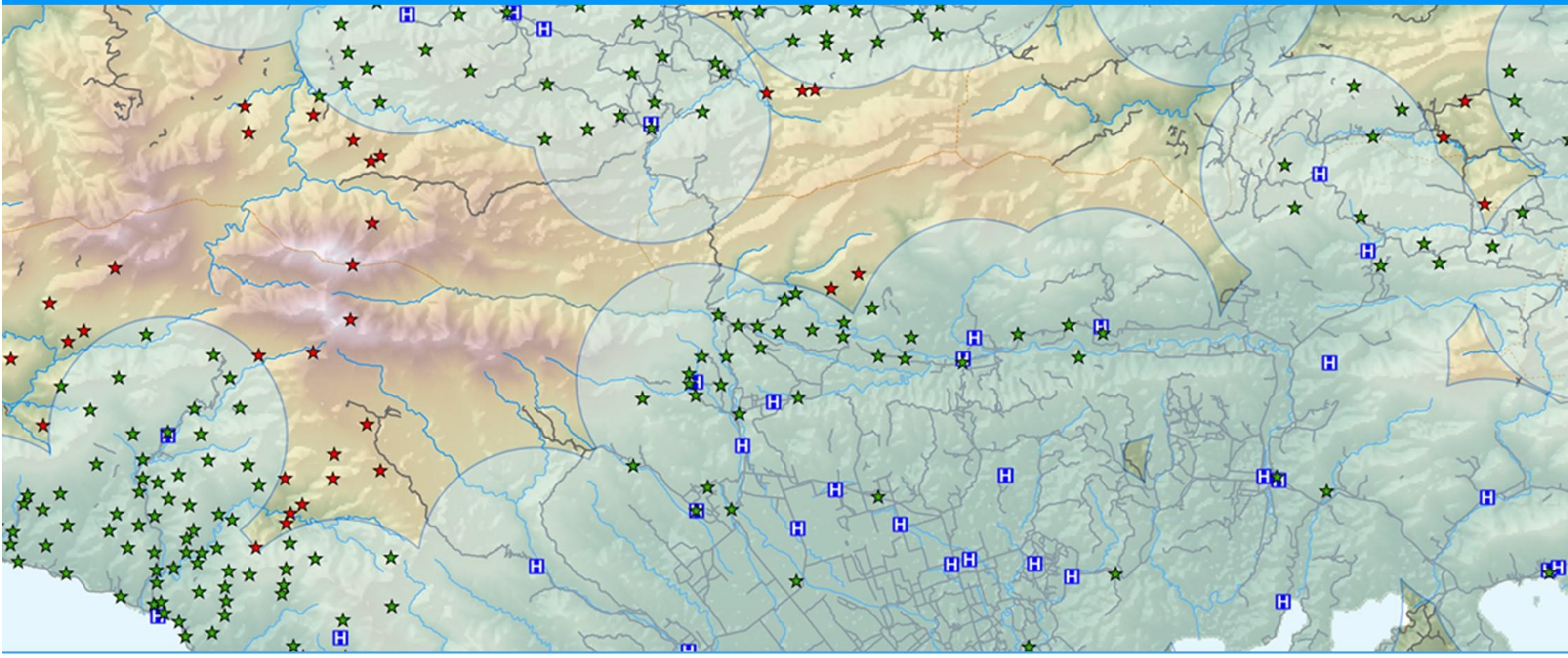

Guidance on the Use of Geospatial Data and Technologies in Immunization Programs

Overview and Managerial Considerations for In-Country Strengthening

Gavi The Vaccine Alliance · unicef · ADB · HEALTH GEOLAB COLLABORATIVE

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[a] https://www.unicef.org/health/files/3._Final_Report_February_2017.pdf
[b] https://bit.ly/2IiZN66

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Glossary

ADB	Asia Development
AeHIN	Asia eHealth Information Network
AFRO	Regional Office for Africa
BMGF	Bill & Melinda Gates Foundation
COD	Common Operational Datasets
CHW	Community Health Worker
DHS	Demographic and Health Surveys
EPI	Extended Programme on Immunization
Gavi	Global Alliance for Vaccines and Immunization
GNSS	Global Navigation Satellite System
GIS	Geographic Information Systems
GLONASS	Globalnaya Navigazionnaya Sputnikovaya Sistema
GPS	Global Positioning System
HGLC	Health GeoLab Collaborative
HIS	Health Information System
LMIC	Low and Middle Income Country
MICS	Multiple Indicators Cluster Survey
MFL	Master Facility List
HIS	Health Information System
NSDI	National Spatial Data Infrastructure
OCHA	Office for the Coordination of Humanitarian Affairs
OpenHIE	Open Health Information Exchange
RCMRD	Regional Centre for Mapping of Resources for Development
RED	Reach Every District
REC	Reach Every Community
SDG	Sustainable Development Goals
RS	Remote Sensing

SIA	Supplemental Immunization Activities
UN-GGIM	UN Committee of Experts on Global Geospatial Information Management
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Introduction

Immunization is a core primary health care intervention critical to assuring the health of children and communities. Overwhelming evidence demonstrates the benefits of immunization as one of the most successful and cost-effective health interventions known, with an estimated 2.5 million deaths averted each year[1]. Over the past several decades, immunization has achieved many outstanding results, including the eradication of smallpox, the reduction of global mortality due to measles by 74% between 2000 and 2007, and the near eradication of polio[2,3].

Despite improvements in individual countries and a strong global rate of new vaccine introduction, global average immunization coverage has increased by only 1% since 2010[3]. In 2015, 68 countries fell short of the target to achieve at least 90% national coverage with the third dose of diphtheria-tetanus-pertussis vaccine[3]. Moreover, 26 countries reported no change in coverage levels and 25 countries reported a net decrease in coverage since 2010. Strong inequities are hidden behind global and national figures of vaccination coverage. These are associated with differences in urban/rural place of residence, wealth and education status, gender and remoteness[1,4].

Despite significant investments by governments and development partners in services for children, women and adolescents, a booming geospatial industry, and the percolation of geospatial technologies in nearly every aspect of our daily lives, the full potential of geospatial data and technologies for improving the delivery of vaccines to the most disadvantaged population and progressing towards equitable immunization coverage is far from being realized.

As a result, critical insights that could be made possible through the use of geospatial data analytics are missed, for instance, to answer questions such as: What percent of the population does not currently have physical access to immunization services/assets, where is this population located? How many health facilities are needed and where should they be located to optimize physical accessibility to immunization services? Where should outreach services take place? Which geographic areas or populations suffer from low immunization coverage and why?

With the ever increasing availability of low-cost geospatial technologies options in the last decade, the factors limiting its use in immunization programs are shifting from the availability of the technology to the availability and accessibility of quality geospatial data, the presence of strong institutional framework supporting the long term sustainability and the strengthening of already existing technical capacities, particularly in low-resource settings.

The technical meeting "Improving Immunization Coverage and Reducing Inequities: Use of GIS in Immunization Programs", which took place at UNICEF Headquarters, New York City, on 25-26 October 2016 provided recommendations aimed at strengthening the management and use of geospatial data and technologies and their integration them into traditional immunization planning, monitoring, and analysis methods (see Appendix A and final report[c] for detailed list of recommendations). As part of these recommendations, it was stressed how increasing the awareness of decision-makers, managers of the Extended Programme on Immunization (EPI), and donors about the opportunities and benefits of the use of

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[c] https://www.unicef.org/health/files/3._Final_Report_February_2017.pdf

geospatial technologies, as well as investing in strengthening geospatial data management capacities and practices were two crucial steps to realize a systemic adoption and use of the technology for immunization programs.

Purpose of the Guidance

Although several guidance documents exist to support the use of geospatial data and spatial analysis in health programs (see Appendix B), to date there has been little guidance on how the introduction, management and use of geospatial data and technologies must relate to the existing policy framework, technical environment and capacity of health and immunization programs in order to result in a cost-effective, sustainable and operational use of geospatial data and technologies.

This document aims to address this gap with a two-fold approach, namely to:

1. Provide a non-technical introduction to the role of geospatial data and technologies in immunization programs; and
2. Propose a process-based framework to guide decision-makers and planners in strengthening the management and use of geospatial data and geospatial technologies in immunization program in countries.

The process-based framework proposed provides both guidance and practical tools to support countries in the process of realizing the operational use of geospatial data and technologies in country immunization programs, by covering all the elements that should be taken into account to ensure sustainability on the long term. The approach taken relies heavily on the geo-enabling process developed by the Health GeoLab Collaborative and the related toolkit[d], but with a more specific focus on immunization programs.

Some of the managerial questions answered by this guidance document are:

- *What is the role of geospatial data and technologies in planning, monitoring, and analysis of immunization delivery?*
- *Why and when should the inclusion of geospatial data and technologies in immunization programs be considered?*
- *How can I strengthen the management and use of geospatial data and technologies in immunization programs in order to enhance equity and coverage of service delivery?*
- *What are the costs versus the benefits of using geospatial data and technologies in immunization programs?*

While the focus of this guidance is on immunization programs, and specifically the planning, monitoring, and analysis of immunization delivery and coverage in Low and Middle-Income countries (LMIC), many of the concepts presented are easily extendable to other health programs and countries.

The guidance provides a reference to help managers address questions such as: What is the role of geospatial technologies in planning, monitoring, and analysis of immunization delivery and coverage? Why and when should the inclusion of geospatial technologies in immunization programs be considered? How can I strengthen the management and use of geospatial data and technologies in immunization programs? What are the costs versus the benefits of using geospatial data and technologies in immunization programs?

[d] https://www.healthgeolab.net/DOCUMENTS/HIS_geo-enabling_toolkit.pdf

It should be noted that this document neither provides specific instructions on how to perform spatial analysis, nor it cover practical details on geospatial data management, analysis or visualization. Readers seeking this kind of information should refer to the relevant guidance documents and educational material listed in Appendix B.

This guidance relies significantly on recommendations, case studies and insights from two recent meetings:

- The technical meeting on "Improving Immunization Coverage and Reducing Inequities: Use of GIS in Immunization Programs"[e], held in New York City in October 2016; and
- The pre-conference workshop held by the AeHIN GIS Lab during the Digital Health Conference in the Asia-Pacific[f] in Naypyitaw, Myanmar in March 2017.

Both events gathered perspectives form government and development partner's representatives, as well as global experts, on opportunities and challenges for strengthening the sustainable use of geospatial data and technologies in the health system.

Structure of the Guidance

The document is structured as follows:

- Chapter 1 provides an introduction to the immunization cycle, discusses the role of geography, geospatial data and technologies in immunization programs, presents examples of applications and discusses benefits, challenges and opportunities for using this technology in immunization programs.
- Chapter 2 proposes a process-based framework for strengthening the sustainable management and use of geospatial data and technologies in immunization programs, and provides practical guidance and tools for the implementation of this framework.
- Chapter 3 concludes the document by presenting a list of recommendations for supporting the proposed framework

Throughout the document, the reader will find links for further and in-depth readings around specific topics.

Target Audience

This document is intended to serve as a guideline for all stakeholders interested in advocating for or investing in the management and use of geospatial data and technologies in immunization programs with the objective to ensure a long term, sustainable, integration of geospatial data and technologies in countries as part of the geo-enablement[g] of their Health Information System (HIS)[5,6].

Little or no prior knowledge of the concepts and analytic methods linked to geospatial data and technologies are required to read this guidance.

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[e] https://www.unicef.org/health/files/3._Final_Report_February_2017.pdf
[f] https://bit.ly/2IiZN66
[g] A geo-enabled HIS is an information system that fully benefits from the power of geography, geospatial data and technologies through the proper integration of geography and time across its business processes

The potential audience of this guidance includes:

- Decision makers and immunization program planners, including representatives of national and local governments, and EPI focal points interested in introducing or strengthening the management and use of geospatial data and technologies in immunization programs;
- National, regional and global advisers from development agencies and donors who provide technical assistance or oversight to health programs, needing to understand what conditions should be in place to achieve sustainable and long-term impacts of investments in geospatial data and technologies, or needing a framework to monitor country preparedness for the introduction of geospatial technologies;
- Technical staffs, such as field manager, field workers and data managers, looking for an introduction to the geographic aspect of immunization programs.

The instruction offered is meant to provide general guidelines whose applicability must be considered and adapted to different country contexts

How to Read this Guidance

- Readers with no or very little knowledge of immunization programs and geospatial data and technologies fundamentals should start with Section 1;
- Readers with a good understanding of immunization programs and geospatial data and technologies fundamentals, and who are seeking to understand the issues associated with the strengthening of geospatial data management and the use of geospatial technologies in immunization programs, should refer to Section 2.

1. Using Geospatial Data and Technologies in Immunization Programs

In this Chapter we provide an introduction to the role played by geospatial data and technologies in immunization programs. In particular, we:

- Review the operational cycle of immunization delivery planning, monitoring and analysis (Section 1.1);
- Introduce how the elements of immunization programs can be captured, represented and linked using geospatial data and technologies (Section 1.2);
- Present examples of applications and discuss the main benefits of introducing geospatial data and technologies in immunization programs (Section 1.3);
- Review the main challenges and opportunities for the application of geospatial data and technologies in immunization programs (Section 1.4).

1.1 The Cycle of Immunization Delivery

The cycle through which vaccination is generally planned, delivered and monitored through microplanning follows the Reach Every District (RED)[7] and the Reach Every Community (REC)[8] approaches, which were introduced by the World Health Organization (WHO) and partners to expand the provision of immunization services with a focus on decentralized planning and monitoring and target population (schematized in Figure 1).

More specifically, the following steps are covered through the microplanning cycle:

1. First the current immunization coverage and target population are assessed at the local level (either facility catchment area or district), by estimating the population in each community to be vaccinated (population "denominators") and comparing it with administrative information on doses of vaccines delivered;
2. A spatial inventory of the district or health area is undertaken, including available immunization resources (health facilities) and all the information needed to efficiently plan for delivery, such as location of communities, road network, geographic barriers (lakes, rivers etc.), typical modes of transport of local population, etc.;
3. Communities are then classified based on their immunization coverage, and both geographic information from maps and other sources of information are used to identify potential barriers to the achievement of immunization target which might be affecting specific communities (e.g., distance, lack of transportation options, socio-economic disadvantage);
4. This information is then used to plan a delivery strategy to ensure every community is served adequately, such as which populations will be served by fixed sessions and which ones require outreach and/or other strategies such as mobile teams from the district level;
5. Finally, the delivery and coverage of vaccination services is monitored, for example through visits to communities, or surveys, to identify communities and children that might have been missed, assess the reason for the defaults, and devise corrective actions;

6. Most of the data collected at the health facility level during this process (e.g., tally sheets recording every dose of vaccine given, the number of vaccinated children or the target population in the facility catchment area, etc.) are consolidated into a monthly report that is forwarded to the district level. The district then consolidates data from all the health facilities into a monthly report and forwards this on to the provincial level. Finally, the province consolidates all the district data in a provincial monthly report, which is then sent up to the national level. A different process occurs when Electronic Immunization Registries (EIR) are used. With these systems, the immunization records of each person are maintained in a centralized electronic database and the need for monthly report is eliminated.

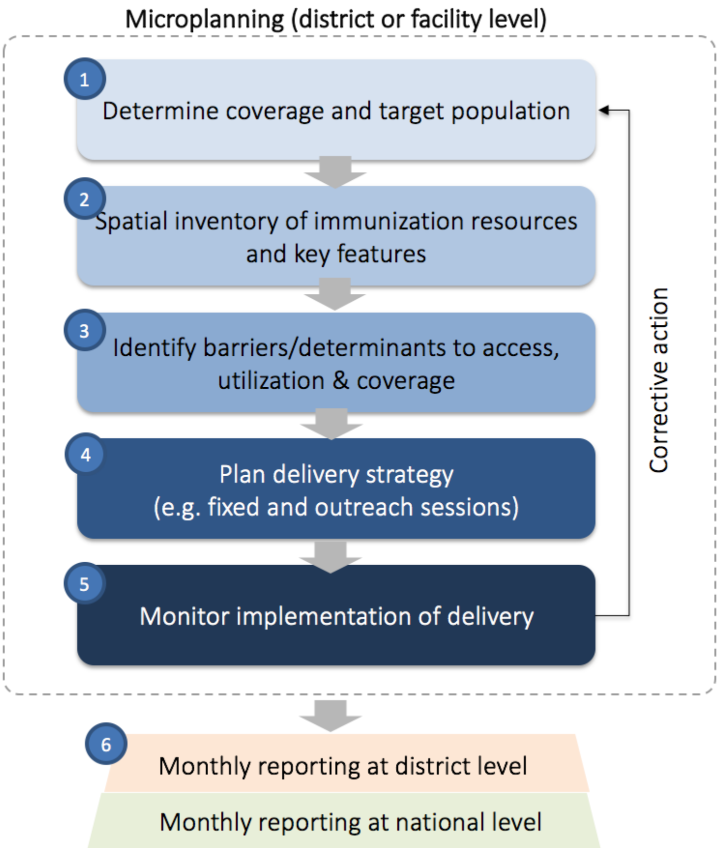

Figure 1 Schematic workflow of the immunization delivery cycle recommended by the Reach Every District (RED) and Reach Every Community (REC) immunization strategies.

In addition to this administrative system of immunization coverage monitoring occurring within the microplanning cycle shown in Figure 1, household surveys are used to infer coverage from the vaccination status of children in a random sample, according to their vaccination record or according to their caregivers' recall. Some of the most common survey types are Demographic and Health Surveys (DHS)[h], Multiple Indicator Cluster Surveys (MICS)[i], and immunization specific survey within the EPI[j].

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[h] http://www.dhsprogram.com/

[i] https://www.unicef.org/statistics/index_24302.html

[j] http://www.who.int/immunization/programmes_systems/supply_chain/benefits_of_immunization/en/

1.2 Geography, Geospatial Data and Technologies in Immunization Programs

In this section we introduce the geography[k] of immunization programs. We first discuss how geography comes into play to describe the elements of immunization programs, and then review how these elements are captured, represented, linked and analyzed using geospatial technologies.

1.2.1 The Geography of Immunization Programs

The cycle described in section 1.1 involves the interaction (e.g. exchange of services, data, resources etc.) between a number of entities (objects), namely (see also diagram in Figure 2):

- Vaccination delivery sites (fixed or outreach, whether located in health facilities, schools, places of worship)
- Mobile vaccination teams
- Vaccines storage and cold chain facilities
- Community health Workers (CHW)
- Community/Settlement (city, towns, villages, hamlets)
- Target population (e.g., children, pregnant mothers)
- Means of vaccines transportation (motorized, animal, walking, boat, etc.)

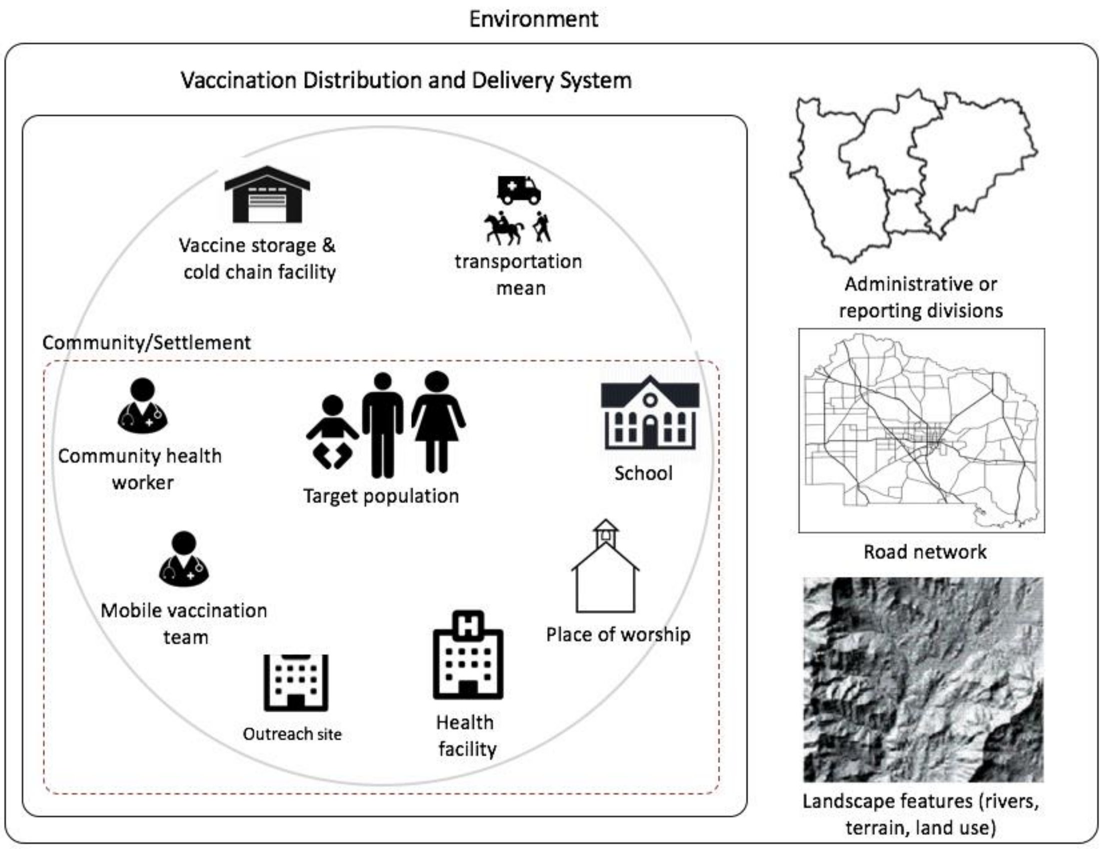

Figure 2. Diagram showing the geographic entities relevant to the immunization delivery system

[k] The study of the natural features of the Earth, such as mountains and rivers

Like all human activities, the elements listed here above are associated with a physical location on the surface of Earth, and their interactions are very often dependent on such geographic location. For example, the distance between a community/settlement and the nearest health facility will have a significant impact on services utilizations by the population of the community/settlement; the vaccination level of a community might have a positive impact on the immunity of nearby communities more so than farthest communities, etc.

In addition to that, one must also consider other elements that allow for the physical geographic linkage between the objects forming the immunization program, namely (see also diagram in Figure 2):

- Administrative divisions or service delivery areas (e.g. national and sub national boundaries, health districts, facilities catchment areas, etc.). Although largely a political and administrative convention, they have a significant role on how immunization programs are planned, monitored and analyzed, and therefore provide geographic context to spatial analysis and visualization.
- Transportation infrastructure (e.g. roads): along which vaccines are delivered to health facilities, population travel to reach facilities or vaccination teams travel to deliver vaccination sessions etc.
- Landscape features (terrain, river, lakes, land cover etc.) which constitute the environment that he population and the vaccine carrier will have to cross to reach a point of care as well as the source of potential physical barriers to movement.

1.2.2 Geospatial Data

The objects and elements of the immunization program listed at the beginning of this section, as well as those of the broader social sciences, can be separated into four groups of features[l] when looking at how they can be captured as geospatial data in a GIS. This is schematically shown in Figure 3:

Namely the four groups of geographic features include:

1. Objects with a fixed location whose geography can be simplified by a point (e.g., health facility, community/settlement, vaccines storage facility, etc.). The geography of these objects is obtained through their geographic coordinates[m].
2. Objects with a fixed location but whose geography has to be represented either by:
    i. Polygons due to their much larger extent (Examples: administrative divisions, health facilities catchment areas, etc.)
    ii. Lines due to their mainly longitudinal extension (e.g., road, river, etc.).
3. Objects which are mobile (i.e., don't have a fixed location such as children, pregnant mothers, vaccination teams, vehicles, etc.). Such objects can be geographically represented as being attached to a fixed object (e.g. individuals in a community/settlement), or as a point whose geographic coordinates (latitude and longitude) change in time.

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[l] A representation of a real-world object on a map.
[m] A measurement of a location on the earth's surface expressed in degrees of latitude and longitude

4. Continuous: some elements of our environment are not defined objects per say and not associated with one specific location, but are rather distributed spatially. These are better represented using a continuous surface (e.g. terrain, land surface attributes, population distribution)

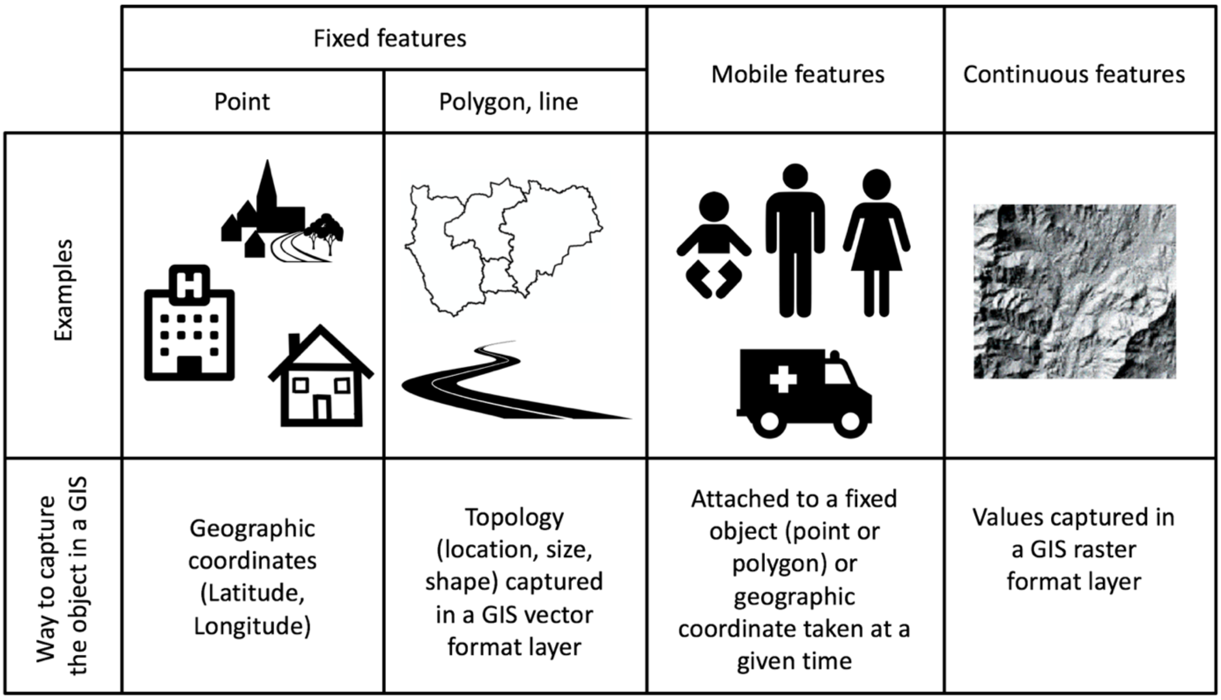

Figure 3. Example of geographic features relevant to immunization programs and the corresponding way to capture them in a GIS (Extracted and modified from Ebener 2016[9]).

Master lists and registries

In an ideal situation, a unique and authoritative, complete, up-to-date and uniquely coded list of all the active records (a "master list") for all the fixed or mobile objects listed in the previous section should be maintained and regularly updated at the national level as well as made accessible to all the stakeholders across the health sector.

Ideally such master list should at least contain 4 crucial group of attributes, namely those allowing for each of its record to be[10–12]:

1. Uniquely identified. While different names can be associated to the same object, the use of a unique and official identifier (ID) recognized and used by all the health sector is key to ensure for data consistency across sources;
2. Categorized according to classifications specific to each object. In the case of health facilities for example, these classifications would cover the type (hospital, health center, etc..) and the ownership (governmental, private, etc.) attached to each of these facilities;
3. Located geographically through the following attribute depending on the considered object:
   i. The address (street name and number, postal code)
   ii. The official code and name of the administrative division down to the lowest existing level observed in the country
   iii. The geographic coordinates (latitude and longitude)

4. Contacted when this applies including by phone (fixed line or mobile number) and could be extended to also contain an e-mail address or fax number when pertinent. The complete name and function of the person to be contacted should also be captured here.

Managing and keeping master lists up-to-date can be challenging. This is why they are generally stored in so called "registries". While the two concepts are closely related, a registry can be can be understood as the underlying technology (e.g. an electronic database) that allows storing, managing, validating, updating and sharing a master list (container), while a "master list" refers to the data set itself (content)[10,12,13]. The National Health Facility Master List developed and maintained by the Department of Health of the Philippines is an example of such registries[n].

The geographic relationship that exists between objects and therefore the need to keep all the master list up-to-date in parallel as well as the cost associated to managing separated registries for each object recently led to the concept of common geo-registry[10]. Combining all the registries, and therefore master lists, into one unique platform, the common geo-registry, does not only reduce cost but provides also access to functionalities that facilitate the work of the staff in charge of managing and updating these master lists. Due to their mobile nature, the location of the mobile type objects (e.g. CHW, children or pregnant women) at a given time is being determined by associating them to one of the fixed geographic object (e.g. community/settlement, health facility, administrative division, etc.). It is therefore recommended for the information relating to their place of living or place of work for CHWs (unique identifier and name of the community/settlement), or place(s) of care (unique identifier and name of the health facility(ies)) to be included in the master list maintained for these mobile objects.

It is also recommended that any additional attributes attached to fixed or mobile objects (e.g., number of staff at a health facility, population of a community/settlement, vaccination coverage of an administrative region) be stored in separated database in order to facilitate the management and update of the master list, and also to avoid information redundancies across databases. As explain further down the text, the link between the records in the master list and the databases containing these additional attributes is ensured through the unique identifier.

Master lists of fixed geographic objects are considered as being key to the geo-enablement[o] of the HIS and immunization programs (see Section 2.1). Not only they are they essential to effectively use the visualization and analytical capacities of GIS, but they are also central to the use of geography as the dimension to exchange and integrate information across different health programs and across sectors.

Master lists also importantly provide the denominator (i.e., the total number of objects of a specific type, such as health facilities) that serves as reference when collecting, updating or maintaining information on the objects. Moreover, they serve as official source of geographic coordinates when this information is being captured for fixed point type data[14].

[n] https://nhfr.doh.gov.ph/rfacilities2list.php [Accessed May 15, 2018]
[o] A geo-enabled HIS is a HIS that fully benefits from the power of geospatial data and technologies

Thematic Layers and Basemaps

All the features associated to the same object or element are generally stored in what we call a layer. We distinguish two main types of layers when it comes to the different f geographic objects and elements relevant to immunization programs are captured, namely:

- Thematic layers (Figure 4a): Geospatial layers containing information specific to a particular theme object, such as health facilities, or road networks.
- Basemaps (Figure 4b): Geospatial layers representing multiple aspects of the earth's surface at once, such as satellite imagery and topographic maps. The function of basemaps is to provide background and context to thematic layers.

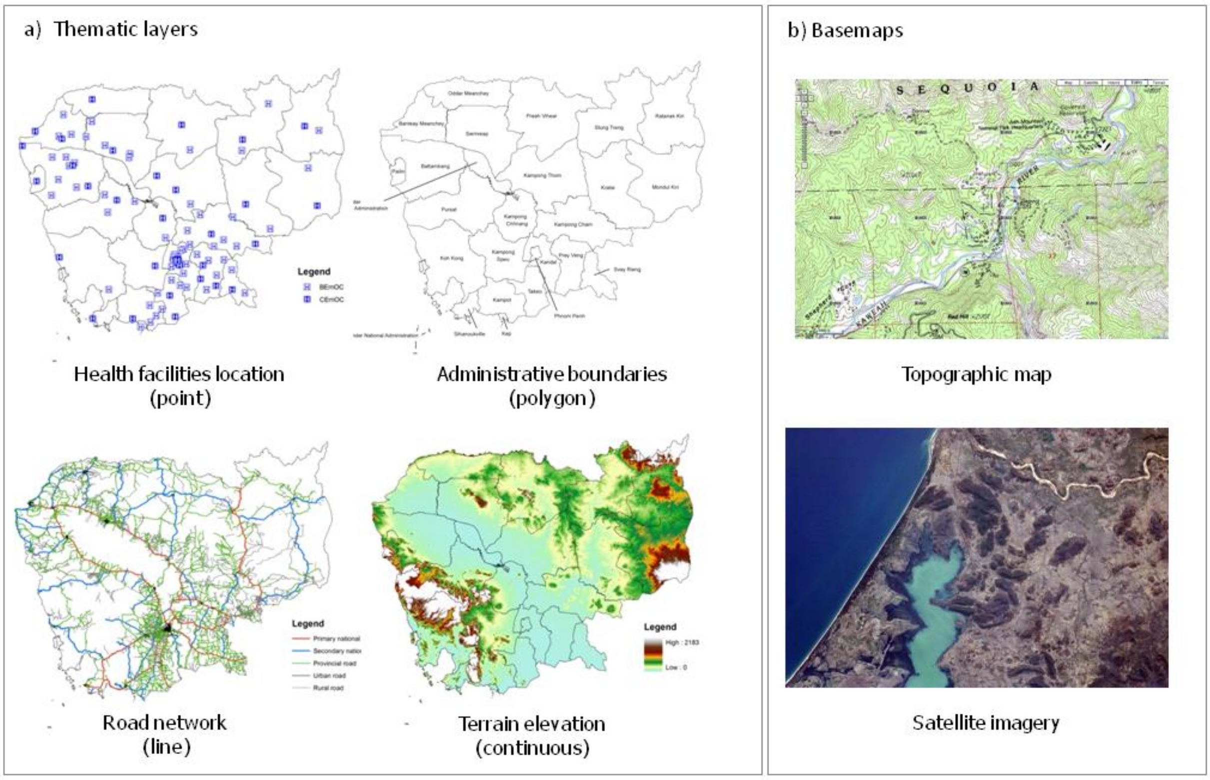

Figure 4. Examples of a) thematic layers - Cambodia (Extracted from WHO 2015[15]) and b) Basemaps relevant to immunization programs.

Linking Attributes to Geospatial Data

The immunization program also collects statistical data and information that can be attached to a specific geographic object through the use of a unique identifier. Such information or statistics, referred to as "attributes", include for example the number of vaccine doses delivered at a facility, or the population count of a community/settlement. Another important example of statistical attributes is the vaccination coverage[p] over a specific area (administrative division, catchment area,...). The composite of attribute and geospatial is referred to as geographic data and represent the way through such attributes are becoming available for spatial management, visualization and analysis.

[p] Percentage of children receiving due vaccinations divided by the total children in a specific cohort in the region

Table 1 gives a non-exhaustive list of attributes that can be attached to some of the objects listed earlier in this section. Data stored in a GIS are can therefore not simply maps, but rather datasets that combine geographic entities with attributes.

Table 1. Example of attributes attached to existing geographic objects related to immunization programs

Object	Example of immunization related attributes
Health facility	• Available vaccine doses and doses given over the past month • Communities/settlements part of the health facility catchment area
Vaccine storage facility	• Stocks • Available volume • Number of refrigerators • Type of electricity supply
Administrative division	• immunization coverage from EPI survey aggregated to administrative division • population count from census • Count of health facilities

1.2.3 Analyzing Data Across Layers

The ability of geospatial technologies to relate different aspects of the immunization programs with the surrounding environment through geography lies in the method used to analyse the information stored in different geospatial layers presenting the same geographic extent. This is illustrated schematically in Figure 5.

In Figure 5, each layer contains one type of geographic object, for example points representing health facilities, or lines representing the road network. Attributes are themselves linked to the point, line or polygon type objects through a unique identifier as mentioned in the previous section.

Once these layers organized in a geospatial database, A GIS can query, combine, analyses these different layers using the relative location of the objects contained in each of them (represented by the arrow going through all the layers in Figure 5).

In the case of immunization programs, such capacity allows for instance to explore whether a cluster of settlements is nearby or far from a health facility, or whether a specific region with low immunization coverage is collocated with an area with fewer immunization delivery sites.

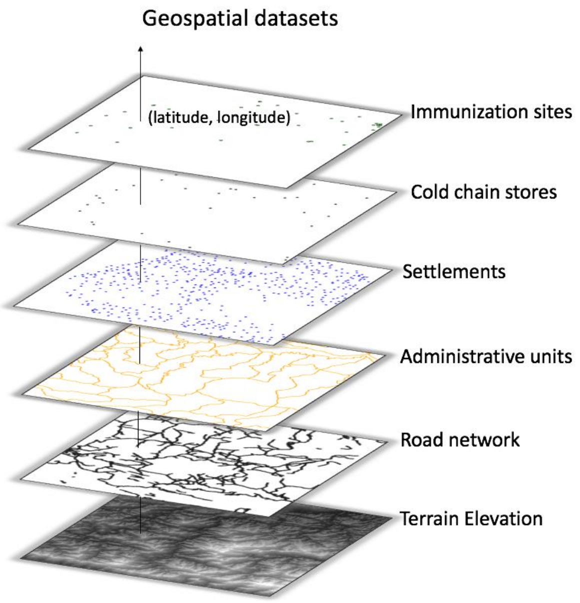

Figure 5. Connection of geospatial datasets through geography in a GIS.

1.2.4 Geospatial Technologies and Immunization

Geospatial technologies form the set of technologies that facilitate the integration of geography into immunization programs. These technologies refer to equipment used in visualization, measurement, and analysis of earth's features, including the natural environment, human infrastructure and the elements of the immunization program listed above.

Geospatial technologies form the set of technologies that facilitates the integration of geography into immunization programs, including Global Navigation Satellite Systems (GNSS) for data collection and navigation, Remote Sensing as the source of aerial imagery for data capture and as base maps as well as GIS software for data management, analysis, and visualization.

In the present context, geospatial technologies principally cover Global Navigation Satellite Systems (GNSS), Geographic Information Systems (GIS) and Remote Sensing (RS). More specifically:

- A GNSS provides the capability to acquire the geographic coordinates, recorded in terms of latitude and longitude, for any location on the surface of the earth. While the Global Positioning System (GPS) is the most widely known GNSS, other constellations of satellites have also been launched over the past decade (e.g. GLONASS, BeiDOU) and are now accessible to GNSS enabled devices and others will be operational in the near future (GALILEO).
- A GIS is an integrated collection of computer software and data needed to view and manage information about geographic places, analyze 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 analyzed[q]
- Remote Sensing (RS) is the science of obtaining information about the earth's surface feature from satellites[r], aircraft or drones

Nowadays, data collected using a GNSS enabled device or extracted from remotely sensed images are at the origin of most of the geospatial data being used in a GIS for visualisation and analysis. In the context of immunization programs. More specifically:

- GNSS enabled devices are being used to collect the geographic location of objects such as health facilities, communities, vaccination storages, transportation means, etc.
- Images captured by satellites or aircrafts are used to extract geographic features visible from the sky and which are frequently needed as ancillary data for analysis of immunization delivery and coverage (such as roads, river network, land cover, landscape, etc.), and as basemaps to provide context for thematic data (see section 1.2.2)

GIS is then used to[5]:

- Manage geospatial data and their associated attributes;
- Produce thematic maps specifically designed to show a particular theme or topics connected with a specific geographic area;

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[q] http://wiki.gis.com/wiki/index.php/GIS_Glossary/

[r] http://oceanservice.noaa.gov/facts/remotesensing.html

- conduct spatial anlaysis to explore spatial relationships between geographic objects and entities (e.g. distance, contiguity, overlap, intersection, etc.), the existence of spatial patterns and trends of a variable using spatial statistics, or assess the level of spatial correlation between multiple variables (e.g. is immunization coverage particular low in several adjacent geographic areas of a country, and do those correspond to areas with low density of vaccination services?)
- Spatially model interaction between geographic objects and phenomena to predict present or future spatial patterns for changing conditions or trying to predict population behaviours (e.g. accessibility to health services). This type of analysis does sometime extend to spatio-temporal domain (e.g., modeling the impact of different scenarios of vaccination supply on the population reached, and predict future coverage based on future location of vaccination delivery sites)

Please refer to Appendix C for more details on the GIS analytical functionalities relevant to immunization programs.

1.3 Applications and Benefits of using Geospatial Data and Technologies across the Immunization Cycle

The role of geography as a unifying dimension between different sources of information, and the use of geospatial technologies as tools to collect, manage, vizualize, analyze, geographic data is crucial to support evidence-based decision-making across the whole immunization cycle.

Identifying, prioritizing, and targeting population based on their geographic location is key to cost-effective public health interventions. Moreover, the causes for the health issue cannot be fully understood without exploring the spatial interplay between the underlying social, environmental, and infrastructural factors. In short, understanding the "where" helps understand the "why."

In the following we provide a brief discussion of how geospatial technologies can be practically used to support improved delivery of immunization services and monitoring coverage. Specifically, in the next sections we:

- Review a selection of published examples on the use of geospatial data and technologies to support various stages of the immunization cycle depicted in Figure 1;
- Summarize the benefits of using geospatial data and technologies across the different phases of the immunization cycle;
- Provide few country level case studies to discuss the benefits of using geospatial data and technologies.

1.3.1 Applications of Geospatial Data and Technologies in Immunization Programs

While basic GIS techniques can produce useful maps depicting the geographic locations of health facilities, the ability to link information from multiple datasets based on spatial relationships and the more advanced techniques of geospatial analysis and modeling can yield a more comprehensive descriptions of immunization programs (e.g., identifying underlying features such as physical access, , disease prevalence, and other factors that can have impact on immunization services and interventions).

Table 2 provides a (non-exhaustive) summary of specific applications of geospatial data and technologies supporting the different phases of the immunization cycle, with reference to published case studies.

Table 2. Applications of geospatial data and technologies across the different phases of the immunization cycle

Phase	Applications
Determine current coverage of target population	• Identifying gaps in immunization coverage and supply of services using geostatistical analysis techniques[16,17] • Mapping distribution of target population and unvaccinated children at high spatial granularity (sub-district level) using satellite maps and spatially disaggregated population and coverage products[18] • Identifying marginalized population characterized by poor accessibility to vaccination services or remoteness • Improving population denominators by characterizing trends and seasonality in population movements using satellite night time lights images and Call Detail Records (CDR)[19]
Mapping immunization resources and key features	• Improving geographic accuracy and comprehensiveness of district or health area maps using GNSS-enabled devices and the interpretation of satellite and aerial imagery[20,21,22]. • Mapping location of vaccination services with respect to the location of population in need of vaccination, and the geographic berries between them to better match supply and demand
Identify barriers/determinants to access, utilization and coverage	• Improving identification of gaps in vaccination supply and delivery in relation to population distribution[23] • Identify impact of distance and travel time to services on access, utilization or coverage[24,25] • Mapping accessibility to vaccination services based on realistic travel times accounting for terrain, natural barriers, and the typical mode of transports[26]. • Identifying determinants of inequities in service delivery, utilization or coverage by spatial overlap with population socio-economic disadvantage and accessibility[27,28,29,30]
Plan intervention	• Optimizing session plans for outreach activities based on physical accessibility to communities[31] • Assessing impact of future or alternative supply scenarios scaling up of programs and optimization of resources[32]
Monitoring implementation	• Identifying gaps in coverage of vaccination outreach activities using satellite images and near real-time GPS tracking[33] • Visualizing subnational or sub-district inequities in vaccination coverage and service utilization[34]

1.3.2 Benefits of Using Geospatial Data and Technologies in Immunization Programs

Application of geospatial data and technologies in immunization programs can bring several benefits, from the specific planning of outreach activities to integration of immunization programs with the larger health system. These benefits can be summarized according to two broad categories:

- Improved efficiency[s]: Geospatial technologies can lead to improved efficiency through a better use of human and material resources, an improvement of accountability and reduction of the potential waste of resources. The integration of geography, and indirectly time, into the immunization process allows to follow an object oriented approach that supports more efficient data management, and consequently more consistent and quicker access to data.
- Improved effectiveness[t]: A sustainable, standardized and integrated use of geospatial data and technologies in immunization programs can result in improved effectiveness of interventions, and indeed improved services to society, meaning lives are saved and human well-being is improved through better delivery of vaccination services in the geographic areas where it is most needed.

In addition to the above, it is important to mention the benefits gained beyond immunization in case the master lists and associated geospatial data created specifically for this purpose is being shared and re-used among stakeholders. Such practice does not only allow reducing costs but facilitate also for the data to be more complete and up-to-date if part of a collaborative and coordinated process.

The following sections provide a more detailed discussion of some of the major benefits identified until now. These benefits apply across the different phases of the immunization cycle discussed in Table 2.

Improve Cost-effective Planning and Monitoring of Outreach Activities

Accurate location of health facilities, population, transportation network and geographic barriers, obtained through the use of GNSS enabled devices or extracted from accurate satellite images, improve planning and monitoring by providing a clearer picture of the spatial distribution of the population in need of vaccination, the location of vaccination services, and the geographic environment between them. Such improved picture leads to a more cost-effective and coordinated planning of vaccination delivery activities based on precise locations, distances and geographic barriers.

For example, accurate information on remote hamlets and population settlements allows isolated communities, frequently missed by vaccination activities, to be made visible and adequately accounted for during planning (Figure 6). By allowing near real-time (daily basis) monitoring of vaccination activities using GPS-tracking techniques, geospatial technologies also ensure for better accountability of vaccination teams by following their movement in the field.

Provide more Comprehensive Insights of Immunization Programs for Evidence-Based Decision Making

Once geospatial and statistical data are linked in a GIS, a variety of powerful spatial analysis techniques can be used to reveal spatial relationships, trends and correlation between different geographic entities and phenomena. For example, geostatistical techniques can be used to identify and monitor areas of low vaccination coverage and high density of unvaccinated children with a high level of granularity (e.g. sub-district level). The patterns identified through this approach can reveal areas where programs are presenting gaps or being ineffective and therefore inform decision making for a better targeting of immunization resources. Figure 7 gives an example of such an approach for Ghana.

[s] Efficiency relates to the amount of output (e.g. services) that can be produced with a certain amount of input by an organization (e.g. investment, human resources)
[t] Effectiveness relates to the impact of the output produced by the project on society (e.g. improvement of population health)

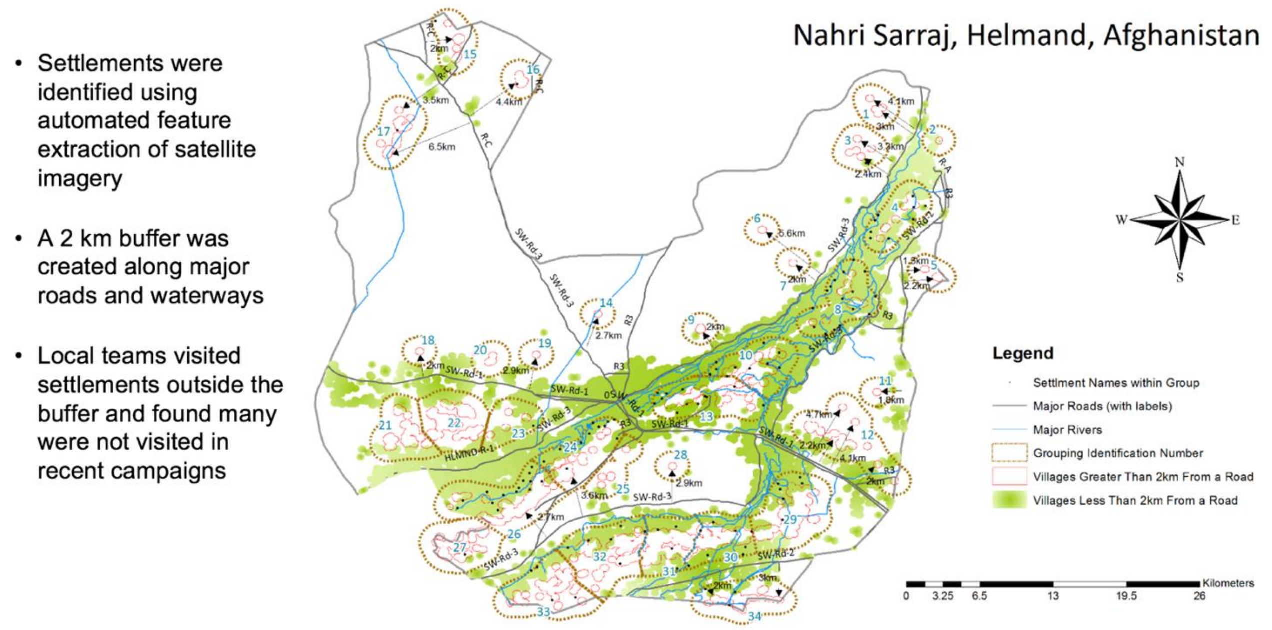

Figure 6. Improved ward microplans using GIS maps allowing monitoring of vaccination teams activities and identification of missed settlements, Afghanistan (courtesy of Vincent Seaman).

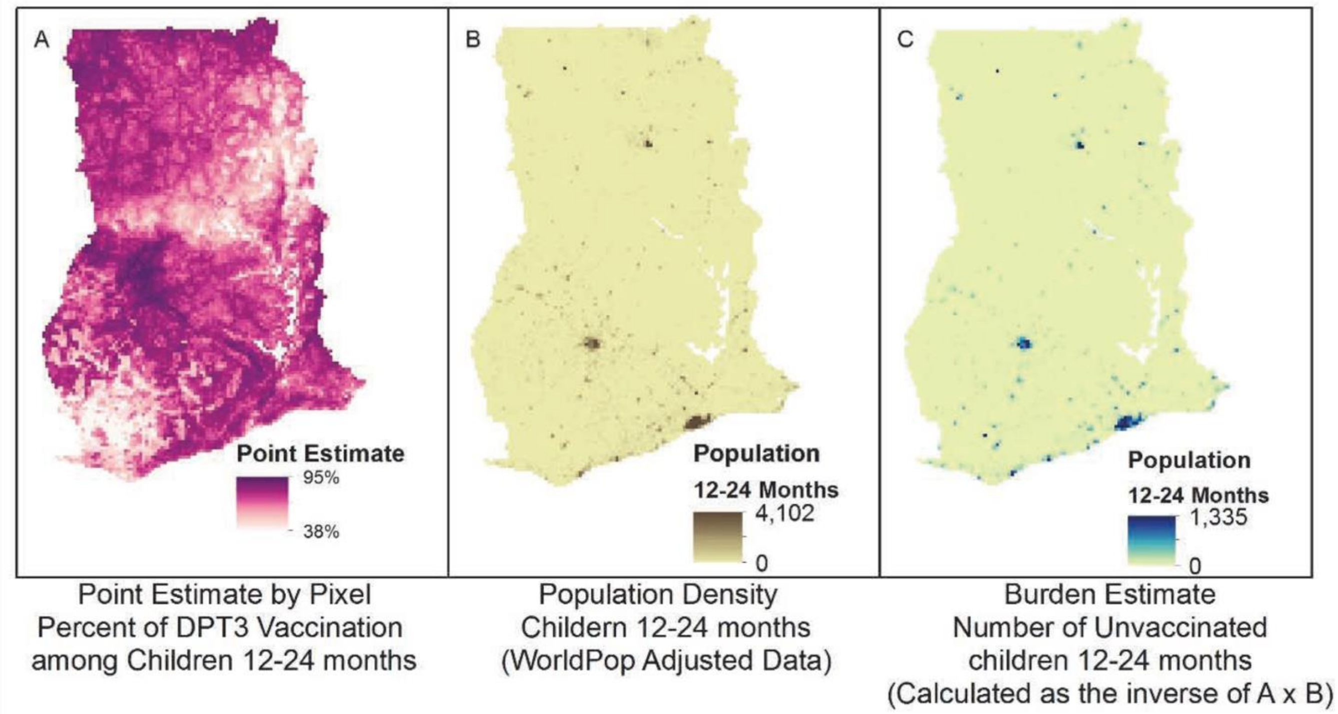

Figure 7. Spatial estimates of unvaccinated children at high spatial granularity (sub-district level) through the combination of disaggregated population and coverage estimates, Ghana[35].

Physical accessibility to health facilities, especially for remote communities, can then be modelled by accounting for terrain conditions, road networks, geographic barriers and typical modes of transport, leading to more informed interventions to solve issues of accessibility to services. Figure 8 shows an example of how GIS has been used in Haiti to determine the areas located further away than 1 hour of travel time to the nearest health facility.

The use of spatial analysis and modelling techniques allow testing different scenarios of resources allocation and provide support for decision-making around scaling up of programs, leading to optimization of immunization resources and investments. This can not only be used to estimate the impact of scaling plans before their implementation but also greatly help coordinate and align efforts as well as avoid duplication of efforts between multiple vertical programs and multi-agency initiatives.

In addition, using geography to link data can eliminate blind spots in understanding the mismatch between supply and demand of vaccination services, and provide insights into the barriers and factors limiting the utilization of immunization services, for example by revealing the relationship between immunization coverage, socio-demographic determinants and accessibility to health services.

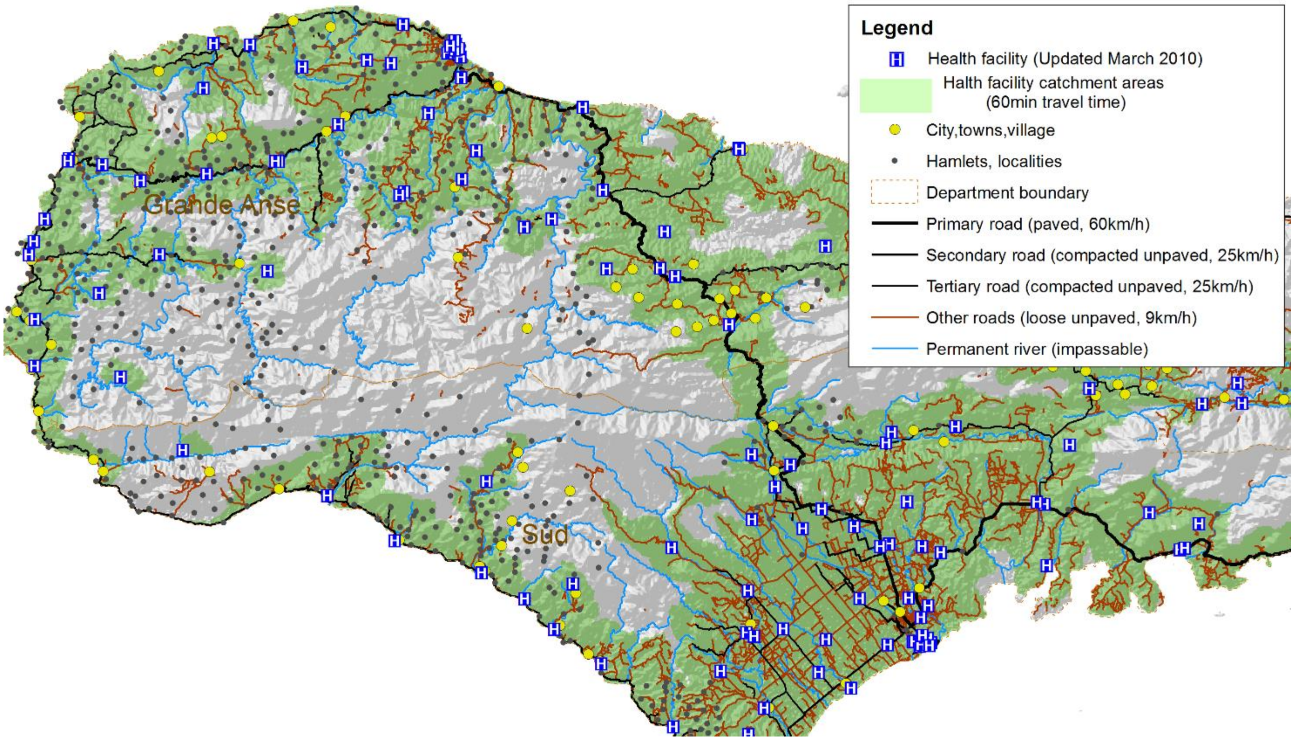

Figure 8. Mapping geographic accessibility to health facilities in Haiti by combination of geospatial data on terrain, land cover, road infrastructure and settlements information (from UNICEF internal report).

Support Evidence-based Advocacy

Maps generated through the use of GIS and shared through different media, including dashboards or online dynamic web mapping services (example in Figure 9) are a powerful way not only to visualize the immunization context and status at different level (regional, national or sub national) but also to advocate for the solving of specific issues that they helped identifying.

Moreover, dynamic maps offer a new entry point into traditional databases, providing new ways to explore, analyze, share, and synthesize data to engage a broader audience and approach data from a new perspective. This is particularly useful when dealing with a large amount of data, like for example vaccine stocks located in 1,000 different service delivery points spread over a specific country, and being able to visually highlight gaps in ways not possible without GIS.

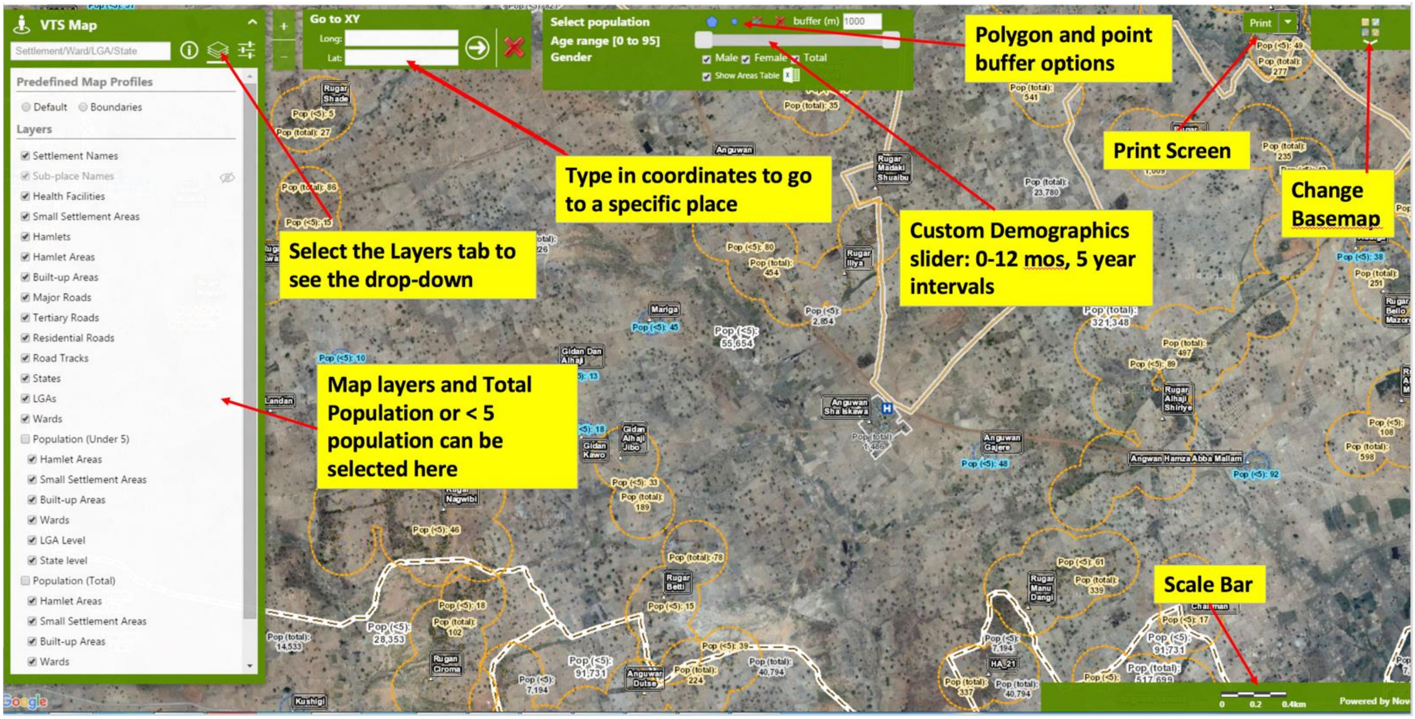

Figure 9. Web-based visualization of vaccination sites, population in settlements and hamlets and background infrastructure, from the Vaccination Tracking System (VTS) in Nigeria[u] (Courtesy of Vincent Seaman).

Allow for a More Systemic Approach to Solving Public Health Issues

Using the same geography and unique identifiers through the use of common master lists across the whole health sector (see Section 1.2.2) makes it possible to bring together data that have been collected by different programs.

This capacity can extend beyond the health sector if governmental agencies and development partners adhere to common guidelines, data specifications, standards and protocols under the umbrella of the National Spatial Data Infrastructure (NSDI)[v], if already in place in the country.

Better insights into the causes of gaps and inequities in immunization coverage can be drawn by combining information on the supply of vaccination services with disparities in population disadvantage, leading to a more holistic understanding of population vulnerabilities and the factors affecting service delivery.

The use of agreed upon unique identifers allows for traditional statistical data to be more easily mapped by linking it with the corresponding geography they are attached (administrative divisions, health districts, etc.), and overlaying them with other sources of information (e.g. health infrastructure, population demographics and socio-economic status).

Finally, the introduction of geospatial data and technologies can have positive impacts on the Health Information System (HIS) itself. Because geography and the use of geospatial technologies allow linking data of different nature and from different sectors, a comprehensive approach to geospatial data management and use across health programs can lead to better management and sharing of health information as well as

[u] http://vts.eocng.org/
[v] The system of policies, human resources, databases, standards and protocols to improve management and utilization of core geospatial datasets of importance to society

a more systemic approach to solving public health problems[5]. Moreover, the multi-sectoral data integration supported by GIS can foster co-financing, collaboration and data sharing across governmental entities, sectors and development partner.

1.3.3 Country Level Case Studies of Integration of Geospatial Data and Technologies in Immunization Programs

The following sections discuss a few country case studies that demonstrate some of the benefits of the introduction of geospatial technologies in immunization programs thus far discussed. The case studies are drawn from presentations by country representatives during the technical meeting on "Improving Immunization Coverage and Reducing Inequities: Use of GIS in Immunization Programs", held at UNICEF, New York City, 25-26 October 2016. More details on each case can be found in the meeting technical report[w].

Polio Eradication using Geospatial Technologies in Bihar, India

In the state of Bihar, East India, a tough reservoir of Polio virus due to low immunization levels, the innovative use of satellite images and GPS data collection was pivotal in improving evidence-based advocacy for additional vaccination sites and cold chain points in urban areas, as well as planning and monitoring Supplemental Immunization Activities (SIAs) to cover pockets of polio in hard-to-reach areas due to rough terrain. Thanks to the introduction of geospatial innovations, outreach immunization activities has led to the rise of full immunization coverage from 32 % (2005 6) to over 70% (2013) in Patna Urban, with polio eradication achieved in 2010.

A clear government vision, high political will, and good leadership were amongst the factors of success of the program conducted by State Health Society, Bihar, WHO, UNICEF and Project Concern International (PCI). However, lack of government ownership and investment in the human and technological geospatial resources employed, and excessive reliance on technology provided by partners with little linkages with government space agencies and health departments is currently undermining the sustainability of the interventions.

Tracking Vaccination Teams using GPS and Satellite Images in Nigeria

Application of innovative geospatial mapping technologies under the guidance of the Bill and Melinda Gates Foundation, including automated Feature Extraction (FE) from high-resolution satellite images and GPS tracking techniques supported vaccination activities in areas with incomplete, inaccurate and out-of-date maps for 10 Northern States in Nigeria. Interpretation of satellite images allowed precise location of remote settlements and hamlets, and GPS tracking improved efficiency in microplanning of vaccination team assignments by allowing tracking vaccination teams daily activities, near-real time (daily) supervision and corrective interventions to optimize coverage of assigned areas.

The resulting detailed GIS Maps completed in 10 states, including all settlements, as well as points of interest, secondary and tertiary roads, allowed accurate maps for planning and monitoring vaccination teams in areas largely unmapped before. This improvement in spatial intelligence and accountability of vaccination teams resulted in dramatic reduction of chronically missed settlements from 4.1% to <0.05% in

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[w] https://www.unicef.org/health/files/3._Final_Report_February_2017.pdf

1 year. However, lack of direct government ownership of programs and reliance on development partners has resulted in less absorption of data use and local capacity building that would have been otherwise possible, with consequent increasing costs of scaling up interventions to the rest of the country.

Low-cost District Mapping using Community Health Workers in Rwanda

An initiative of the University of Rwanda demonstrated the use of local CHWs as a viable method for low-cost, low-literacy geospatial data acquisition using GPS receivers. Using innovative solutions, such as developing GPS training material in the local language, the initiative achieved a 50% reduction of the cost of geospatial data acquisition compare to using GIS professionals. The resulting information provided the basis for accurate mapping of physical accessibility to services, improved scheduling of outreach vaccination services and evidence-based advocacy that lead to additional supply of much needed health resources.

Successful factors included a participatory approach with Involvement of local level workforce, production of low-literacy training/ capacity building material for CHWs, and significant collaboration and data sharing between the University of Rwanda, the Ministry of Health and the National Statistics office.

Updating District Maps in Cameroon

In response to a polio outbreak in 2013, which highlighted inefficient deployment and poor performance of vaccination teams, the Cameroun Ministry of Health, with support from WHO and the Bill & Melinda Gates Foundation (BMGF), rolled out a national update of health area, district maps, and administrative boundaries to improve the accuracy and of maps used for routine and SIA activities. Building on the lessons from Nigeria, GPS-enabled smartphones, open-source data collection tools and satellite imagery were used to acquire coordinates of all health facilities, refugee camps, settlements and geographical features such as lakes, rivers, forests and mountains maps.

The geographic coordinates for 77,778 of these features were collected and validated throughout the country, completing 70% of the national territory. The maps produced based on this data improved spatial localisation and response to measles outbreaks, monitoring of surveillance site visits, and monitoring and analysis of administrative routine EPI vaccine coverage information. Significant Ministry of Health (MoH) leadership and investment allowed extensive national roll-out and training at central and peripheral level. However, challenges were faced in ensuring participation and operational use of maps by the local-level workforce.

1.4 Challenges and Opportunities for Using Geospatial Data and Technologies in Immunization Programs

The following sections describe in more detail the main challenges and opportunities linked to the use of geospatial data and technologies in light of the recent trends observed in the health sector as well as country level experiences discussed in Section 1.3.3.

1.4.1 Challenges in Using Geospatial Data and Technologies in Immunization Programs

The main challenges in using geospatial data and technologies are no longer of technological nature. Rather, they are gradually shifting towards issues pertaining to the availability and accessibility of quality geospatial data, the absence of a supportive institutional framework (strategy and plan, governance, policies, resources), and the need to improve the already existing GIS technical capacity in countries. This has been demonstrated by a number of surveys (UN-GGIM 2015[36], Agbaje 2014[37], Kim 2016[38], and assessment by the AeHIN GIS Lab[x]). The main challenges currently faced for a widespread use of geospatial technologies can be summarized as follows:

- Institutional framework: A sustainable and cost-effective use of geospatial data and technologies for decision making within the health sector requires for a supportive environment to be in place. Unfortunately, the elements constituting such environment (strategy and plan, governance, policies and financial resources) are often lacking or incomplete to ensure institutionalization and therefore long term sustainability. The lack of familiarity and awareness regarding the use and benefits of using geospatial data and technologies as decision making tools amongst managers and policy makers can pose a major obstacle for the introduction of these data and technologies in organizational budgets and strategic plans. This might be aggravated by verticality of programs and lack of inter-institutional collaboration and knowledge sharing. Without addressing these issues, the activities being implemented and the capacity being established or strengthened are most likely to stop at the end of the project that is at their origin.
- Availability of geospatial data**:** While governmental institutions tend to generate more geospatial data, significant gaps remains in the availability of complete, up-to-date and uniquely coded master lists for the geographic objects relevant to public health in general (health facilities, communities/settlements, administrative and reporting divisions) and vaccination programs in particular (vaccination delivery sites, vaccines storages and cold chain facilities) and their associated geography (geographic coordinates or boundaries) (see Section 1.2.2). A lack of governmental sources is also generally observed for some of the ancillary geospatial data needed by immunization programs (e.g. transportation network, terrain elevation, hydrography, see section 1.2.1). However, this is generally filled by the existence of regional or global datasets (see Section 1.4.2).
- Quality of geospatial data: The quality issue is mainly linked to the absence of agreed upon and enforced guidelines, specifications, standards and protocols across all partners within the health sector. This gaps results in data which have been collected with different levels of accuracy, are not related to the master lists mentioned previously (use of different coding schemes for example), and are often poorly documented. All of this makes it difficult to ensure for their proper use and potentially lead to errors having an impact on decision making. In addition to that, the level of completeness and timeliness observed for some of the ancillary geospatial data relevant to immunization programs remain an important issue. Among those, we can mention the one observed for the transportation network, as the currently available datasets are often incomplete, out-of-date and/or not based on the official road classification used in each country
- Accessibility of geospatial data: the challenges around data accessibility are mainly related to: a) the difficulty to discover which geospatial datasets are available and where to find them; b) the restriction in access and/or use to the data in question. While growing efforts toward the establishment of NSDIs (see Box I) aim at addressing these issues through the development of online data catalogues and the release of open data policies, the later is difficult to be enforced and is often conflicting with other laws and regulations in place in the country.

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[x] https://docs.google.com/presentation/d/1iu1z15sm1lPrYcDMkiDCcRzr2ufKuUwltIhK5IoLbNs/edit?usp=sharing

- Personnel technical capacities: Ministries of Health in many cases organize staff trainings on geospatial data and technologies. Unfortunately, such trainings are generally more focused on the use of a particular geospatial solution (e.g. use of GIS software, or a specific type analysis), and rarely cover geospatial data management practices or the integration of geospatial data and technologies into the HIS from a broader perspective. Such trainings are generally one off events, with little or no follow up or updates on recent technological development, resulting in difficulties in maintaining a consistent geospatial capacity in Ministries.

1.4.2 Opportunities and Trends for the Use of Geospatial Data and Technologies in Immunization Programs

While challenges for the use of geospatial technologies in immunization programs remain, as described in the previous section, several activities have been taking place and new resources established over the past few years in order to help addressing them. These are briefly discussed below.

Global, Regional and National Institutional Frameworks

In recent years, several efforts and resources have been devoted at global, regional and national with the common objectives of:

- Recognizing the importance of strengthening the use of geospatial data (and data in a broader sense),
- Reaching a more collaborative and coordinated approach to geospatial data management and use
- Improving the availability, quality and accessibility of geospatial data developed and maintained by countries
- Establishing the necessary institutional framework to sustain the established capacities on the long term

These initiatives include, from the global to the national level:

- Global frameworks such as the Sustainable Development Goal (SDG)[y] and the Sendai Framework for Disaster Risk Reduction[z]. These two frameworks will shape the landscape of the developmental and humanitarian agenda over the coming 15 years and can therefore offer an important leverage to support the introduction and strengthening of geospatial data and technologies in the health sector in countries.
- International coordinating agencies: the United Nationals Committee of Experts on Global Geospatial Information Management (UN-GGIM)[aa] is developing a global strategic framework on geospatial information and services for disasters[bb] whose objective is to help countries benefit from the use of geospatial information and services across the all emergency cycle. The United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA)[cc] is itself revisiting the concept of

[y] http://www.un.org/sustainabledevelopment/

[z] http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

[aa] http://ggim.un.org/

[bb] http://ggim.un.org/documents/UN-GGIM_Strategic_Framework_Disasters_final.pdf

[cc] http://www.unocha.org/

Common Operational Data Sets (CODs)[dd] to make the distinction between Core CODs (administrative divisions, population statistics and humanitarian profile) and country specific ones (populated places, health facilities, schools, roads, hydrology) based on their respective hazard profile. Although mainly focused on humanitarian applications, such initiatives can significantly benefit the availability, accessibility of quality geospatial datasets for the health sectors.

- Data-focused collaboratives: such as the Health Data Collaborative (HDC)[ee], and the global partnership for sustainable development data[ff], which support countries at improving the availability, quality and use of data for local decision-making by keeping data high on the political agenda, aligning efforts to improve demand and supply of data at national level, and improve data use through development of reference standards, norms and practical tools. Also to be mentioned is the Open Health Information Exchange (OpenHIE) initiative, a global community of practice dedicated to open and collaborative support of country driven, large scale health information sharing architectures.
- Regional knowledge hubs: There has been increasing investment of donor agencies in establishing regional knowledge hubs to support countries in strengthening the use of geospatial data and technologies. Examples include the Health GeoLab Collaborative[gg] (former AeHIN GIS Lab) established with the support of the Asian Development Bank (ADB), WHO, UNICEF, Esri and AeHIN and which focuses on supporting countries in Asia and Pacific with the geo-enablement of their HIS, The WHO/AFRO Regional GIS center for the Polio Eradication Program established with the support of BMGF and the multi-sectoral Regional Centre for Mapping of Resources for Development (RCMRD)[hh] established in Kenya.
- National Spatial Data Infrastructures (NSDI): At the national level, awareness and efforts are growing to create institutional frameworks to facilitate the production, standardization and sharing of geospatial data crucial across sectors of societies, also known as National Spatial Data Infrastructure (NSDI). Such infrastructure aims at maximizing the use and minimize the redundant creation of geospatial information for use across sectors, including health, for social and economic development in countries(see Box I).

The immunization programs in countries can therefore benefit from the global, regional and national initiatives discussed above. Not only they can leverage such channels to address the challenges for the integration of geospatial data and technologies mentioned in the previous section, but also to pave the way for multi-sectoral planning and co-financing between government departments and development partners for the development, maintenance, update and sharing of the master lists and associated geospatial data of relevance to immunization programs.

[dd] https://sites.google.com/site/commonoperationaldataset/introduction
[ee] https://www.healthdatacollaborative.org/
[ff] http://www.data4sdgs.org/
[gg] http://www.healthgeolab.net
[hh] http://www.rcmrd.org/

Box I: National Spatial Data Infrastructure (NSDI)[39]

The National Spatial Data Infrastructure (NSDI) is a system of policies, human resources, databases, standards and protocols dedicated to acquire, process, store, distribute, and improve utilization of core geospatial datasets of importance to society[39,40].

A basic organizational structure for an NSDI includes a ministry in charge, a lead agency, a forum or network of data producers and users, a steering committee and technical working groups. Data are maintained in a centralized data center, or network of interconnected data centers, and data are searchable and accessible in standard geospatial formats to a wide range of users.

The main function of an NSDI are to provide broad access to quality geospatial information and avoid duplication of efforts by:

- Provide government, businesses, and citizens with a way to visualize, explore and use data to derive information and knowledge.
- Create a network of resources and services for the seamless integration of location-based information into broader information assets to serve the needs of government, the business community, and citizens.
- Serve as an enabling resource for discovery, access, integration, and application of location information for a growing body of users.
- Leverage shared and open standards-based services and focus on applied information for improved decision-making.
- Include a core set of geospatial layers that interface with other non spatial data being generated (e.g. statistical).
- Integrate and use advanced geospatial technologies and their associated standards and best practices.
- Facilitate use of community-driven open standards with multiple implementations.

Political awareness and institutional efforts towards establishing policy frameworks and infrastructures to strengthen NSDI are growing in some developing countries. Notable cases are those of Nigeria[37], Kenya[41], Malaysia[ii] and Indonesia[40]**.**

Availability and Accessibility of Geospatial Data

From a data availability perspective, it is also important to mention the increasing number of global and regional datasets accessible for public use. While these datasets might not be validated by countries they do represent a useful source when official country data are not available or accessible. Among those datasets we can mention for example (See Appendix D for a more complete list and links): OpenStreetMap (road network, hydrographic network, populated places, etc.), WorldPop and Socioeconomic Data and Applications Center (SEDAC)(distribution of population and socio-economic characteristics), Demographic and Health Survey (DHS, for demographic, health, and development indicators), OpenAerialMap, GlobeLand30 and the Global Land Cover Facility (Land cover, satellite images and other remote sensing products) . Some agencies do also maintain portal for the sharing of a wide range of country specific datasets. Among those we can mention the Humanitarian Data Exchange (HDX) and the Group of Earth Observations System of Systems (GEOSS).

[ii] http://www.mygeoportal.gov.my/

Geospatial Software and Tools

Finally, while access to geospatial technologies is not so much of an issue anymore due to a competitive geospatial software and services market[≈], and the increasing availability of low-cost or free and open source solutions[34], it is useful to provide here a non-exhaustive list of some existing solutions that can be used depending on the environment, purposes and resources of the immunization program. These solutions are listed in Appendix D and include:

- Field data collection tools allow to also collect geographic coordinates through the use of a GPS based device
- Desktop GIS Software and tools for geospatial data management, visualization and/or analysis
- Online GIS Software and tools for geospatial data management, visualization and/or analysis
- Database management systems with a mapping interface

Among these resources it is important to highlight those that have been developed primarily for the health sector, namely: EpiCollect, AccessMod, EPiMap and DHIS2 and the fact that others are currently under development like PlanWise[jj], a software tool to map geographic accessibility to obstetric care to support health planners and decision makers.

[jj] www.concernusa.org/story/planwise-a-data-driven-tool-for-placing-help-where-its-needed/

2. Strengthening the Use of Geospatial Data and Technologies in Country Immunization Programs

This chapter proposes a process-based framework to guide decision-makers and planners in strengthening the use of geospatial data and geospatial technologies in country immunization programs (the "geo-enabling framework").

The proposed approach aims at leveraging the existing in-country institutional framework, capacity and data ecosystem with the vision to achieve a long-term, sustainable integration of geospatial technologies in immunization programs.

In the following sections, first the framework is presented and its relation with the country HIS discussed (Section 2.1). The different steps of the framework are then detailed, and guidance and tools are provided to facilitate their operational implementation (Section 2.2).

2.1 The Geo-enabling Framework

As partially anticipated in section 1.4, a long term and sustainable use of geospatial data and technologies in immunization programs requires for several elements to be in place. Given the fact that all health programs share the same geography and that an overlap do exist between immunization service delivery and the broader health sector, reaching an effective use of geospatial data and technologies by the immunization programs can only be seen in the larger context of geo-enabling the country HIS.

The HIS Geo-enabling Framework

The concept of a "geo-enabled" HIS can be defined using the model proposed by the AeHIN GIS Lab. According to this model, a HIS is considered as being geo-enabled once[6,kk]:

1. A clearly define vision, strategy and plan have been defined on the basis of an assessment;
2. A governance structure has been initiated
3. A minimum technical capacity has been established;
4. Geospatial data specifications, standards and protocols have been defined and are being implemented to ensure the availability, quality (completeness, uniqueness, timeliness, validity, accuracy and consistency[42]) of geospatial information across the whole data life cycle;
5. Master lists for the geographic objects core to public health (health facilities, communities/settlements, administrative and reporting divisions) and their associated geography have been developed and an updating mechanism put in place for each of them;
6. The appropriate geospatial technologies have been identified and are being used in accordance to good geospatial data management practices;
7. Use cases exist where geography, geospatial data and technologies are being used in support of health programs (e.g. communicable diseases surveillance, malaria elimination, health service

[kk] https://www.healthgeolab.net/DOCUMENTS/HIS_geo-enabling_toolkit.pdf

coverage, disaster management, etc.) towards reaching SDG 3 and improving Universal Health Coverage in countries;

8. Policies supporting and enforcing all of the above as well as geospatial data accessibility have been released;
9. The necessary resources to ensure sustainability on the long term have been identified and secured.

It should be noted that ancillary thematic geospatial[ll] layers such as terrain elevation, road networks and hydrographic networks, although not strictly related to the health system, will be required in order to perform several of the spatial analysis tasks relevant to immunization programs (see section 1.3). However, the above list represents the minimum list of elements that should be in place in order to fully benefit from the use of geography, geospatial data and technologies not only in the immunization program but across all health programs. Issues associated with the sourcing and management of the additional geospatial layers are not strictly related to these elements.

These 9 elements can also be organized in a hierarchical manner (Figure 10) in order to illustrate how each of them contributes to each other in order to support program operations. This graph represents the framework which is followed in the context of the present guidance.

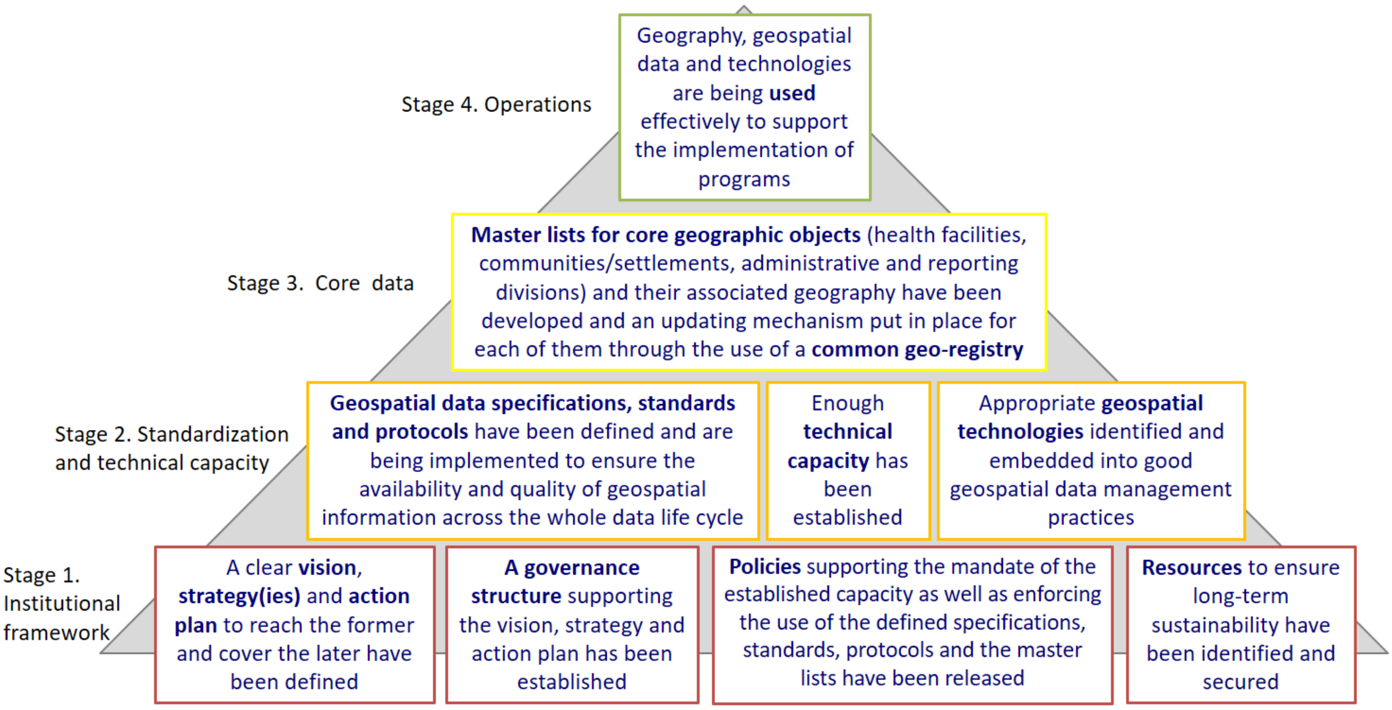

Figure 10. Hierarchical organization of the 9 elements composing a geo-enabled HIS h

While most of the elements listed here above will also have to be defined at the level of the immunization program, three of them will have to be in common across all health programs in order to ensure data quality[42] (completeness, uniqueness, timeliness, validity, accuracy, consistency) as well as reduce duplication of efforts, namely:

[ll] geospatial layer composed only of information related to a specific aspect of the real-world

1. Geospatial data specifications, standards, and protocols
2. Master lists for the geographic objects core to public health (health facilities, communities/settlements, administrative and reporting divisions)
3. Policies supporting and enforcing the use of the data specifications, standards, protocols and master lists

Adaptation of the HIS Geo-enabling Framework for the Immunization Program

In line with the geo-enabling framework for the HIS, we consider an immunization program as being "geo-enabled" when the 9 elements listed above are realized in regards to the component of the immunization program. Geo-enabling the immunization programs therefore refers to the process of ensuring the realization of these 9 elements within both the HIS and the immunization program, which lead to (i) adequate institutional framework, (ii) data standardization and technical capacity, (iii) availability of master lists for the core geographic objects, and (iv) operational use of geospatial data and technologies in the immunization program.

When applying the geo-enabling framework to the immunization program, the list of core objects for which master lists should be in place should be expanded from those generally considered in public health (health facilities, communities/settlements, administrative and reporting divisions) to include immunization-specific objects, namely:

- Vaccination delivery sites: Such sites could correspond to a fixed infrastructure where vaccination activities are taking places (e.g. health facility, school, place of worship) but also the location where a mobile clinic is temporarily situated
- Vaccines storage & cold chain facilities
- CHWs performing immunization-related activities[mm]
- Children (or pregnant mothers as an alternative in the absence of children master list)

While a master list should be developed, maintained and regularly updated for all the above objects[nn], only the first two (vaccination delivery sites and vaccine storage & cold chain facilities) are related to fixed geographic objects and therefore hereby considered as core, immunization specific master lists for the proposed geo-enabling framework (in addition to those generally considered in public health).

However, the master lists for the other mobile objects (CHW, children or pregnant mothers) are also relevant and therefore important to immunization programs. Their development, maintenance and update should therefore be promoted in countries, and these should

Summary of important master lists for geo-enabling the HIS and the immunization programs:

Core fixed objects of the Health Information System:

- *Health facilities*
- *Communities/settlements*
- *Administrative and reporting divisions*

Immunization specific fixed objects:

- *Vaccination delivery sites*
- *Vaccine storage & cold chain facilities*

Mobile objects relevant to immunization:

- *Community Health Workers*
- *Children or pregnant mothers*

[mm] e.g.: build awareness on importance of vaccination, keep track and mobilize children who need vaccination, etc.
[nn] For guidance documents about implementing and managing master lists and registries, please see Appendix B.

be connected to the master lists for the geographic objects core to public health and immunization through the use of the unique identifiers (as described also in section 1.2.2), so as to ensure that the information they contain can be plotted on a map and utilized for planning, monitoring and analysis of the immunization program. It should here be flagged here that these additional master lists (CHW, children or pregnant mothers) might involve privacy and confidentiality issues, and therefore a certain level of aggregation of information is recommended, which can be achieved once again by linking such information to one of the geographic objects core to public health (health facilities, community/settlements, administrative or reporting divisions).

A few observations are crucial in regards to the two immunization-specific master lists (vaccination delivery sites and vaccine storage & cold chain facilities):

- In an ideal case, the country would have complete master lists for all the types of infrastructure or place where vaccination services are delivered (e.g. health facilities, school, places of worship, etc.) and one could leverage these to create the master list of vaccination delivery sites. However, this ideal situation will be rare. It is therefore more cost-effective to directly create a master list of vaccination delivery site which includes a mix of the above infrastructures together with the location where a mobile clinic is temporarily situated.
- It can sometimes happen that all the vaccines storage & cold chain facilities in a country are actually located within health facilities. In this case, their geographic location can be defined using the location information reported in the health facility master list. Additional information about vaccines storage and cold chain (e.g. storage volume, type of equipment, etc.) should be stored in a separated database linked to the health facility master list through the use of the health facility unique identifier (see "Statistical Attributes attached to geospatial Data" in Section 1.2.2).

Taking the above into account as well as the need for the geo-enablement of the immunization program to be aligned with the HIS and the NSDI, an ideal situation for the immunization program can be defined based on the following indicators (numbers corresponding to the 9 elements of the HIS geo-enabling framework):

1. Vision, strategy and plan: The MoH has a vision, strategy(ies), and plans regarding the management and use of geospatial data and technologies. The vision, strategy and plan of the immunization program is aligned to the MoH one.
2. Governance: A National Spatial Data Infrastructure (NSDI) is established in the country. The MoH is on board of NSDI. The MoH has established a governance structure to handle issues pertaining to geography, geospatial data management and geospatial technologies. All the program, including immunization, as well as the development partners using geospatial data and technologies, are involved in this structure.
3. Technical capacity:
    - The MoH has a central level geospatial data management unit with enough technical capacity to: a) ensure guardianship over the defined guidelines, standards and protocols; b) support the development, maintenance, regular update and sharing of the master lists for geographic objects core to public health and immunization; c) support the implementation of the guidelines, standards, protocols and master lists in all the health programs and information systems; d) providing GIS services to HIS unit and beyond if needed.

- The immunization program has access to enough technical capacity to answer its needs for geospatial data and technologies, including capacity and expertise for immunization specific geospatial data collection, extraction, management, analysis, and visualization, with the support of the central level unit

4. Data specifications, standards and protocols: Data specification, standards and protocols have been defined as part of the NSDI and the MoH is already using them across all the programs, including immunization.
5. Master lists and registries:
   - The MoH has a complete, up-to-date, uniquely coded and geo-referenced master list of health facilities, vaccination delivery sites, vaccine storage and cold chain facilities (if located outside health facilities). These master lists are stored and made accessible through registries. An updating mechanism is in place for each of them and the master lists are regularly updated taking changes in administrative and reporting divisions into account
   - If reporting divisions are being used by the MoH, a complete, up-to-date and uniquely coded master list is available for these divisions. An updated shapefile containing the boundaries of these divisions is available
   - The government maintains and regularly updates both an administrative divisions and community/settlement master list. An updated geospatial layer containing the boundaries of these administrative divisions and one containing the location of all the communities/settlements are available
   - The master lists for the other mobile objects relevant to immunization (CHW, children or pregnant women) are connected to the master lists for the geographic objects core to public health or immunization through the use of the unique identifiers and this to ensure that the information they contain can also be plotted on a map
   - The master lists for the geographic objects core to public health and immunization are simultaneously hosted, maintained, updated and shared through a common geo-registry
   - All the above master lists, and especially their officially recognized codes are being integrated in all the information systems and used during data collection, reporting and monitoring across all programs including the immunization one (in the immunization registry for example)
6. Availability of geospatial technologies:
   a. The central level geospatial data management and technologies unit has access to the necessary geospatial technologies, or combination of technologies (GNSS enabled devices, GIS software or RS[oo] imagery), to support its mandate. This will include tools for geospatial data collection, software and platforms for geospatial data management, sharing, analyzing and visualization.
   b. The immunization program has access to the necessary geospatial technology to support its activities
7. Use cases supporting health program implementation: Geospatial data and technologies are recognized as being important and are being operationally used to support the implementation of

[oo] Remote Sensing imagery from satellite, aircrafts or drones

health programs, including immunization, towards reaching SDG 3 and improving Universal Health Coverage in countries

8. Policies supporting the geo-enabling process:
   a. A policy enforcing the following has been released:
      i. The mandate over the guardianship on geospatial data specifications, standards and protocols as well as over the development, maintenance, update and sharing of the master lists for the objects core to public health and immunization through the use of a common geo-registry;
      ii. The use of the developed guidelines, standards, protocols and master lists by all the stakeholders in the health sector.
   b. The immunization program is complying to this policy
9. Resource for sustainability: The MoH and the immunization programs have the necessary human and financial resources to ensure the sustainability of their geospatial data and technologies related activities

Finally, it should be stressed that the geo-enablement of the HIS should normally be part of the National Spatial Data Infrastructure (NDSI) efforts, in order to cover all the sectors crucial to society when it comes to the management and use of geospatial data, technologies and services. Efforts towards geo-enabling the HIS and the immunization program in countries, should therefore be aligned with, and when possible, contribute to the establishment or strengthening of the NSDI.

2.2 Geo-enabling the immunization program

The process proposed in this guidance in order to geo-enable the immunization program according to the framework described in the previous sections is summarized in Figure 11.

The next sections of the document detail each of these steps and give examples as a way to further guide the person who will be in charge of their implementation. Tools for the practical implementation of each step are provided in the relevant appendices. It should be stressed that the process illustrated in Figure 11 is not a one-off process, and should be regularly implemented in order to account for the evolution of the immunization context in the country.

When possible, and appropriate, steps 1 to 3 can be implemented in the context of a workshop grouping HIS and immunization stakeholder (decision makers, data managers, GIS experts) as well as representatives from the NSDI if one is already in place in the country. This being said, conducting a preliminary assessment of the geo-enabling level of the HIS and immunization program prior to the workshop would greatly help the discussions. This workshop would also be a good occasion to present on the use of geospatial data and technologies in public health in general and by immunization programs in particular as well as their application, benefits, challenges and opportunities (See Chapter 1).

2.2.1 Step 1 - Determining Immunization Needs and Gaps

During this first step, the country-specific needs and gaps in immunization planning monitoring and analysis should be identified and translated into specific questions. This should be done through a broad stakeholder consultation, including immunization managers and decision makers from the Ministry of Health, International development partners, national and local NGO's involved in immunization service delivery, etc. It is particularly crucial at this stage that stakeholders from all levels (from local to national) be involved in the consultation. This is to ensure that the introduction of new technology meets the needs and capacity of front-level immunization workforce, therefore improving absorption and participation at the local level.

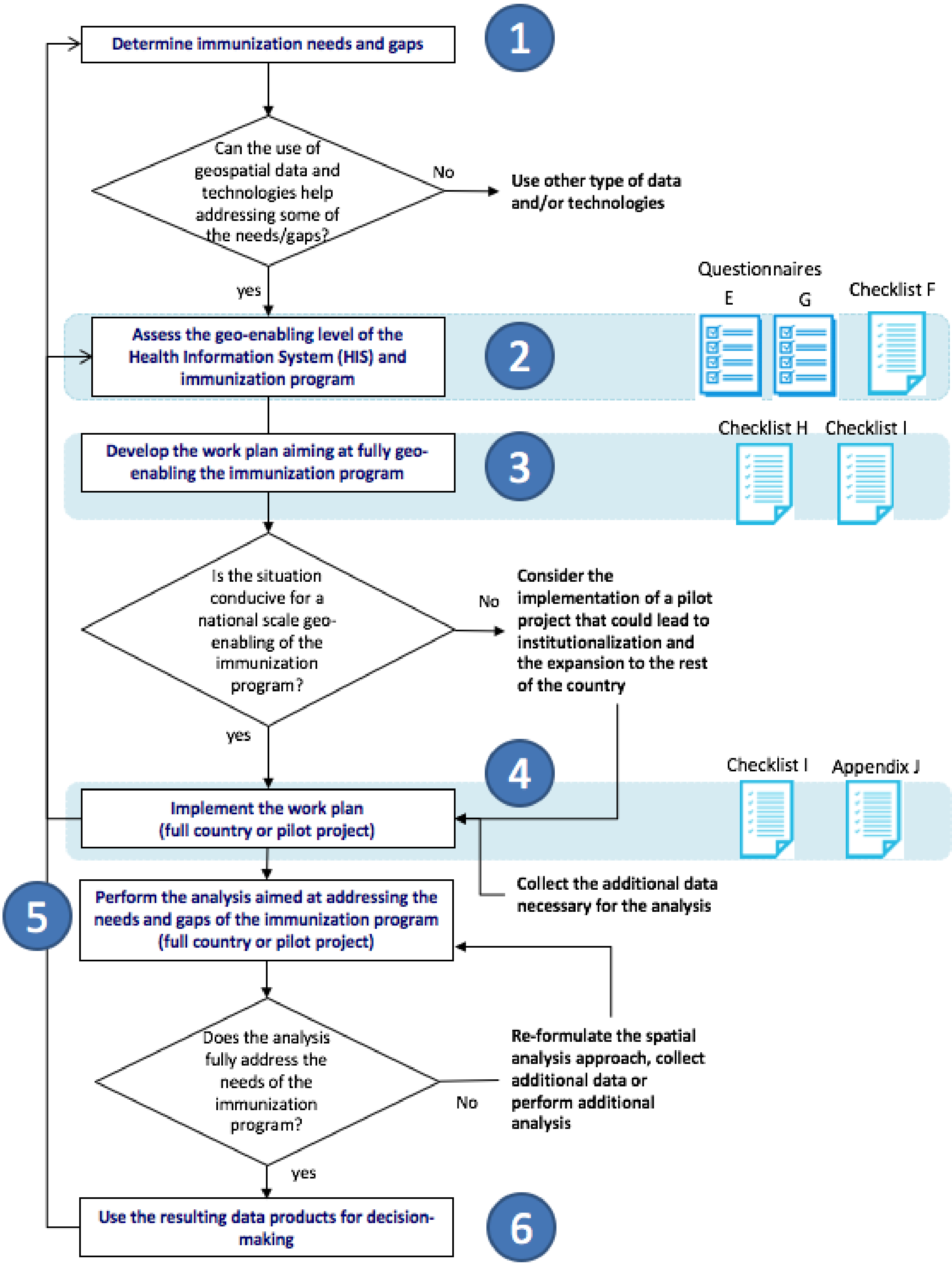

Figure 11. Process aiming at geo-enabling the immunization program (Numbers refer to steps in section headings). The tools provided in the appendices for the implementation of the process are also indicated for each step

Through consultation with data analytics and GIS experts, these questions should then be translated into the data products (tables, graphs, maps) that are seen as suitable to answer the needs and gaps identified, and the list of data and analytical methods that will be required to generate these products.

The consultative process should then establish whether a spatial approach will be needed to produce these products, or whether the problem can be sufficiently resolved using traditional, non spatial approaches, such as statistical analysis. For example, to respond to the question "is vaccination coverage poorer amongst population of a particular ethnicity?", national or regional figures of coverage disaggregated by ethnicity might simply provide the answer with readily available data from national coverage surveys. However, if the question was rather "are population of a particular ethnicity suffering from poor accessibility to services", one would require examining the geographic distribution of population relatively to the location of the health facilities, a task with obvious geographic implications not answerable without geospatial information such as geographic location of health facilities and spatial distribution of population by socio-demographic stratifiers.

Although a large variety of specific needs can be address using geospatial technologies, the list below attempts to summarize them around a number of specific questions crucial to immunization programs. The reader can also refer to the references cited in Table 2 for more details into specific analysis:

- **Inefficient microplans and poor accountability of vaccination teams:** Mapping spatial location of immunization infrastructure, human resources, population distribution and geographic features at district or health area level, using GNSS enabled devices and the interpretation of satellite images, will lead to more efficient planning of outreach sessions based on distances, population in need and geographic barriers, and improved monitoring and accountability of immunization teams.
- **Inefficient use of vaccination resources (human resources, stocks, cold chain):** More geographically accurate maps of resources versus populations, together with spatial analysis of the barriers between supply and demand, can lead to better identification of gaps in the supply based on the distribution of demand for services.
- **Evidence of chronically missed communities**: demonstrated, for example, by pockets of disease despite reported high vaccination coverage. More efficient microplans and use of GNSS enabled devices and satellite images has demonstrated strong reduction of chronically missed communities in even hard-to-reach areas.
- **Poor quality of information on location of the target population**: improved spatial intelligence on location of settlements, hamlets and remote communities, as well as spatially disaggregated population products can provide better evidence for allocating resources at sub-district level and within health areas. Changes in population denominators can also be improved by capturing population dynamics due to growth and migratory flows using innovative spatial technologies (e.g., satellite night time lights and mobile phone records).
- **Lack of evidence on inequities of vaccination coverage at sub-national, sub-district or health area level to identify low performing areas:** Identification of spatial patterns in immunization coverage and

application of geostatistical methods to identify significantly low performing areas can provide compelling evidence to prioritize intervention.

- **Lack of evidence on geographic barriers and limitations to accessibility and utilization of services**: Modelling of geographic accessibility to services including realistic travel times, geographic barriers and typical modes of transport can support better identification of inequities in service delivery and optimization of such delivery.
- **Poor understanding of geographic and socio-economic factors determining access to vaccination services, coverage and efficacy**: Spatial analysis and modelling techniques can shed light on the interplay between various factors in determining low immunization coverage, and highlight how this interplay can vary between regions of the same country (e.g. areas where geographic accessibility is the main limiting factor to achieving coverage, such as rural areas, versus areas where other factors such as poor economic conditions are the major driver of accessibility to services, such as urban slums).
- **Lack of evidence for assessing the impact of future or alternative delivery scenarios**: GIS offers powerful tools to model service delivery scenarios and optimize location of services and allocation of resources. For example, the accessibility to future or alternative facilities can be modeled with respect to the target population based on considerations of distances and transport options, supporting evidence-based decision-making on future investment of vaccination resources.
- **Need for evidence-based advocacy for program improvement and request for additional resources:** Maps, charts, and the growing ecosystem of interactive web-mapping tools provide powerful communication tools to bring the analytical insights behind maps to decision-makers and drive change.

This list, although not comprehensive, can serve as a guideline to identify if geospatial data and technologies could be used to address some, or all, of these gaps or if traditional non spatial approach is sufficient.

2.2.2 Step 2 - Assessing the Current Level of Geo-enablement of the HIS and Immunization Program

Once the benefits of using geospatial data and technologies confirmed during the first step, it is crucial to assess the level of geo-enablement already in place not only within the immunization program but also at the level of the HIS in general. Such assessment will allow determining the gaps that exist across the 9 elements of the HIS geo-enabling framework presented in Section 2.1.

In this effect, it is important to start by conducting the assessment at the HIS level in order to obtain the general picture before focusing on the immunization program. A simple questionnaire like the one reported in Appendix E can be used to perform such assessment.

This questionnaire is organized according to the 9 elements of the HIS geo-enabling framework, and should be preferably conducted by the person at the head of the unit in charge of data management within the Ministry of Health (e.g., the HMIS/HIS unit), or the person in charge of the geospatial unit if such a section exists in the MoH. When considering the individual elements of the HIS geo-enabling framework, the indicators defining the ideal situation can be used as a guideline to assess progress in each area (see indicators listed in Section 2.1 and Appendix H).

As an example of the practical application of the questionnaire, Figure 12 presents the results of such assessment undertaken by the AeHIN GIS Lab at the beginning of 2017[6]. The matrix in Figure 12 summarizes he answers received from 13 countries in the Region (List indicated at the bottom of the Figure).

While the kind of matrix shown in Figure 12 allows to rapidly and simply assessing where the main gaps resides, having the possibility to collect additional information would permit for a much more precise estimation when developing the work plan during the next step. Appendix F therefore provides a non-exhaustive list of additional information that should be collected during the implementation of the questionnaire. Some additional material such as the "Global Geospatial Industry Outlook"[40] conducted by Geospatial media and communication, or web sites such as the one for the Global Spatial Data Infrastructure (GSDI) association[pp] and the United Nations Committee of Experts on Global Geospatial Information Management (GGIM)[qq] can also help in this regards.

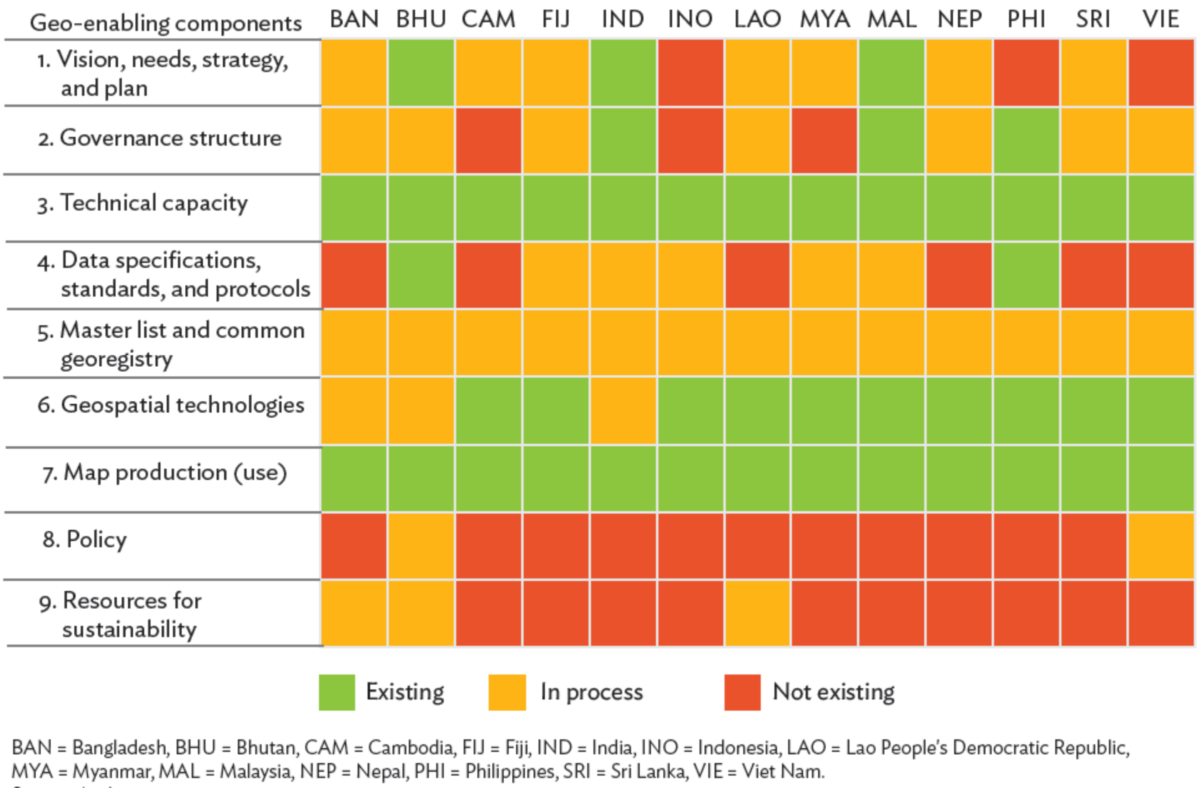

Figure 12. Summary results of the quick HIS geo-enabling assessment conducted by the AeHIN GIS Lab at the beginning of 2017 (Extracted from Ebener et al., 2018).

The questionnaire to use to assess the level of geo-enablement of the immunization program is based on the one used at the HIS level after adjusting it to account for the specific role and needs of the program compare to the broader HIS context. This questionnaire (Appendix G) should preferably be filled through a consultative workshop involving representatives (decision makers, data managers, GIS experts) from the key stakeholders involved in the immunization program and, if possible and appropriate, the respondents to the HIS geo-enabling assessment survey as well as representatives from the NSDI if one is already in place in the country.

This workshop should aim to:

[pp] http://gsdiassociation.org/
[qq] http://ggim.un.org/

1. Present the NSDI framework and activities
2. Present the result of the HIS geo-enabling assessment
3. Conduct the geo-enabling assessment of the immunization program
4. Identify the potential gaps and activities to be implemented to reach a full geo-enablement of the HIS in general and the immunization program in particular

Appendix H can be used to help defining the activities to be implemented based on the gaps that have been identified during the assessment. This annex also provides recommendations on the main MOH entities to be involved in each activity as well as the scale at which they should be implemented (national or pilot project).

2.2.3 Step 3 - Developing the Work Plan Supporting the Geo-enablement of the Immunization Program

The result of the assessments conducted during the previous step is used to develop a work plan aiming at addressing the gaps identified during the assessment and support the full geo-enablement of the HIS in general and the immunization program in particular.

The final work plan is being reached through the following activities describe in more details in the following sections:

1. Developing a preliminary work plan
2. Costing the preliminary work plan
3. Determining the implementation scale
4. Releasing the final work plan

Developing a Preliminary Work Plan

The list of activities thus compiled can directly be used to develop a preliminary work plan aiming at filling the gaps in the geo-enabling framework.

Such preliminary work plan should at least contain the:

- Purpose, goal and objectives
- List of activities obtained through the assessment
- Estimated budget and timeline for each activity
- List of the resources at disposal

Costing the Preliminary Work Plan

While the exact cost for each activity will depend on the local context, including the availability of the needed material and expertise on site, Appendix I can be used as a guide to ensure that all the items linked to geospatial related activities are taken into account in the estimation. It should be noted that this list does not contain items common to any project implementation such as project management, meetings and workshop, communication, running costs, etc.

When developing the budget based on the activities included in the work plan, it is important to note the following:

- The cost linked to field data collection should not be underestimated. Example of GIS projects for immunization planning and monitoring conducted in Cameroun, India, and Rwanda (see Section

1.3.3), indicate up to 70% of budgets dedicated to equipment, manpower, training and supervision of field work activities alone, with figures of US$10-30K per district, and between US$150K and up to the million$ mark for national level mapping

- Existing leadership, capacity and resources should be leveraged, such as existing and used equipment, software, local champions and skills available at both the central and field levels not only from within the MoH but also other institutions that could provide on-site technical support like universities. This is of particular importance when selecting appropriate geospatial technology(ies) that will not only be sustainable on the long term but also balance the advantages and disadvantages of proprietary vs open source solutions. The final choice might be a combination of both.

It should be stressed that the introduction of any new technology and/or practice always results in a significant change in the routine and expenses. The major costs generally occur in the early stages of a project and the benefits may materialize later into the project cycle, resulting in cost saving in the long run. As the geospatial infrastructure and capacity become part of the organization and the initial cost of data collection is incurred, the cost of maintenance and update of the different geospatial assets will be much lower.

Determining the Implementation Scale

At the end of the costing exercise, the developed work plan should allow the immunization stakeholders to determine the scale at which the immunization programs can be geo-enabled. In particular, it should be established whether:

1. The current level of geo-enablement and availability of financial resources is conducive for an implementation at the national scale, or if a pilot project would be more suitable to the country-specific conditions. A pilot project is frequently a crucial step to demonstrate the benefits of the process before aiming at institutionalizing and expending it to the whole country; or whether
2. Investments and efforts should rather be directed toward raising awareness in the MoH, improving the institutional framework, working on establishing the master lists for the geographic objects core to public health and immunization and/or the strengthening of the technical capacities and skills in the MoH.

Releasing the final work plan

The process described in the previous section provide the necessary information to come up with the final work plan to be implemented as a way to improve the geo-enablement of both the HIS and the immunization program.

The final work plan should contain the following in relation to the implementation:

- Purpose, goal and objectives
- Scale of implementation
- List of activities to be implemented with the mention of the person/unit in charge
- Budget and timeline for the all implementation
- Expected outcomes and deliverables

2.2.4 Step 4 - Implementing the Work Plan Supporting the Geo-enablement of the Immunization Program

The activities included in the final work plan defined during the previous step (see Section 2.2.3) are being implemented here to either complete the geo-enablement at the national level or demonstrate the benefit of the process through a pilot project. In both cases, the concrete needs from the immunization programs identified during the first step (see Section 2.2.1) are being used as the driver for the implementation.

The final list of activities included in the work plan can generally be grouped according to 7 broad categories:

1. Awareness raising and advocacy on the importance of: a) integrating geospatial data and technologies in immunization programs; b) ensuring for the MoH to be on board of the NSDI; c) aligning visions, strategies, plan across health program and with the NSDI; d) collaboration and coordination among all stakeholders; e) integrating the master list for the geographic objects core to public health and immunization across all the information systems;
2. Writing essential documents to support geo-enabling activities (policy, strategy, plan, guidelines, protocols, etc.);
3. Transferring knowledge or practices, for example the transfer of the geospatial data specifications, standards and protocols from the NSDI to the health sector;
4. Establishing a governance structure within the health sector for geospatial data and technologies in case none exists yet;
5. Strengthening technical capacity for geospatial data collection, management and analysis and for the management and use of geospatial data and technologies through onsite training and collaboration with local technical institutions;
6. Establishing, maintaining or updating the master lists for the geographic objects core to public health and immunization and ensuring their integration across all the information systems, including the master lists for the other mobile objects (CHW, children or pregnant women);
7. Collecting additional data: This task might include, data collection, extraction, cleaning and sharing of the additional data (geospatial and/or statistical) needed for conducting the analysis identified during the needs and gaps assessment (section 2.2.1). These could include for example ancillary geospatial layers such as road networks, terrain elevation, hydrography, or statistical data such as immunization coverage from surveys.

Among the above list, there are two types of activities in particular for which it is important to provide more information in the context of the present guidance, namely:

1. An approach to technical capacity strengthening;
2. Key points when collecting the additional data needed for conducting the analysis identified

Approach to In-country Technical Capacity Strengthening

A good approach to strengthening the management and use of geospatial data and technologies in the immunization program consists in organizing on-site training sessions covering the steps of the geospatial data management chain or cycle (Figure 13).

The advantages with this approach are that:

1. The personnel being trained on geospatial data management and the use of geospatial technologies are provided with a process widely applicable to the use of geospatial data and technologies in any sector
2. The development of technical skills is directly linked to the needs of the immunization program (point 1 in Figure 13)
3. The concepts leading to good geospatial data management and the proper use of geospatial technologies are introduced in a logical order
4. Concrete outputs, including the data specifications, standards and protocols, are being defined during the implementation of the chain

When implementing the above mentioned approach it is important to aim at developing the appropriate geospatial skill within the MoH. Appendix J provides a reference TOR describing the type of profile suitable for the position of geospatial data manager/GIS technician.

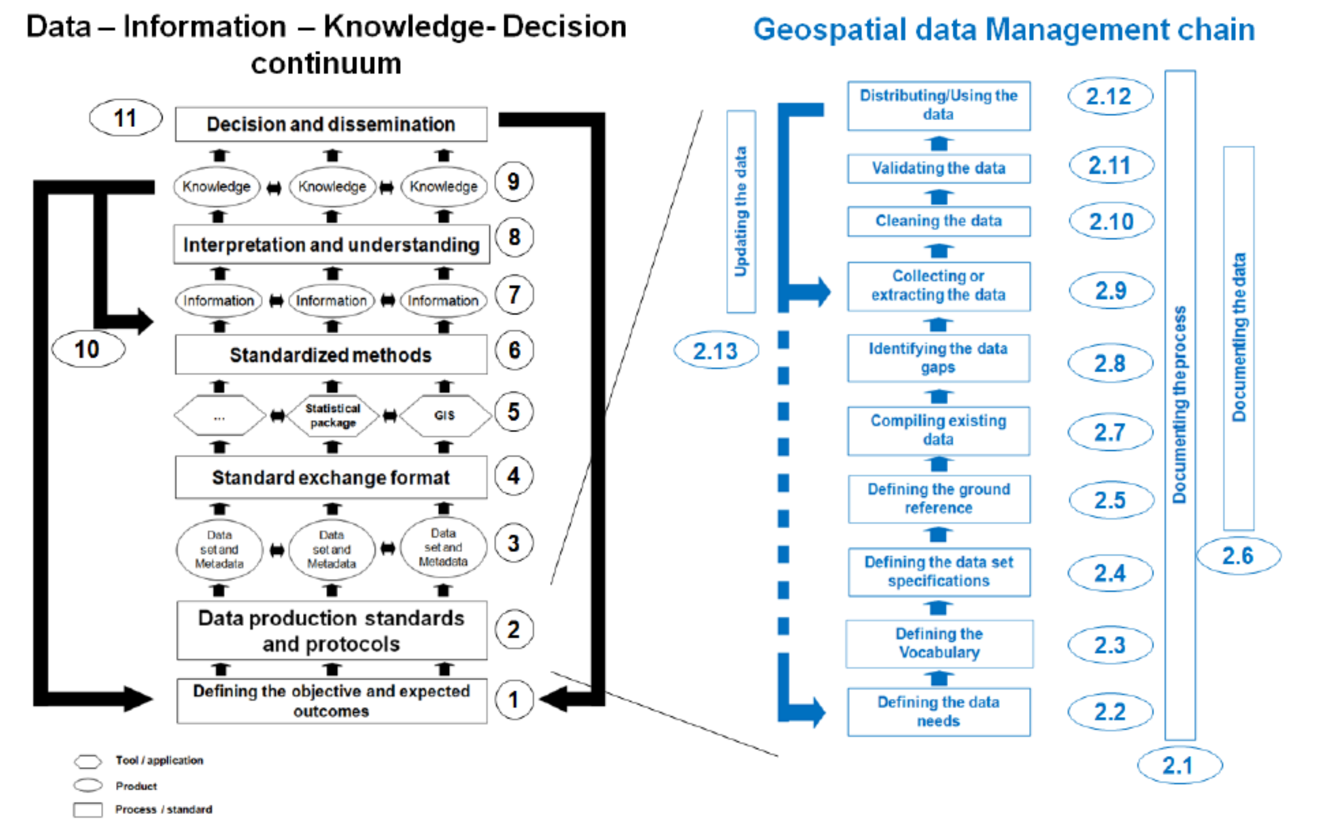

Figure 13. The data-information-knowledge-decision continuum and the geospatial data management chain (extracted from Ebener 2016 [43])

Collect Additional Data for the Analysis

When it comes to the managing the additional data (geospatial and statistical) necessary for conducting the analysis identified during the needs and gaps assessment (section 2.2.1), it is important to note that:

1. The first step of the geospatial data management chain (step 2.2 in Figure 13) aims at defining the data needed to perform the necessary analysis and develop the data products requested by the immunization program
2. These data should comply with the specifications and standards defined by the MoH in order to be consistent with the master lists for the geographic objects core to public health and immunization. This consistency does not only concern the spatial aspect of the data (projection, scale, accuracy, etc.) but also the use of the agreed upon coding schemes. This point underlines once again the importance for the MoH to be involved in the NSDI if in place in the country. For the MoH to be involved in the NSDI might actually facilitate access to some of the auxiliairy layers described previously
3. Regional and global datasets containing key layers do exists (see Section1.4.2 and Appendix D) but these might have to be adjusted in order to comply with the official classification used in the country. For example, the road type classification in the global dataset might need to be reclassified to match the national classification; global geospatial products of population distribution might have to be adjusted to match the last population census figures when aggregated; or administrative divisions names and unique IDs on global datasets might have to be adjusted to the country official coding scheme.
4. Independently from the source, these layers will have to be checked, potentially cleaned or even completed through digitizing (especially if important time discrepancies are observed between sources) in order to ensure for proper results.

2.2.5 Step 5 - Performing the Analysis Aimed at Addressing the Needs and Gaps of the Immunization Program

Once the necessary data (master lists, additional geospatial and statistical data), have been compiled, checked, cleaned, homogenized and potentially completed for the area of concern, the methods defined during the assessment of the immunization program needs and gaps can be implemented in order to generate the data products (maps, tables, graphs) that will be used for decision making.

Depending on the level of geo-enablement already in place in the country and the availability of the necessary data, this step can either take place while filling the gaps identified in the framework (Section 2.2.4) or after it. The objective is to reach concrete results and insights from the application of geospatial data and technologies, at the level at which the implementation took place (national scale or pilot project).

Describing the method beyond each of the analysis that can be performed is beyond the scope of the present guidance and should be the object of a separated document. Reader interested in further information on specific analysis tasks can refer to the published work referred to in Section 1.3.1 or the educational and guidance material listed in Appendix B of this guidance.

Once the different analysis performed, the results are converted into data products (maps, graphs, tables) meant to be used by decision makers. Before that, it is important to make sure that these products do fully address the initial needs of the immunization program. If this is not the case, there might be a need to re-formulate the spatial analysis approach, collect additional data or perform additional analysis.

It is also important to mention here the need for the technician preparing the final data products to include all the necessary information, also referred to as metadata, that will allow decision makers assess the quality of the data/information he is looking at (source, date, level of completeness, etc.).

2.2.6 Step 6 - Using the Resulting Data Products for Planning and Decision-making

The last step consists in using the data products resulting from the spatial analysis, frequently in conjunction with the products generated through traditional statistical methods, to support and inform planning and decision-making.

Describing in details what should be taken care of during this particular step is also beyond the scope of the present guidance and should be the topic on a separated document that would guide decision makers on how to read, be critical about and interpret data products generated through the use of geospatial data and technologies. Reader interested in further information on this topics should refer to the educational and guidance material listed in Appendix B as a starting point.

Apart from resulting into actions aiming at improving vaccination planning, delivering and monitoring, the products that have been generated can be used to support the institutionalization of the geo-enabling process as well as its expansion to the rest of the country by demonstrating the added value and benefits brought through the use of geospatial data and technologies.

3. Conclusion and Recommendations

The present guidance aims at contributing to the introduction and use of geospatial data and technologies in immunization programs. This is done by first providing a non-technical introduction to the role of geospatial data and technologies in such programs before proposing a process-based framework to guide decision-makers and planners in strengthening the use of geospatial data and geospatial technologies in countries.

Through the topics it covers, the introduction does not only demonstrate the importance of geography in immunization programs but does also illustrate how the geographic dimension of immunization programs is captured, represented and linked using geospatial technologies. The presentation of applications as well as the discussion on the main benefits, challenges and opportunities in using geospatial data and technologies then completes the picture and provides the necessary material to advocate for their introduction or strengthening in countries immunization programs.

The process-based framework provides guidance and practical tools to support countries in the process of realizing the operational use of geospatial data and technologies in country immunization programs and this by covering all the elements that should be taken into account to ensure sustainability on the long term. Although the HIS geo-enabling framework has been largely developed and tested in the Asia-Pacific region, it is based on experience and consultation with experts that go well beyond the region, and is therefore expected to be flexible enough to be applied to other regions. Future application of the framework in different context will contribute to its further development or improvement.

While being as comprehensive as possible, this document only represents a first piece that should be completed with other material covering for example the question of the analysis being performed as well as the use and communication of the resulting products for planning and decision making.

The country-level work describe in this document also needs to be completed by supporting activities to take place at the regional and/or global level. Among those is the need to:

- Develop courses and educational material covering medical geography, geospatial data management and the use of geospatial technologies in the curriculum of the Schools of Public Health;
- Promote private-public partnership to increase access to geospatial data and technologies developed by the private sector;
- Promote understanding of the advantages of geospatial data and technologies in the health sector through consultative meetings/capacity building workshops, national stakeholder summits etc.;
- Promote sharing of successful experiences and lessons between countries;
- Continue supporting and expand the capacity of regional centers of excellence and the development of rosters of national, regional and global experts that could support the in-country implementation of the proposed process-based framework presented in this guidance document;

- Support countries in the development of the master lists for the geographic objects core to public health and immunization and other geographic databases necessary for the operation of immunization programs through the NSDI when this forum is in place;
- Encourage for global health initiatives, such as the HDC[rr] and the The Global Partnership Sustainable Development Data[ss] to establish a working group on geospatial data and technologies for health;
- Develop more marketing material on the benefits of using geospatial data and technologies in the health sector in general and for immunization programs in particular.

In view of the above, it is recommended for the immunization community to use the present guidance and the process-based framework it contains as tools to strengthen the use of geospatial data and technologies in countries. In addition, it is also suggested that decision-makers and managers consider a number of more specific recommendations that resulted from the technical meeting "Improving Immunization Coverage and Reducing Inequities: Use of GIS in Immunization Programs" (New York, 25-26 October 2016), which are listed in Appendix A.

[rr] https://www.healthdatacollaborative.org/
[ss] www.data4sdg.org

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Appendix A. Recommendations from the technical meeting "Improving Immunization Coverage and Reducing Inequities: Use of GIS in Immunization Programs" (New York, 25-26 October 2016)

The following recommendations were compiled as part of a global consultation of GIS and immunization experts and country representative convened during the technical meeting "Improving Immunization Coverage and Reducing Inequities: Use of GIS in Immunization Programs", which took place at UNICEF Headquarters, New York City, on 25-26 October 2016.

- Government leadership and involvement in geospatial data collection, management, and updating should be promoted: Active engagement of government from the early stages of projects, as well as direct investment of government in providing the human, technical and financial resources for GIS activities, was demonstrated to increase local capacity and improve use of geospatial data and mapping products, as well as reducing external investment. It was suggested that a successful strategy to improve government engagement and reduce investment from external partners is to pursue partnerships between government and other local stakeholders, including universities, national statistics offices, and the private sector.
- Establishment of national master list of health facilities (or Master Facility List – MFL) including geolocation information should be prioritized: An authoritative, complete and up-to-date listing of all active facilities (including private and public) is a crucial component of the planning, monitoring and analysis of immunization delivery and other programs, allowing accurate session plans based on geographic catchment areas, accurate analysis of accessibility to health services and therefore more efficient allocation of resources relative to target population. Interoperability of MFL with other master lists relevant to immunization (children, communities/settlements, CHW, pregnant women and so on...) based on common data standards, unique electronic identification and the possibility to integrate them in a GIS to benefit from its functionalities will allow leveraging geography as the linking factor between components of the health system.
- Support countries in the development of geospatial databases: Accurate, complete and up-to-date geospatial database crucial to support mapping, analysis and visualization of immunization programs, such as administrative divisions, transportation networks, terrain elevation, etc., should be available and institutional mechanisms for updating in place.
- Bottom-up, participatory mapping approaches should be pursued: Utilization of local workforce for mapping activities has the multiple benefits to reduce the cost of data collection and increase local capacity for geospatial data collection and maintenance, resulting in improved sustainability of the acquisition, maintenance and use of maps and geospatial datasets. Adequate communication of the long-term benefits of the integration of GIS to local government, program managers, and health workforce was also suggested as an important practice to ensure participation and absorption of the new practices.
- A more holistic and systemic approach to immunization program strengthening should be promoted: The potential of geography for cross-cutting data integration should be leveraged by promoting and strengthening practices and platforms for data collection and sharing, as well as mechanisms for co-financing, and multi-sectoral planning. This will require improving the quality and compatibility of geospatial data, strengthening interoperability between different health-related information systems

using geocoded master lists accessible through a common geo-registry, and building centralized repositories of fundamental geospatial data and base maps of relevance across health system sectors, such as MFL, satellite images, settlements, road infrastructures etc.). Such repositories will also reduce the time lag associated with spatial data gathering and processing, improving responsiveness for decision-making.

- Capacity building activities to strengthen trust and absorption of GIS at the programmatic level should be undertaken. Investment should be directed to provide training not only on geospatial data management and GIS but also on the use of spatial products (e.g. gridded population products) and their integration with routine and administrative data for estimation of population denominators and immunization coverage. This will increase the trust in the added value of such products at the programmatic level, and provide guidance on appropriate interpretation and use of spatial products, their uncertainties, and limitations. It was suggested that the integration of GIS in curriculums of health schools and university should be part of this capacity building process.
- The potential of novel GIS technologies should be explored: Upcoming technologies with the potential to address current limitations of traditional immunization data and GIS should be promoted and funded. For example, the use of drones to improve mapping of settlements and landscape features in remote areas or security-restricted areas, and the nascent use of mobile phones geotagging and nigh time light satellite images to account for the impact of migration on population denominators, which are not currently captured by sporadic censuses.

Appendix B. Guidance Documents and Educational Material on the use of GIS for Health

GIS Fundamentals (by alphabetical order, last accessed on May 15, 2018):

- *MEASURE Evaluation*. Introduction to Data Linking Using GIS. http://www.measureevaluation.org/resources/training/materials/gis-data-linking-page
- *MEASURE Evaluation*: Spatial Data Fundamentals. http://www.measureevaluation.org/resources/training/materials/spatial-data-fundamentals-page

GIS and Public Health (by alphabetical order, last accessed on May 15, 2018):

- ***Health GeoLab Collaborative:*** Guides and other documents to improve the quality of geospatial data and the use of geospatial technologies in Public Health. https://healthgeolab.net/resources/reference-materials/
- ***Health GeoLabl collaborative:*** HIS Geo-enabling toolkit https://www.healthgeolab.net/DOCUMENTS/HIS_geo-enabling_toolkit.pdf
- ***Centers for Disease Control and Prevention:*** GIS and Public Health at CDC. www.cdc.gov/gis/gis-training.htm
- ***Global Health Learning Center:*** Geographic Approaches to Global Health. www.globalhealthlearning.org/course/geographic-approaches-global-health
- ***MEASURE Evaluation:*** GIS Techniques for M&E of HIV/AIDS and Related Programs. www.measureevaluation.org/resources/publications/ms-15-106
- *MEASURE Evaluation*: Geographic Approaches to Global Health: A Self-Directed Mini-Course www.measureevaluation.org/resources/publications/ms-12-56
- *MEASURE Evaluation*: Geospatial Analysis in Global Health M&E: A Process Guide to Monitoring and Evaluation for Informed Decision Making. www.measureevaluation.org/resources/publications/ms-14-98
- *MEASURE Evaluation*: Mapping Community-Based Global Health Programs: A Reference Guide for Community-Based Practitioners. www.measureevaluation.org/resources/publications/ms-13-76
- ***MEASURE Evaluation:*** Using Geospatial Analysis to Inform Decision Making in Targeting Health Facility-Based Programs: A Guidance Document. www.measureevaluation.org/resources/publications/ms-14-88
- ***MEASURE Evaluation:*** An Overview of Spatial Data Protocols for Family Planning Activities: Why and How to Include the "Where" in Your Data. www.measureevaluation.org/resources/publications/ms-11-41-b
- *MEASURE Evaluation*: An Overview of Spatial Data Protocols for HIV/AIDS Activities: Why and How to Include the "Where" in Your Data. www.measureevaluation.org/resources/publications/ms-11-41a
- ***MEASURE Evaluation:*** Guidelines for Data Management Standards in Routine Health Information Systems. http://pdf.usaid.gov/pdf_docs/PA00KB8N.pdf

Appendix C. GIS Analytical Functionalities Relevant to Immunization Programs

When several geospatial datasets are stored in GIS, a vast array of GIS analytical functionalities can be applied to analyse spatial patterns and relationships between multiple geospatial datasets, and to gain better insights into immunization programs. Following is a brief overview of the spatial analytical functions most relevant to the planning, monitoring and analysis of immunization programs.

<u>Measurement functions</u>: Allow the user to explore spatial characteristics of geographic entities (e.g. length, perimeter, area) and the relationship between geographic entities, such a distance between locations, a key factor in immunization service delivery.

<u>Topological functions</u>: Describe and analyse the spatial relationships between geographic objects, such as contiguity, overlap or intersection of polygons, or whether a point falls within or outside of a polygon. This can be used for example to check whether a community/settlement falls within a threshold distance from a health facility (see Figure A.1).

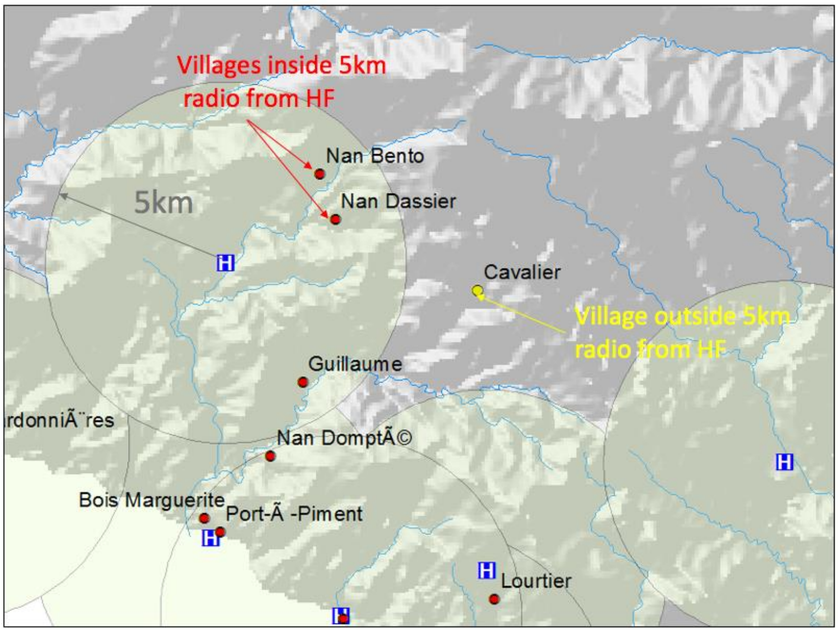

Figure A.1 An example of point-in-polygon topological functions to determine communities/settlements falling within specific distances form health services.

<u>Network and location-allocation analysis</u>: Explore relationship between geographic entities or phenomena along transportation networks, for example to identify the shortest route to a health service or to improve the location and allocation of resources along that same network. Figure A.2 shows for example the most effective routes for truck to transport vaccines between the storage site and the point of care in part of Ethiopia obtained through the use of GIS.

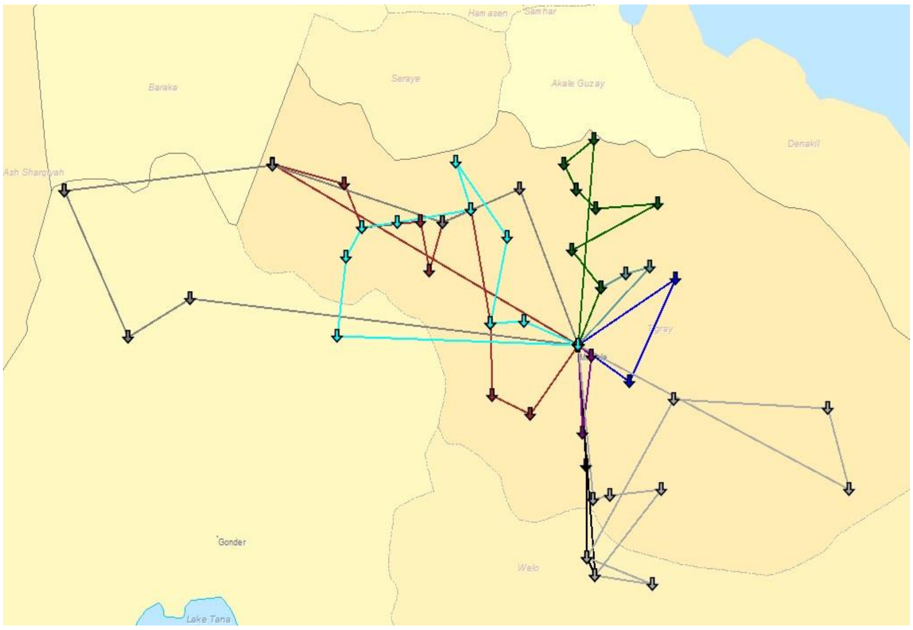

Figure A.2. Vaccines transportation routes between the Mekelle Hub to the points of care in the Woredas (districts)- Ethiopia (Courtesy of Andrew Inglis)

Pattern analysis or spatial statistics: Use statistical techniques to analyze spatial patterns, spatial concentration or clustering of phenomena, for example to determine areas of significant concentration of low vaccination coverage, or spatial correlation between vaccination coverage and population socio-economic characteristics.

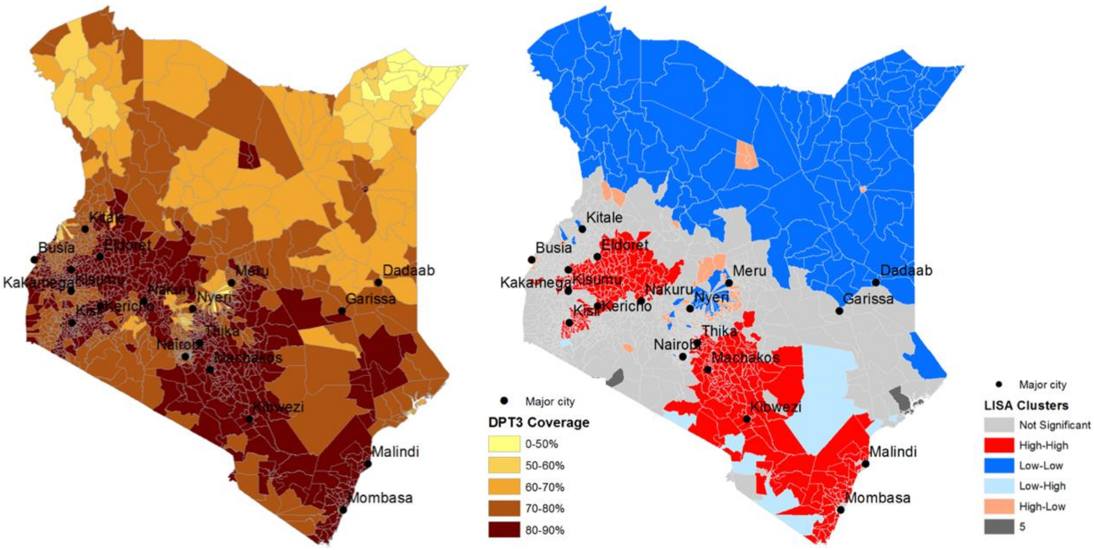

Figure A.3. An example of spatial statistic analysis to identify statistically significant clusters of high (“high-high”) and low (“low-low”) vaccination coverage in Kenya

Spatial modeling: Model the spatial interactions between multiple variables in order to gain insights into the relationships between health system, population and environment, and to predict future outcomes based on changing conditions or intervention scenarios. These methods are for example used to determine the impact of vaccination campaigns on the spatial distribution of disease prevalence (see See Figure A.4) or to model physical accessibility to health care services using more information and data than just the road network (Figure A.5).

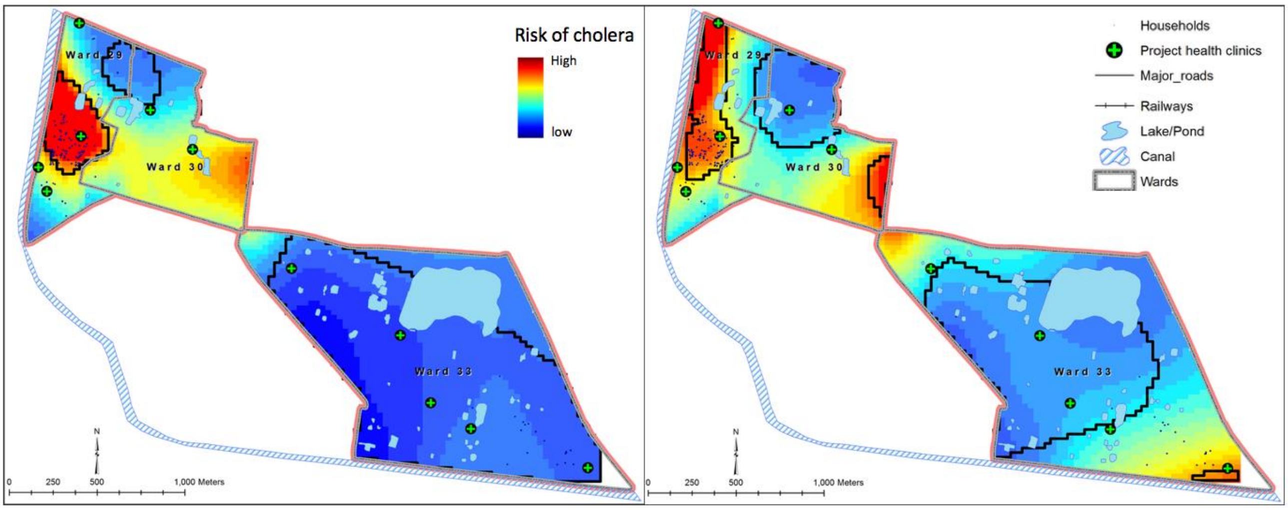

Figure A.4 An example of spatial model to map the risk of cholera based on reported cases, socio-environmental characteristics and distance from clinics in Kolkata, analyzed before (left) and after (right) a vaccination campaign (sourced from[44])

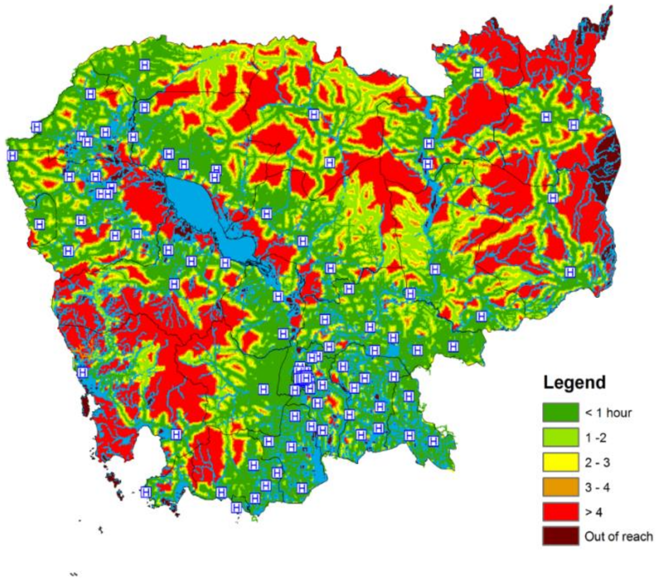

Figure A.5. An example of modelling geographic accessibility analysis to health facilities conducted using the spatial model included in AccessMod - Cambodia (sourced from WHO 2015[15])

The analytical functionalities listed above can be combined to obtain complex geospatial analytical workflow to respond to advanced queries. In the next section, we will see how these analytical capabilities can result in a better understanding of the dynamics of immunization programs.

Appendix D. Non-exhaustive list of resources supporting the integration of geospatial data and technologies in immunization programs

Geospatial Data Portals (by alphabetical order, last accessed on May 15, 2018):

- **CGIAR CSI interface:** Portal for the download of the Digital Elevation Model (DEM) created using the data collected by the Shuttle Radar Topography Mission (SRTM) http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1#download
- **Demographic and Health Surveys (DHS):** portal for the download of both statistical and geospatial data with demographic and health indocators from the DHS surveys. spatialdata.dhsprogram.com/home/
- ***GEOSS (Group of Earth Observations System of Systems):*** A global repository of earth observation datasets with diverse information for a broad range of thematics, from satellite imagery to infrastructure to health system data. www.geoportal.org/
- ***Global Administrative Area (GADM):*** a spatial database of the boundaries of the world's administrative areas (or administrative boundaries). www.gadm.org/
- **Global Land cover facility:** Web application for searching, browsing, and downloading remote sensing based data from the online holdings. http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp
- **GLobeLand30**: 30 meter resolution global Land cover layer http://www.globallandcover.com/GLC30Download/index.aspx
- ***Healthsites.io:*** A free, open, crowd-sourcing platform for the sharing of health facility location databases. healthsites.io/
- ***Humanitarian Data Exchange (HEX):*** a global repository of standardized core and thematic datasets for humanitarian applications. data.humdata.org
- **OpenAerialMap:** Open service to provide access to a commons of openly licensed imagery and map layer services. https://openaerialmap.org/
- ***OpenStreetMap:*** A free and collaborative archive of geographic data for the world. wiki.openstreetmap.org/wiki/Main_Page
- ***SEDAC (Socioeconomic Data and Applications Center):*** A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS), contains a variety of spatial products on population socio-economic characteristics. sedac.ciesin.columbia.edu/
- ***WorldPop:*** Non-profit entity providing a global repository of high spatial resolution, contemporary data on human population distributions. www.worldpop.org.uk/
- ***World Food Programme GeoNode***: A global respository of various core and thematic data for humanitarian applications. geonode.wfp.org/

Field data collection tools (by alphabetical order, last accessed on May 15, 2018):

- ***EPICollect:*** A Mobile and Web application for smartphone data collection including GPS. www.epicollect.net/
- ***Kobo Toolbox:*** A free an open source application for collection, management and visualization of geospatial data for field application. www.kobotoolbox.org/
- ***Open Data kit (ODK):*** A free and open-source set of tools which help organizations author, field, and manage mobile data collection solutions. opendatakit.org/
- **Survey123:** form centric field data collection solution developped by Esri and directly connectedf to ArcGIS Online for real time data visualization. https://survey123.arcgis.com/

Desktop GIS Software for geospatial data management, visualization and/or analysis (by alphabetical order, last accessed on May 15, 2018):

- ***AccessMod:*** A stand-alone open-source application supporting Universal Health Coverage by modelling physical accessibility to health care: http://www.accessmod.org/
- ***ESRI ArcGIS***: A proprietary, complete data management, analysis, and visualization solution, including desktop and cloud enterprise solutions. www.arcgis.com/features/index.html
- ***GRASS:*** A free and open source Geographic Information System (GIS) software suite used for geospatial data management and analysis. grass.osgeo.org
- ***QGIS:*** A Free and Open Source Geographic Information System. www.qgis.org/en/site/
- ***OpenGeoDA:*** A free software package that conducts spatial data analysis, visualization, spatial autocorrelation and spatial modeling. geodacenter.github.io/
- ***SatScan***: A free software to perform spatial, temporal, or space-time scan statistics. www.satscan.org/
- **SAGA** (System for Automated Geoscientific Analyses): A free and open source software with strong raster handling capabilities http://www.saga-gis.org/en/
- **R:** a free software environment for statistical computing and graphics, recently expanded with GIS handling modules for other GIS softwares. https://pakillo.github.io/R-GIS-tutorial/

Online GIS Software and tools for geospatial data management, visualization and/or analysis (by alphabetical order, last accessed May 15, 2018):

- **ArcGIS Online**: A collaborative web GIS that allows you to use, create, and share maps, scenes, apps, layers, analytics, and data. https://www.arcgis.com/home/index.html
- ***Carto***: A could-based GIS platform for geospatial data analysis, visualization and web-mapping. carto.com/
- ***E2G (Excel to Google Earth) Tool***: a tool for mapping health data by administrative units from excel files without the need for a GIS software. www.cpc.unc.edu/measure/e2g
- ***Google Earth***: A virtual globe, map and geographical information program www.google.com/earth/
- ***GeoNode:*** A free and open sources web-based application and platform for developing geospatial information systems (GIS) and for deploying spatial data infrastructures (SDI). geonode.org/
- ***ResourceMap:*** A free and open sources tool that allow to collaboratively record, track and analyze resources at a glance using a live map. resourcemap.instedd.org/en
- ***MapBox***. An open source mapping platform for custom designed maps. https://www.mapbox.com/

Database management systems with a mapping interface (by alphabetical order, last accessed on May 15, 2018):

- ***EpiMap:*** EpiMap is the mapping part of Epi Info, CDC's communicative disease analysis tool. www.cdc.gov/EpiInfo/
- ***DevInfo:*** DevInfo is a database reader and administration tool which is distributed by the United Nations. It includes limited mapping capabilities to visualize development goals. www.devinfo.org
- ***DHIS2 (District Health Information System):*** DHIS 2 is the flexible, web-based open-source health information system with visualization features including GIS. www.dhis2.org/

Appendix E. HIS geo-enabling quick assessment form

Quick HIS geo-enabling assessment survey

Full Name of the respondent: ______________________________

Full name of the institution and Department: ______________________

Address: ______________________________

City/Town: ________________

State/Province: ________________

Country: ________________

Email address: ________________

Phone number: ________________

Question 1: Has the Ministry of Health defined its vision, strategy(ies) and action plan regarding the management and use of geospatial technologies to support its programs? Please check what applies

☐ The vision, strategy(ies) and action plan have been defined, they are being captured in official documents

☐ The vision, strategy(ies) and action plan have been defined but have not yet been captured in official documents

☐ The Ministry is in the process of defining its vision, needs, strategy and plan

☐ No vision, needs, strategy or plan have been defined yet

☐ Other (please specify:) ________________

Question 2: Has a governance structure been established in the MOH to handle issues pertaining to geography, geospatial data management and geospatial technologies?

☐ Yes ☐ Partially ☐ No

Can you please indicate which type of structure has been established and who are the members when applicable (board, committee, working group,...)?

Question 3: Does the MOH have staffs trained on the management and use of geospatial data and technologies in the following MOH entities ? If yes, please indicate the year when they received their last training.

			Year
Health Information System	☐ Yes	☐ No	
Planning	☐ Yes	☐ No	
Communicable diseases	☐ Yes	☐ No	
Emergency management	☐ Yes	☐ No	
Immunization	☐ Yes	☐ No	

Please indicate here any additional information you think relevant about this topic

Question 4: Has the Ministry of Health determined geospatial data and technologies related specifications, standards and protocols? Please check what applies

☐ Specifications, standards and protocols have been determined, are captured in an official document (guideline) and are aligned with the National Spatial Data Infrastructure (NSDI)

☐ Specifications, standards and protocols have been determined, are captured in an official document (guideline) but they are not aligned with the NSDI

☐ Specifications, standards and protocols have been determined but are not captured in an official document

☐ Specifications, standards and protocols are in the process of being determined

☐ Specifications, standards and protocols have not been determined yet

Please indicate here any additional information you think relevant about this topic

Question 5: Please enter "Yes", "No" or "NA" (Not applicable) in each cell of the matrix below to indicate the current status for the different core master lists (health facilities, administrative divisions, vilages, reporting divisions):

	Available (indicate the name of the government entity in charge if "Yes")	Complete	Up-to-date (Indicate the year of last update if "No")	Uniquely coded (only one coding scheme used across the MOH)	Precisely geo-referenced (latitude/Longitude)	Enforced use (Policy)
Health facilities						
Reporting divisions					NA	
Administrative divisions					NA	
Villages						

Please indicate here any additional information you think relevant about this topic:

Question 6: Which GIS software and GPS devices are being accessible? Please inidcate "NA"(not available) when necessary

	GIS sofware			GPS devices	
	ArcGIS (version)	QGIS (version)	Other (specify)	Model	Number of pieces
Health Information System					
Planning					
Communicable diseases					
Emergency management					
Immunization					

Please indicate here what technology(ies) you are missing in order to be able implementing your activities:

Question 7: Please fill each of the cell with a "Yes" or a "No" to have a better idea on the recognition and use of geospatial data and technologies in the MOH

The follwoing MOH entity...	...recognises the importance of geospatial data and technologies	...currently uses geospatial data and technologies	...uses it at its full potential	...has documented use cases
Health Information System				
Planning				
Communicable diseases				
Emergency management				
Immunization				

Question 8: Has the Ministry of Health released a policy recognizing: 1) the governance structure and technical capacity that has been established; 2) enforcing the use of the determined geospatial data specifications, standards, protocols and master lists?

☐ Yes ☐ No

Please provide here information about the policy in question if it exists or is in the process of being released

Question 9: Does the Ministry of Health have all the necessary information and/or resource to ensure the sustainability of its GIS activities?

☐ Yes ☐ No

If no, what information and/or resources are needed?

Appendix F. Additional information and documents to be collected in complement to the quick HIS geo-enabling assessment

Framework element	Information and documents to be collected
1. Vision, strategy and plan	• The spelling of the vision • The strategic and/or plan document • Information regarding the National Spatial Data Infrastructure (NSDI) in the country • Is the MoH involved in the NSDI process?
2. Governance structure	• Document describing the structure, role and mode of operation of the established governance structure • Existence of a National Spatial Data Infrastructure (NSDI) in the country
3. Technical capacity	• When did the staffs receive their last training? • What was the content of the training that they received? • Who gave the training?
4. Data specifications, standards and protocols	• Document containing the specifications, standards and protocols • Are those coming from the NSDI or aligned to it?
5. Master list and common geo-registry	• Official source for the master lists not managed by the MoH (communities/settlements and administrative divisions) • Structure of the coding schemes used in each master list • Description of the updating mechanism • When were the master lists updated for the last time • Are the master lists for the other mobile objects relevant to immunization (CHW, children or pregnant women) connected to the core and immunization specific master list through a unique identifier? • Have the unique codes and names from the master list been integrated into the different information systems maintained by the MoH? • Is a common geo-registry for the simultaneous storage, management, validation, updating and sharing of the different master lists available?
6. Geospatial technologies	• Which version of the software is being used? • Date of purchase of the GNSS enabled device. Are they functional?
7. Use cases	• Example of programs having used geospatial data and technologies for the implementation of their program
8. Policy	• The policy document itself
9. Resource for sustainability	• Any work plan and/or budget that would have been prepared by the MoH

Appendix G. Immunization program geo-enabling quick assessment form

Quick immunization program geo-enabling assessment survey

Full Name of the responden ______________________________

ull name of the institution and Departmen ______________________

Address: ______________________________

City/Town: ________________

State/Province: ________________

Country: ________________

Email address: ________________

Phone number: ________________

Question 1: Has the immunization program defined its vision, strategy(ies) and action plan regarding the management and use of geospatial technologies to support its programs? Please check what applies

☐ The vision, needs, strategy and plan have been defined and are being captured in official documents (policy, strategy, plan,...)

☐ The vision, needs, strategy and plan have been defined but have not yet been captured in official documents

☐ The program is in the process of defining its vision, needs, strategy and plan

☐ No vision, needs, strategy or plan have been defined yet

☐ Other (please specify:) ________________

Question 2: Has a governance structure been established in the immunization program to handle issues pertaining to geography, geospatial data management and geospatial technologies?

☐ Yes ☐ Partially ☐ No ☐ We are part of the MOH level structure

Can you please indicate which type of structure when applicable (board, committee, working group,...)?

Question 3: Does the immunization program have a GIS capacity (staff that have received a training on geospatial data management and GIS)?

☐ Yes ☐ No

Please briefly describe the number of skilled staff and the range of

Question 4: Has the Immunization program determined geospatial data specifications, standards and protocols? Please check what applies

- ☐ We are following the specifications, standards and protocols determined at the MOH level
- ☐ We have determined our own specifications, standards and protocols and they are captured in an official document (guideline,...)
- ☐ We have determined our own specifications, standards and protocols but they are not captured in an official document
- ☐ Specifications, standards and protocols are in the process of being determined
- ☐ Specifications, standards and protocols have not been determined yet

Comments

Question 5: Please enter "Yes" or "No" in each cell of the matrix below to indicate the current status for the different core master lists (health facilities, communities/settlements, vaccination delivery sites, vaccine storage and cold chain facilities, administrative divisions, reporting

	Same as the rest of the MOH	Complete	Up-to-date (Indicate the year of last update if "No")	Uniquely coded (only one coding scheme used across the MOH)	Precisely geo-referenced (latitude/Longitude)	Enforced use (Policy)
Health facilities						
Communities /Settlements						
Administrative divisions						
Reporting divisions						
Vaccination delivery sites						
Vaccine storage & cold chain facilities						

<u>Question 6:</u> Which GIS software is being used by the immunization program? Please select what

☐ ArcGIS

☐ QGIS

☐ None

☐ Other (please specify:) ______________________

Do you have GPS devices? ☐ Yes ☐ No

If yes, please precive their number:_____ and type(s):____________________

<u>Question 7:</u> How is GIS currently being used in the immunization program? Please select what applies

☐ Thematica mapping

☐ Spatial analysis

☐ Spatial modeling

☐ Gis is not being utilized

<u>Question 8:</u> Has the immunization program released a policy recognizing: 1) the governance structure and technical capacity that has been established; 2) enforcing the use of the determined geospatial data specifications, standards and protocols and master lists?

☐ Yes ☐ No

Comments

<u>Question 9:</u> Does the immunization program have all the necessary information and/or resource to ensure the sustainability of its GIS activities?

☐ Yes ☐ No

If no, what information and/or resources are needed?

Appendix H. Potential gaps and corresponding activities to be implemented in order to reach the geo-enabling of the HIS in general and immunization program in particular

Element of geo-enabling framework	Benchmarks	Potential identified gap	Activities to fill the gap	MOH entities to be involved in the activity		Recommended implementation scale	
				HIS unit	Immunization program	National	pilot project
1. Vision, strategy(ies) and plans	1.1 The MOH has a vision, strategy(ies), and plans regarding the management and use of geospatial data and technologies 1.2 The vision, strategy and plan of the immunization program is aligned to the MOH one	The MOH has defined its vision, needs, strategy(ies) and plan but they have not yet been captured in official documents	Support the MOH with the development of such documents	X		X	
		The MOH has not yet defined/finalized its vision, strategy(ies) and/or action plan regarding the management and use of geospatial data and technologies in health	Use the support of the immunization program to help the MOH with the definition and documentation of this vision, strategy(ies) and plan in concordance with the NSDI if in place	X	X		X
		The Immunization program has defined its vision, strategy(ies) and plan regarding the use of geospatial data and technologies but they are not aligned to MOH's	Support the alignment with the MOH vision, strategy(ies) and plan		X	X	
		The Immunization program has not yet defined its vision regarding the use of geospatial data and technologies	Support the immunization program with the development of such documents and ensure their alignment with MOH's		X		X
2. Governance structure	2.1. The MOH has established a governance structure to handle issues pertaining to geography, geospatial data management and geospatial technologies 2.2. All the program, including immunization, as well as the development partners using geospatial data and technologies, are involved in this structure 2.3 The MOH is on board of the National Spatial Data Infrastructure (NSDI)	The MOH has established a governance structure but not all the immunization stakeholders are not on board	Advocate for the immunization stakeholders to be on board of the established governance structure	X	X	X	
		The MOH has not yet established a governance structure to handle issues pertaining to the management of geospatial data and technologies	Use the support to the immunization program to support the establishment of such governance structure at the MOH level	X	X		X
		The country does not yet have a NSDI	Use immunization as an example that could support the establishment of a NSDI in the country	X	X		X
		A NSDI is in place but the MOH is not yet involved	Advocate for the MOH to be on board of the NSDI	X		X	

Element of geo-enabling framework	Benchmarks	Potential identified gap	Activities to fill the gap	MOH entities to be involved in the activity		Recommended implementation scale	
				HIS unit	Immunization program	National	pilot project
3. Technical capacity	3.1. The MOH has a central level geospatial data management unit with enough technical capacity: a) ensure guardianship over the defined guidelines, standards and protocols; b) support the development, maintenance, regular update and sharing of the master lists for the geographic objects core to public health and immunization ; c) support the implementation of the guidelines, standards, protocols and registries in all the health programs and information systems; d) providing GIS services to HIS unit and beyond if needed.	There is no central level unit within the MOH with capacity for the management and use of geospatial data and technologies	Use the support to the immunization program to start developing such capacity within the MOH		X		X
		The technical capacity of the central unit is not sufficient to support its mandate	Look at other potential local (universities for example)and regional (see Section 1.4.2) resources that could support the MOH with the strengthening of its technical capacity	X	X	X	X
		There is some capacity for the management and use of geospatial data and technologies within the MOH but none within the immunization program	Build on the already existing capacity to develop the GIS capacity of the immunization program as well as strengthen the core capacities at the MOH level in such a way that it could be self sustained.	X	X		X
	3.2. The immunization program has access to enough technical capacity and expertise for immunization specific geospatial data collection, extraction, management, analysis, and visualization	Technical capacity exists in both the central unit and the immunization program but they are disconnected	Promote for the different entities to collaborate in order to avoid duplication of efforts and ensure for the same geography to be used across programs	x	x	x	
4. Data specifications, standards and protocols	4.1. A NSDI is established in the country 4.2. The MOH is involved in the National Spatial Data Infrastructure (NSDI) 4.3. Data specification, standards and protocols have been defined as part of the NSDI and the MOH is already using them across all the programs, including immunization	Data specifications, standards and protocols defined as part of the NSDI but not implemented within the health sector	Support the transfer of the defined data specifications, standards and protocols from the NSDI to the health sector	X		X	
		There is no NSDI in place and the MOH has not yet defined any data specifications, standards nor protocols	Use the support to the immunization program to support the definition and documentation of data specifications, standards and protocols	X			X
		Data specifications, standards and protocols have been defined by the MOH but are not yet captured in an official document	Use the support to the immunization program to review the specifications, standards and protocols and support the MOH by documenting them (guidelines)	X	X	X	
		Data specifications, standards and protocols have been defined at the MOH level (HIS) but these are not yet being used by the immunization program	Support the use of data specifications, standards and protocols defined at the MOH level within the immunization program	X	X		X

Element of geo-enabling framework	Benchmarks	Potential identified gap	Activities to fill the gap	MOH entities to be involved in the activity		Recommended implementation scale	
				HIS unit	Immunization program	National	pilot project
5. Master lists and common geo-registry	5.1. The MOH has a complete, up-to-date, uniquely coded and geo-referenced master list of health facilities, vaccination delivery sites and vaccine storage and cold chain facilities (if located outside health facilities). These master lists are accessible through a common geo-regsitry. An updating mechanism is in place and the master lists are regularly updated taking changes in administrative and reporting divisions into account 5.2. If reporting divisions are being used by the MOH, a complete, up-to-date and uniquely coded master list is available for these divisions. An updated shapefile containing the boundaries of these divisions is available 5.3. The government maintains and regularly updates both an administrative divisions and communities/settlements master list. An updated shapefile containing the boundaries of these administrative divisions and one containing the location of all the communities/settlements are available. 5.4. The other master lists key to immunization (CHW, children or pregnant women) are connected to master lists for the corresponding geographic objects through the use of the unique identifiers and this to ensure that the information they contain can also be plotted on a map 5.5. All the above registries, and especially their officially recognized codes, are being integrated in all the information systems and used during data collection, reporting and monitoring across all programs including the immunization one (in the immunization registry for example)	The MOH does not have any health facility, vaccination delivery sites and/or vaccines storage and col chain facility master list	Use the support to the immunization program to start the development of the master lists		X		X
			Use of bottom-up, participatory mapping approaches and maximum involvement of local workforce at the local, regional and national levels, to reduce cost of data collection, improve sustainability and increase local capacity	X	X	X	
		The MOH has a health facility, vaccination delivery sites and/or vaccines storage and cold chain facility master lists but they are incomplete, do not contain a precise location for all the facilities and/or have not been updated for several years	Use the support to the immunization program to try completing and updating the master lists as much as possible, at least for the facilities involved in the immunization program as well as put an updating mechanism in place	X	X	X	
		No coding system has been developed for the different master lists or the one being used is not meaningless (e.g. include the code of the administrative divisions)	Use the support to the immunization program to propose a coding scheme or the revision of the one that is being used	X	X		X
		When it applies, the MOH does not have a complete, up-dated and uniquely coded master list of reporting divisions and/or the most updated version of the boundaries for these divisions is not available	Use the support to the immunization program to improve the reporting divisions master list as well as the shapefile containing their boundaries if needed as well as the establishment of an updating mechanism for both	X		X	
		The administrative divisions and communities/settlements master lists are either incomplete, out-of-date, not uniquely coded, not accessible and/or their associated geographies not complete or up-to-date	Promote collaboration between the MOH and the concerned governmental agencies	X		X	
			Strengthen data sharing and partnership between data producers and users including government, universities, national statistic offices and private sector	X		X	
			Promote open data policies and initiatives	X		X	
		The other master lists key to immunization (CHW, children or pregnant women) are not connected to the master lists for the corresponding geographic objects	Support the connection between the CHW and children (or pregnant women) master lists with the master list for the corresponding geographic object through the integration of the unique identifier		X		X
		The MOH does not have acommon geo-registry in place for the simulteanous hosting, management, updating and sharing of the master lists	Identify if a platform already used by the MOH could serve as common geo-registry by fullfilling the requirements from the guidance on this subject (Ebener et al., 2017)	X		X	
		The official master lists and their coding schemes are not integrated in all the information system within the health sector, including the immunization one	Promote for the integration of these master lists across all the information systems starting with the immunization one	X	X	X	

Element of geo-enabling framework	Benchmarks	Potential identified gap	Activities to fill the gap	MOH entities to be involved in the activity		Recommended implementation scale	
				HIS unit	Immunization program	National	pilot project
6. Availability of geospatial technologies	6.1. The central level geospatial data management and technologies unit has access to the necessary geospatial technologies (GNSS, GIS) to support its mandate	The MOH central unit does not have access to the necessary geospatial technologies to support its mandate	Start by equipping the immunization program with the appropriate technology and use this as a way for the MOH		X		X
	6.2. The immunization program has access to the necessary geospatial technology to support its activities		Take advantage of already established public-private partnership to facilitate access to geospatial technologies	X	X	X	X
		The MOH central unit has access to some geospatial technology but the immunization program does not have the technology it needs	Support the equipment of the immunization program with the appropriate geospatial technology(ies)		X	X	
7. Use of geospatial technologies	7.1. Geospatial data and technologies are recognized as being important and are being used to support the implementation of the health programs, including immunization, towards reaching SDG 3 and improving Universal Health Coverage in countries	The MOH does not recognize the importance of geospatial data and/or technologies	Use the support to the immunization program to promote and demonstrate the benefits of using geospatial data and technologies in the health sector	X	X		X
		The person in charge of the immunization program does not recognize the importance of geospatial data and/or technologies	Raise awareness of the immunization program regarding its benefits and implement a pilot project to demonstrate them		X		X
			Ensure government leadership, involvement and direct investment in geospatial data collection, management, updating, sharing and use for immunization programs		X		X
		The importance of geospatial data and/or technologies is recognized but they are not being used at their full potential across program, the immunization program in particular	Support the participation of Ministries of Health in programs involving use of GIS for health/immunization sector		X	X	
			Promote the use of geospatial data and technologies in the immunization program		X		X
		The non-health geospatial data needed by the immunization program is not available or innacessible	Support the implementation of activities similar to those reported for the lack of master list for the core and immunization specific master lists	X	X		X
		Geospatial data and technologies are being used within the MOH but the use cases have not yet been documented	Support the documentation of the use cases through simple two-pagers documents	X	X	X	X

Element of geo-enabling framework	Benchmarks	Potential identified gap	Activities to fill the gap	MOH entities to be involved in the activity		Recommended implementation scale	
				HIS unit	Immunization program	National	pilot project
8. Policy	8.1. A policy enforcing the following has been released: a) the mandate over the guardianship on geospatial data specifications, standards and protocols as well as over the development, maintenance, update and sharing of master lists for the geographic objects core to public health through the use of a common geo-registry; b) the use of the developed guidelines, standards, protocols and master lists by all the stakeholders in the health sector.	The MOH does not have such policy in place	Use the support to the immunization program to support the development of such a policy	X	X	X	
			Encourage policy development toward strengthening digital health infrastructure	X		X	
			Promote sharing of experiences and lessons from countries with more developed geospatial policy framework	X		X	
	8.2. The immunization program is complying to this policy	The MOH have such policy but the immunization program is not complying to it	Advocate for the immunization program to comply to the policy		X	X	
9. Resource for sustainability	9.1. The MOH and the immunization programs have the necessary human and financial resources to ensure the sustainability of their geospatial data and technologies related activities	The MOH does not have the necessary resources to sustain its activities	Use the support to the immunization program as a demonstration of the benefit for the MOH to sustain resources for its activities on the long term	X		X	
		The immunization program does not have the necessary resources to sustain its activities	Encourage the immunization program to include resources for geospatial data and technologies in their regular budget		X	X	
			Support resource mobilization for the immunization program based on a clear plan, timeline and budget		X		X

Appendix I. Item to be consider when estimating the cost for the geospatial related activities listed in the work plan

Activity	Item to be included in the costing
Geospatial data management	• Data manager/GIS technician salary as well as continuous education and participation to conference and training • Regular update of the master lists for the geographic objects core to public health and immunization and their associated geography • Availability of a common geo-registry for the simultaneous hosting, management, updating and sharing of the master lists
Equipment/software	• GIS software and MS Excel • GNSS enabled devices • Laptop matching the minimum requirements of the GIS software being used and having enough hard disk capacity to store geospatial data (1 TB recommended) • Separated large screen and external keyboard to facilitate the work of the technician and extend the life of the laptop • Shared drive or enterprise geospatial server solution for data and product storage when having several GIS technicians • Internet connection with a good bandwidth
Training on geospatial data management and/or technologies	• Equipment used during the training (GNSS enabled devices, laptop with the GIS software) • Good internet access in case some web based tools and/or data are being used • Facilitator
Field data collection	• Pilot study for testing data collection • Field work planning and monitoring (visits and surveys) • Field data acquisition software • Salary for data collectors • GIS expert (training and supervision) • Workshops and materials for training in field data collection
Data extraction	• Purchase of satellite images or topographic maps • Working time to digitize features from base maps (satellite images, topographic maps,...)

Appendix J. Generic Terms of Reference (TOR) for the position of geospatial data manager/GIS technician

1. Background

The Ministry of Health (MoH) has embarked in a process aiming at geo-enabling its Health Information System (HIS) in order for the all Ministry to share the same geography and therefore benefit from the visualization and analytical power that GIS technology offers.

In this context, the MOH is looking for a data manager/GIS technician in order to be in the position to provide technical support in the areas of geospatial data management and GIS services during the geo-enabling process.

2. Main responsibilities

The main responsibilities of the incumbent will be to provide technical support in the areas of geospatial data management and GIS services in line with the guidelines, standards, and protocols identified/defined as part of the activities of the TWG on geospatial data management and GIS services.

3. Description of duties

Working under the supervision of head of the MoH HIS unit and in close collaboration with the TWG Members, the incumbent will be in charge of:

- Providing geospatial data management and GIS technical support to the Department of Public Health in a first phase and then to the entire MoH;
- Developing, maintaining, updating and sharing the master lists for the geographic objects core to public health (health facilities, communities/settlements and administrative divisions);
- Supporting the definition of guidelines, standards and protocols aiming at improving the availability, quality (completeness, uniqueness, timeliness, validity, accuracy and consistency) and accessibility of geospatial data;
- Supporting the implementation of the guidelines, standards, protocols and master lists in all the information systems across the MoH;
- Generating GIS based data products to support decision making.

4. Expected deliverables

- Authoritative, standardized, complete, up-to-date and uniquely coded master lists of health facilities, communities/settlements and administrative divisions in the country;
- Guidelines, standards and protocols endorsed by the TWG on geospatial data management and GIS;
- Geo-enable Health Information System (HIS);
- Data products (table, graphs and maps) as per the established SOPs

5. Required qualifications

a. Education:

- University degree with a background in data management and/or GIS or enough professional experience in data management and/or the use of GIS to be considered as equivalent;
- Background in public health

b. Skills:

- Good knowledge in the use of ArcView, ArcGIS or other GIS software as well as MS Office suite,
- Demonstrable skills in relation to data standardization and data management;
- Ability to work harmoniously as part of a team.

c. Experience:

- At least one experience working in a GIS related project;
- Experience in the area of Public Health would be seen as an advantage;

d. Languages:

- National language: Proficient
- English would be seen as an advantage