Ananya GIS: Enhancing Health Service Delivery with GIS Mapping in Bihar, India

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ABSTRACT
The scale, complexity, pace, emphasis on information dissemination and monitoring requirements of the Bill & Melinda Gates Foundation's Ananya program to improve maternal and child health and reduce infectious diseases in Bihar, India, made it imperative that information management be integrated and automated in a way that reports data geographically for diverse audiences. In response to this need, a GIS application was developed to spatially associate and depict public and program-specific information to support planning, analysis, and decision making. Development and implementation of the Ananya GIS has followed a participatory and phased approach. Ananya's employment of GIS indicates the tremendous potential that GIS technology holds for upgrading public health service management, delivery, and transparency.

1. Introduction

Bihar is one of India's largest and poorest states. It faces several challenges related to maternal, newborn, and child health. The state accounts for about 10% of all births in India every year, but suffers 12% of the country's maternal and newborn deaths (Annual Health Survey, 2010-2011). As many as 42% of Bihar's approximately 15 million children under the age of five are underweight (Naandi Foundation, 2011). Every year there are 3.6 million cases of childhood pneumonia in the state (Unicef, 2013). While Bihar's per capita income has increased three-fold since 2004-05, it still remains the lowest among all Indian states and is less than half the national average (Government of Bihar, 2012). Despite recent improvements in public health resources, there are significant shortfalls in the number of health centers as well as staff to support health services. Encouraged by the improvements already taking place, and aware of the needs that remain, the Government of Bihar seized a significant opportunity for progress in health and development. In May 2010, the Government of Bihar entered into a five-year partnership with the Bill & Melinda Gates Foundation to accelerate progress towards the state's ambitious health goals.Through a package of grants, called "Ananya" (meaning unique), the Gates Foundation agreed to support the state's aims to reduce child mortality, improve maternal health, and reduce infectious diseases, namely diarrhea, pneumonia, tuberculosis, and visceral leishmaniasis Bihar.

The Ananya program brings together a large gamut of players, including the state's Department of Health and Family Welfare; the Gates Foundation; and ten partner organizations among several other stakeholders, to implement eight projects, initially in eight districts (Begusarai, Gopalganj, Khagaria, East Champaran, West Champaran, Samastipur, Patna, and Saharsa) and eventually across the state. The size, complexity, and pace of the program present an ideal opportunity to employ Geographic Information Systems (GIS) to promote maternal, child, and integrated health services in Bihar. (Visit www.ananya.org.in).

1.1 Benefits of GIS inPublic Health

Given the stark inequalities in access to and utilization of maternal healthcare services in India (Mohanty and Pathak, 2009), GIS was considered an appropriate technology to empower the program's diverse audiences with local knowledge and public health skills (Fisher and Myers, 2011) through dissemination of information and analyses of public health and intervention data (Tanser, 2006). Modern GIS technology allows efficient integration, visualization, and utilization of information that can inform decisions affecting child, maternal, and public healthcare. By classifying its applications, health GIS systems are typically categorized in two distinct areas: epidemiology and healthcare services (Gatrelland Senior, 1999, Kamel et al., 2001 and

Vanmeulebrouk et al., 2008). Epidemiology is an area where traditional analytical tools are employed more extensively. Healthcare is an area where hospital and clinic placement and accessibility to services contribute to the health of people. The Ananya GIS was motivated by the application of GIS technology to both areas (i.e., epidemiological analyses and strengthening healthcare services).

1.2 Origins of the Ananya GIS

Consultations with key stakeholders revealed two types of needs: *i*) dynamic mapping tools with information about health facilities, geographic proximity, and directional information; and *ii*) analytical tools with strong customization and visualization capabilities. Diverse audiences, including the program's implementing partners, the Government of Bihar, and the Ananya team, identified a range of opportunities for GIS to automate and integrate information management and gather and analyze geographic data quickly and efficiently to inform decision making. Data gathered during user consultations guided the design of the GIS application. The application design has been founded on three guiding principles: *i)* simplicity, *ii)* speed, and *iii)* accessibility. In order for the GIS to be of value to its many potential users possessing varying needs and expectations, internet connectivity speeds, and knowledge of and access to technology and infrastructure, it was necessary to design a GIS that embraces these principles. Health GIS applications have been extensively critiqued (Vanmeulebrouk et al., 2008) for being undemocratic (Obermeyer, 1998) and further exacerbating gaps between powerful and less empowered people through differential access to data and technology. Thus, addressing these concerns was critical to developing a participatory GIS system. A participatory GIS system is one that addresses the needs of its users by including them in its design process and remaining responsive to their needs over time (Nyerges et al., 2002 and Vanmeulebrouk et al., 2008).

1.3 The Roles of GIS in Ananya

The GIS application was designed to analyze public health and program data by using GIS's strong mapping, analysis, and presentation capabilities; shareinformation about the program's goals, activities, and intervention results with diverse stakeholders in efficient, visual, and easy-to-use formats; and demonstrate technology's relevance to the program's public health objectives. The Ananya GIS is evolving to progressively address these roles. Given the staged structure of Ananya and concomitant evolving demands of the program, it was considered appropriate to phase development of the GIS application. The program's developing MIS, growing partnerships, and expanding program activities across Bihar provided crucial guidance in prioritizing elements for integration with various phases of the GIS's development. The first and current phase primarily focuses on disseminating geo-information about Ananya. It encompasses a very basic design and geo-spatial information capabilities. In addition to displaying location-specific data (such as government and program health facilities, directions, and proximity) and data relating to key project indicators (such as infant and neonatal mortality rates), the Ananya GIS can be used to locate partner activity by district and to compare indicators across district, state, and national averages; locate healthcare facility contacts; and look up physicians and medical facilities supported by the government and project partners.In its next phase, geo-tagging of specific images, videos, and other relevant state- and district-level data will be added,and a variety of interactive tools to visually display and analyze data will be incorporated for monitoring, managing the program, and supporting analyses of MIS and intervention data. The Ananya GIS will ultimately automate information sharing, analysis, and visualization of program information and data to facilitate planning, analysis, and decision making.

2. Methods

A highly customized version of Google Maps was chosen as a platform to build the Ananya GIS. Google Maps was selected because it is easily accessible and highly useable (Nivala et al., 2008). Furthermore, an online GIS is quicker and easier to update with relevant information, thereby enhancing the accuracy of its content. Primarily three programming languages—Javascript, JQuery, and PHP—were used to customize Google Maps for the Ananya GIS. The basic architecture of the Ananya GIS embraces two linked but separate tools: a map tool and an analytics tool. The map tool presents geo-information on maps specific to the program. The analytical tool analyzes and presents public health and Ananya program data to support decision making. The rationale for a GIS with two linked but separate tools is to support functionality, while remaining accessible across varied connectivity speeds. The overall design and interface of the GIS application is intended to be simple and intuitive for all user types, including those less familiar with

internet and geo-spatial technologies.The process of developing the interface of the GIS involved close collaboration with the Ananya team, monitoring experts, and partners. This demanded several meetings and discussions to plan, develop, test, and launch the first-generation GIS prototype, and to continue developing and refining enhancements to the application. Specifically, the following steps were applied in the process of developing the first-generation Ananya GIS tool:

1. Identifying the scope of the Ananya GIS and its potential contribution to the field of maternal, child, and integrated health services in Bihar
2. Tailoring the Ananya GIS tool to satisfy the needs and expectations of the program
3. Acquiring maps from Google and customizing them to the needs of the Ananya GIS
4. Obtaining state- and district-level secondary data, such as demographic data, data about primary health facilities, and contacts from various sources
5. Acquiring GPS data with the support of Ananya partners to accurately plot locations on GIS maps
6. Conducting geo-coded data verification in collaboration with Ananya partners (e.g., GPS data verification for Sky Health Centers was conducted in collaboration with World Health Partners, an Ananya partner which collects and manages this data)
7. Digitizing data to build a GIS database within a highly customized version of Google Maps
8. Examining data visualization techniques to support customized views for a GIS system
9. Testing, re-testing, and debugging the GIS application
10. Launching the Ananya GIS system

3. Results

Ananya launched the first phase of its GIS application on its website in mid-2013. In their current form, the GIS's map and analytical tools broadly fulfill the aforementioned roles of the Ananya GIS.

3.1 The Map Tool

The map tool is designed to manage and share geographic information relevant to health services supported by the government and the Ananya program in Bihar. In its current form, the Ananya map tool primarily focuses on three kinds of geo-information: *i*) display of location-specific data, such as government and partner health facilities and information relating to projects and partner activities by state and district (Figure 1); *ii*) proximity analysis to locate healthcare facilities and look up physicians and medical facilities supported by the government and program partners (Figure 2); and *iii*) access to district-level factsheets that contain summary information on key health indicators, trends, demographics, health infrastructure, manpower status, and key program highlights for the state and all Ananya districts.

3.2 Design and Functionality of the Map Tool

The map displays markers for each Ananya district as well as for the state of Bihar. Selecting a marker displays a menu of options which represents geographic and partner data corresponding to the selected location. This includes the option to view more information about health and sanitation indicators, population profile, infrastructure indicators, activities led by partners, graphs highlighting key maternal and child health data, and downloadable district and state factsheets. A drop-down menu above the map allows users to directly select and view a location from the list. A pair of radio buttons located below the map present the number of Primary Health Centers (i.e., government health facilities) and Sky Health Centers (i.e., partner health facilities) corresponding to the selected location. Clicking the buttons displays markers on the map. Each marker represents a health center location. Clicking a marker displays a pop-up containing data specific to the chosen health center, including the name and number of the physician, and a directions link that allows users the option of viewing step-by-step directions, approximate distance, and estimated travel time to the health center from any point chosen on the map (Figure 2).

3.3. The Analytics Tool

The analytics tool is designed to support visualization of public and program data on key health indicators to aid decision making. The analytics tool integrates customized interactive, searchable menus to assemble geographically referenced data using *i*) color coded displays via a heat map, *ii*) charts to visualize data graphically, and *iii*) downloadable matrices designed to compare indicators across Ananya districts, the state, and national averages. The tool facilitates identification of the existence, severity, and location of disparities in critical health indicators and infrastructure.

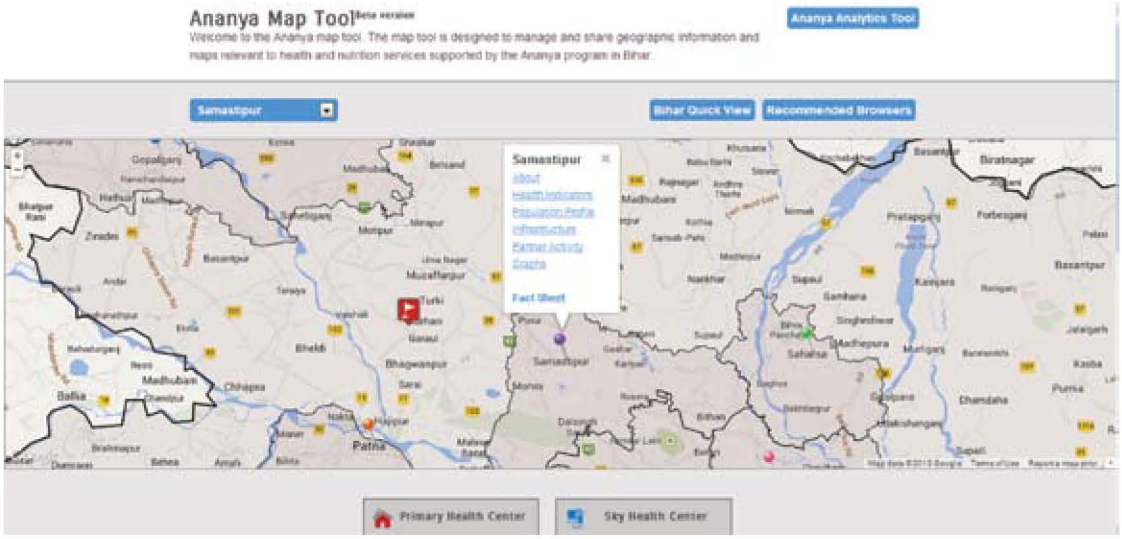

Figure 1: Ananya GIS map tool displays location specific data. © Ananya

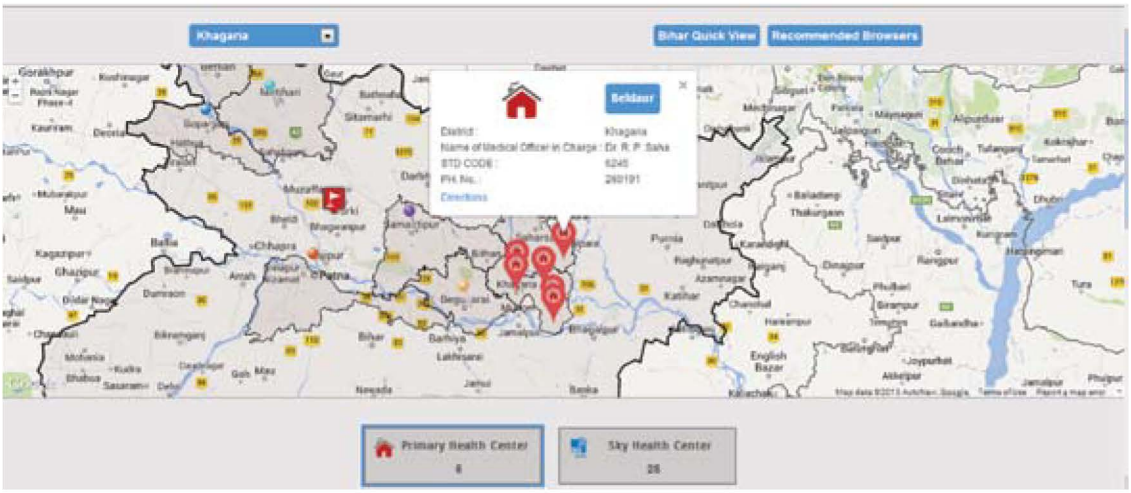

Figure 2: Ananya GIS map tool displays health center contacts and locations across districts. © Ananya

3.4 Design and Functionality of the Analytics Tool

There are three categories of public health indicators currently integrated with the tool. These include health, population profile, and infrastructure indicators. Clicking a category reveals a list of corresponding indicators. Selecting an indicator from the list activates a color legend on the heat map. Using the slider, users can select a color display. By default the map displays color-coded intensities in red. Hovering over the interval legend located at the bottom of the heat map flags Ananya districts that fall within specified intervals on the map. Hovering over districts on the map reveals data sources and indicator values for corresponding districts.Indicators may also be visualized graphically using the charting feature. Clicking a category reveals a list of indicators within that category. Selecting an indicator from the list activates a chart type menu. Users may select eithercolumn or barchart view. Hovering the cursor over a bar or column in the display reveals the district name and indicator value (Figure 3). Public health data may also be viewed using the "compare indicators" feature. Selecting "compare indicators" activates specific locations across which users can compare data, including the eight current Ananya districts, Bihar, and India. One or more locations may be selected at a time. Users may also select one or more indicators for comparison. The "generate" command reveals a comparative matrix of selected indicators and districts. The matrix may be viewed online or exported to a local drive (Figure 4).

Downloaded matrices are saved in easily accessible Excel formats. Users may alter their selection by clicking the "locations" and/or "indicators" button at anytime. Hovering the cursor over cells in a matrix reveals data sources for each cell. The "compare indicators" tool is particularly useful to quickly and easily compare indicators across districts and spot outliers. Overall, the Ananya analytics are useful for quick and efficient identification and assessment of district performance across indicators and for easy comparison of district performance against state and national averages. For example, Gopalganj District's low percentage of children suffering from acute respiratory infection who sought treatment is immediately apparent when districts are compared in a chart (Figure 3).

4. Findings

The current paper does not report a study in the traditional sense, but rather describes the process by which the Ananya GIS was designed, its features, and its purpose. The findings, though very early, are reported in this section based on user feedback on the potential value of the application and analysis of website metrics. Initial user feedback about the Ananya GIS application indicates its utility for diverse users, which include program staff and partners, Government of Bihar health officials, researchers, students, and media, who have used the GIS to obtain Ananya program information and locations, interpret data, compare health indicators across districts, and find and contact health centers.

The Ananya GIS has proven useful for quickly viewing location-specific data (such as government and program health facilities, directions, and proximity) and tracking data relating to key health indicators (such as infant and neonatal mortality rates).

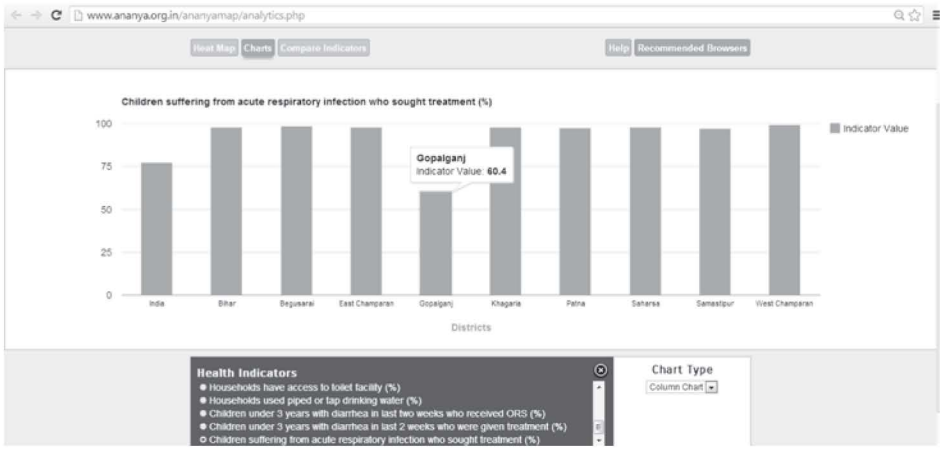

Figure 3: Ananya analytics chart visualization. © Ananya

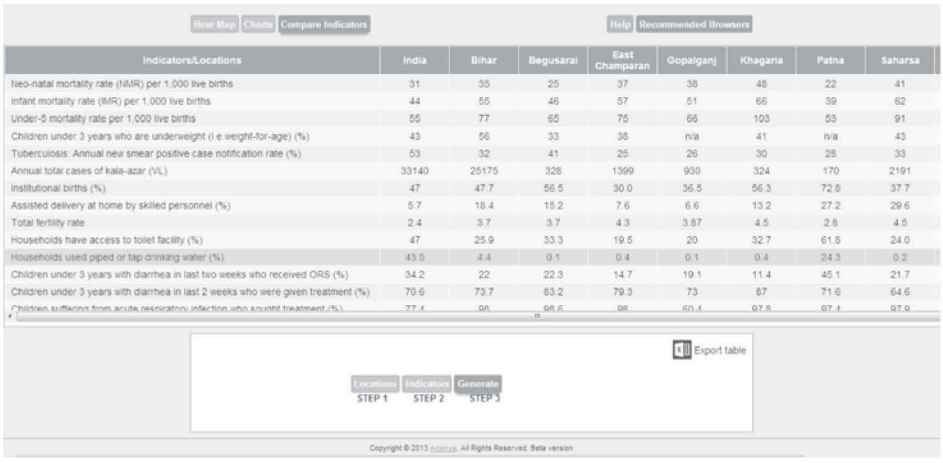

Figure 4: Ananya analytics "compare indicators" visualization. © Ananya

Additionally, the Ananya analytics tool has been useful for comparing health indicators between district, state and national averages. Analysis of Ananya website metrics reveals a near 100% increase in traffic in the month following introduction of the GIS. Visitors appear to be spending longer periods of time on the website in general, and on the GIS application in particular. Increased numbers of new visitors have viewed the site since the GIS was launched. The geographic spread of users also appears to have expanded. Greater numbers of visitors from South and East Asia, Europe, and the US have been found to be visiting the site. The number of direct visits to the website has increased three-fold since the GIS was introduced. This points to greater user knowledge about and experience with the site. However, integration of the Ananya GIS application is recent, and additional data, analyses, and experience are needed to draw concrete conclusions about the relationship between increased website traffic and introduction of the Ananya GIS. These metrics and analyses will shed light on how the GIS can support the Ananyaprogram going forward.

5. Discussion

The Ananya GIS application is designed to support the program by accelerating, simplifying, and decentralizing access to and interpretation of public health and Ananya-specific information for efficient planning, analysis, and decision making. In its first phase, the Ananya GIS has successfully integrated interactive tools for retrieving program information and visually representing public health data. In the future, the GIS will make three major contributions in Ananya's crucial quest to improve people's health and welfare in Bihar. One, it will encompass additional geo-tagged public health and Ananyaprogram-specific data (e.g., location of community health workers and services) as well as audio-visual presentations of case studies and lessons from the field. Two, it will embrace more flexible data display techniques to support visualizations of public health and program data. Enhanced tool capabilities will support analysis, including correlation and comparison of individual indicators across interventions (e.g., outreach) and program areas (e.g., maternal health). Three, going forward, the GIS will offer greater accessibility so more people can use Ananya GIS tools to learn about Ananya, track overall progress of the program, and follow developments in the field.However, the Ananya GIS still faces a number of constraints to its optimal employment to address public health in India. This is due to various data reliability, dependability, and accessibility challenges, similar to those encountered by others elsewhere (Fisher and Myers, 2011). As a variety of stakeholders are collecting various portions of health data that serve Ananya, maintaining standardization and completeness of data formats to support the GIS are issues. Uniformity of data file formats is imperative to store, collate, retrieve, and integrate geo-spatial and health data sets. Additionally, although there is a large volume of data available from clinical, epidemiological, socio-behavioral, and social science research in India, diverse data collection procedures complicate integration with geospatial applications. The base maps developed on country-wide and regional data feeds do not follow unique, uniform, and standard geo-projection formats. Additionally, many conflicts exist regarding issues in demarcation of geographic boundaries. Although primary healthcare in India is well established, digital mapping for health systems is almost nonexistent. Thus, tracking of epidemics and determining unambiguous parameters for program implementation can be challenging. If primary health centers, community health centers, and rural hospitals are properly defined in terms of digitally defined maps, it would be feasible to utilize GIS data more effectively to plan and implement disease prevention and control strategies (Mehendale and Joshua, 2013). Despite these challenges, GIS application is becoming increasingly appreciated as an important arena within public health in India. This is evident from the proliferation of GIS-focused mentorship and training programs,the dissemination of innovative geo-spatial research,interdisciplinary collaboration,and the emergence of forums devoted to debate and discussion that contribute to significant advancements in the field of geo-spatial analysis and application (Mehendale and Joshua, 2013). If developed and used effectively, Ananya's GIS application can act as a powerful evidence-based tool for early problem solving, management, and decision support for integrated health service delivery in Bihar.

6. Conclusion

The aim of the Ananya GIS is to support the program with efficient geo-information sharing and visual analyses, while demonstrating the potential of technology to improve maternal, child, and integrated health services in Bihar. The potential benefits of a participatory, internet-based, accessible GIS have been underscored in the first phase of the

Ananya GIS. The application demonstrates that it is possible to customize a familiar Google platform to build a user-friendly GIS application, containing functionality that provides diverse audiences with spatial information.The Ananya GIS features two linked but separate map and analytics tools that are the interfaces of a highly functional yet lightweight application, which is accessible across varied connectivity speeds.

The tools have been developed to spatially associate and visually depict public health and Ananya-specific information and support efficient planning, analysis, and decision making. Overall, the Ananya GIS is designed to simplify and accelerate learning about the health situation in Bihar. While a number of challenges still remain, the introduction of GIS technology in the area of public health has paved new ways for health-oriented planning, analysis, and delivery of services to develop. By integrating geospatial technology to maternal, child, and integrated health, Ananya offers to unleash the potential of GIS to promote health and empower communities in Bihar.

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