis and coverage modelling | Track by location vaccinator activities, immunisation sessions, supervision and allocation of financial resources   |
| <b>Geospatial Data &amp; Immunisation Foundations</b>                      | <p><b>Health System Mapping (essential):</b> Develop and maintain master lists and data standards for health facilities, vaccination delivery sites and cold chain, settlements, infrastructure, health area boundaries and other core geographic objects</p> <p><b>Population Estimation (essential):</b> Generate and use accurate population estimates (human density and distribution) to establish targets (denominators) in immunisation programme planning</p> <p><b>Analytics &amp; Modeling for Accessibility, Coverage, and Surveillance Planning and Monitoring (when possible):</b> Use modeling to understand geographic accessibility to services, vaccine distribution, and immunisation coverage with links to data (through HIS, IHRIS, and eLMIS) on vaccine-preventable diseases and AEFI</p> |  |   |
| <b>Enablers</b>  | <ul style="list-style-type: none"> <li>Clearly defined vision, strategy and plan for a geo-enabled HIS/immunisation programme</li> <li>Information system governance structure covering geospatial data and technologies</li> <li>Policies supporting and enforcing the strategy and governance, including data accessibility</li> <li>Necessary human and financial resources to ensure effective use and sustainability of geospatial data over the long-term</li> </ul>   |  |   |

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## Conclusion

It is clear that the proper management and use of geospatial data and technologies has the potential to improve immunisation service delivery and thereby increase coverage and equity. The experiences and reports to-date show that the effective use of geospatial data and technologies in a number of planning, service delivery and monitoring approaches can contribute to data-driven decision-making, accountability and improvements in reaching every child in every district with essential vaccination services. To continue the momentum and expanded application of geospatial data and technologies in the future, partners, donors and implementing agencies must commit to more documentation, sharing of experiences and systematic evaluations of geospatial technology use in immunisation programmes, measuring process indicators and coverage outcomes as well as demonstrated impacts on equity, accessibility, feasibility and uptake of services. The projects and experiences explored in this landscape analysis provide lessons that can be applied as the use of these technologies expand in the future. First and foremost, GIS and other geospatial technologies should be viewed as one class of tools that are available to address national priorities, needs and challenges. They can provide valuable opportunities for addressing prioritised gaps in immunisation service delivery.

Governments and implementing partners should conduct needs assessments to identify national priorities and gaps in service delivery that may be addressed effectively with geospatial data and technologies. A foundation of governance and policies can guide system-wide georeferenced data collection and should be prioritised to ensure sustainability. Integration into the national HIS can help ensure efficient data entry, maximise data-driven decision-making and benefit from the shared investment in geospatial data across all health and development programmes at all levels of operation. Emphasis should be given to sound evaluations of geospatial technologies to validate the use of geospatial data for scaled-up and more widespread implementation.

The momentum and potential for the effective use of geospatial data and technologies to increase immunisation coverage and equity exists, particularly in the identification and immunisation of zero dose and under-immunised children. In order to make positive

gains and investment in the expanded use of geospatial data and technologies for immunisation programming we present the following recommendations for policy-makers, donors and implementing partners based on the existing landscape and state of the art in this field:

### Recommendations

1. Prioritise building foundations for a sustainable geo-enabled immunisation information system, including national governance, policies, resource allocation, capacity building and proper data management practices;
2. Invest in and promote the strengthening of in-country technical expertise in the management and use of geospatial data and technologies through collaboration with regional partners, local universities and research centres, integrated training and local capacity building for all donor-funded applications;
3. Promote the use of the appropriate geospatial technologies and tool platforms, including open-source solutions, for the management, visualization, analysis, modelling and sharing of geospatial data within and across sectors in support of immunisation programmes;
4. Address data privacy and security issues when using geospatial data and technologies in-line with global best practices and national policies;
5. Promote the use of geospatial data and technologies and the products they generate as advocacy tools for decision-makers to see the potential of a geo-enabled immunisation information system;
6. When assessing the impact of geospatial technologies on immunisation programmes, adopt an impact framework not limited to coverage outcomes but rather a comprehensive analysis of the variety of pathways to change, including accountability, accessibility, equity, cost-benefit/cost-effectiveness and efficiency;
7. Document and share program experiences and lessons learned to promote the expanded use of geospatial data and technologies for immunisation programming.

This landscape provides insights into the effective management and use of geospatial data and technologies for improved immunisation service delivery as a foundational investment for countries as they strive to improve the planning, delivery and monitoring of routine immunisation and campaign activities so that no child is left without life-saving immunisation services.

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## APPENDIX

# List of Key Informants

Many thanks to all of the following individuals who took the time to speak to HealthEnabled about experiences using GIS for immunisation programming.

| <b>Name</b>              | <b>Organization</b>                              |
|--------------------------|--|
| 1. Danya Arif            | IRD  |
| 2. Mamadou Saliou Diallo | UNICEF   |
| 3. Steeve Ebener         | Health GeoLab Collaborative                      |
| 4. GRASP Team            | Centers for Disease Control and Prevention (CDC) |
| 5. Jan Grevendonk        | World Health Organization                        |
| 6. Andrew Inglis         | IBM  |
| 7. Nicholas Oliphant     | Global Fund                                      |
| 8. Rocco Panciera        | UNICEF   |
| 9. Narottam Pradhan      | Project Concern International/India              |
| 10. Nicolas Ray          | University of Geneva–AccessMod                   |
| 11. Frank Salet          | Independent Contractor                           |
| 12. Emilie Schnarr       | CIESIN/Columbia University                       |
| 13. Vincent Seaman       | Bill and Melinda Gates Foundation                |
| 14. Ravi Shankar         | World Health Organization                        |
| 15. Nay Myo Thu          | UNICEF–Myanmar                                   |
| 16. Kebba Touray         | WHO Regional Office for Africa                   |
| 17. Kevin Tschirhart     | CIESIN/Columbia University                       |
| 18. Josh Wunderlich      | The Gavi Secretariat                             |





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