Optimizing Maternal and Child Health Data Systems in Tamil Nadu

SAIS IDEV Practicum in partnership with Athena Infonomics, Chennai, India

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Though Athena Infonomics provided invaluable support to this project, the views and opinions expressed in this paper are those of the student authors and do not necessarily reflect the official position of Athena Infonomics.

Images and photographs within this report are credited to the SAIS IDEV Practicum team unless noted otherwise.

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Executive Summary

In collaboration with Athena Infonomics, a data-analytics firm based in Chennai, India, the SAIS IDEV Practicum Team conducted an evaluation to understand the challenges related to maternal and child health (MCH) data management in Tamil Nadu. The research team collaborated with Athena Infonomics for nine months and completed a field assessment in January 2017.

Tamil Nadu is a frontrunner in MCH within India. Relative to other states, Tamil Nadu has wider public access to MCH services, higher service quality and patient satisfaction, as well as remarkably lower infant and child mortality rates. The major drivers behind the state's success are dedicated MCH staff, strong data management systems, and effective cash transfer programs.

Avenues for improvement

In the transition to a paperless health management information system (HMIS), more efficient data collection and registration are key to maintaining MCH service delivery performance. In Tamil Nadu, there are opportunities for improving data collection and registration. These improvements would ensure data accuracy/consistency, boost real-time data availability, data-registrant satisfaction, and enhance data categorization and case-tracking.

The SAIS IDEV Practicum Team conducted a review of literature pertaining to the state's health system, the status of health care in Tamil Nadu, and innovative mHealth approaches in various countries. The Team also administered interviews, observations, and focus group discussions at various levels of the health system while visiting Tamil Nadu in January. During the visit, the team met with IT experts, government officials, and policymakers to discuss the usage of health data and the potential for mHealth solutions to address front-line data collection challenges.

Key findings

- Due to a growing population, VHNs are covering increasing numbers of households. The average VHN covers a population of 7,500 within the Poonamallee health district.
- VHNs rely on 8-9 different paper-based registers to cover all their weekly activities.

- On average VHNs spend at least 9-15 hours weekly on data management.
- While computerizing data, nurses consistently face challenges with connecting to the internet, as well as Tamil Nadu's Pregnancy & Infant Cohort Monitoring & Evaluation (PICME) and Health Management Information System (HMIS) websites. It takes them an average of 1-2 hours per night to enter and upload PICME data.
- There are frequent backlogs of data verification and inadequate inspection of reports.
- There is scope to improve the usage of data already existing within the system.

Health data management app

A blueprint for a tablet-based application has been designed to enable remote and rapid MCH data registration. The app seeks to serve as a gateway between the data registrant—the VHNs—and the various health data systems. By streamlining paperless data registration, the app will enhance data accuracy and improve VHNs' service quality. The app's core functions will include offline data entry, geotagging, patient-tracking, Aadhaar-compatibility, and data-feeding from PICME to HMIS.

By focusing on data collection at the VHN level, we expect that the proposed app presents health authorities with several opportunities to build upon Tamil Nadu's progress in improving health.

- Through improved efficiency of data collection, the app will allow nurses to save as much as a full working day each week, allowing them to devote more time to their patients, improve service quality, and better patient experiences.
- Through reduced duplication and improved cross-verification capabilities, the app will reduce the scope for errors in individual case files and in aggregate statistics, enabling more rapid reporting of more reliable data.
- Improved accuracy and timeliness of data will allow for higher quality reporting outputs to be made available to policymakers. It will also create opportunities for nurses and medical officers to leverage their own data to make important decisions about their own coverage areas.

Data quality and timeliness are critical in protecting the health of high-risk antenatal mothers. By enhancing VHNs' and the health system's ability to manage and leverage data, the app aims to facilitate improved health outcomes throughout the state.

The road ahead

Moving forward, the first step will be to develop a systems requirement specification (SRS), including detailed functional requirements and use cases for the application. It is anticipated that rolling-out the proposed application will involve a 12-month pilot in 3 health districts of Tamil Nadu, followed by scaling to all districts in the subsequent year. The projected cost for the one-year pilot and three-year project lifecycle is INR 15.51 crore (US$ 2.4 million).

Acronym List

AN	Antenatal
ASHA	Accredited Social Health Activist
AW	Anganwadi Center, under Nutrition Dept.
BPL	Below Poverty Line
CHW	Community Health Workers
CRS	Catholic Relief Services
DES	Department of Economics and Statistics
DPH	Department of Public Health
DHFW	Department of Health and Family Welfare
DSW	Department of Social Welfare
GoTN	Government of Tamil Nadu
HMIS	Health Management Information System
HSA	Health surveillance assistants
HSC	Health Sub-Center, below a PHC
ICDS	Integrated Child Development Services scheme
ICT	Information & communications technology
IDEV	International Development program, within Johns Hopkins SAIS
IMR	Infant mortality rate
INR	Indian rupees (also, Rs.)
IPH	Institute of Public Health
IPHS	Institute of Public Health Standards
J-PAL	Abdul Latif Jameel Poverty Action Lab
JSY	Janani Suraksha Yojana, a program of the Govt. of India
M&E	Monitoring & evaluation
MAMA	Mobile Alliance for Maternal Action
MCH	Maternal & child health
MCTS	Mother & child tracking system
MIS	Management Information System
MMR	Maternal mortality rate
MO	Medical Officer
NRHM	National Rural Health Mission
MRMBS	Muthulakshmi Reddy Maternity Benefit Scheme, a program of the Govt. of Tamil Nadu
NCD	Non-communicable disease
NIC	National Informatics Center
OpenSRP	Open Smart Registrar Platform
PHC	Primary Health Center
PICME	Pregnancy & Infant Cohort Monitoring & Evaluation electronic system
PN	Postnatal
QR code	Quick response matrix barcode
RCH	Reproductive & child health
SAIS	Johns Hopkins University School of Advanced International Studies
SC/ST	Scheduled Caste / Scheduled Tribe
SDG	Sustainable Development Goals
SHDRC	State of Tamil Nadu Health Data Resource Center
SRS	System requirements specification
TN	Tamil Nadu
US$	U.S. dollars
VHN	Village Health Nurse

1. Introduction

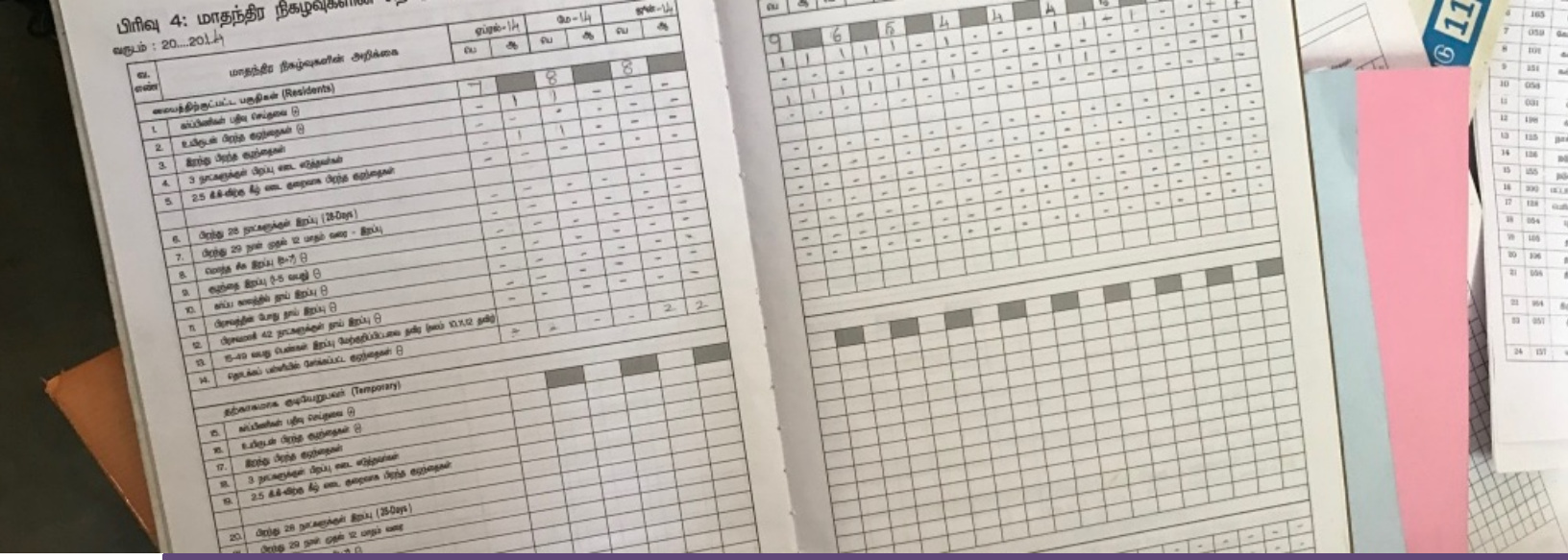
Health Information Systems, when properly managed, monitored, and employed, have the potential to transform a health system. Standardized, concise data management can significantly improve service delivery, workforce participation, information sharing, and healthcare decision-making by government officials.

Tamil Nadu has emerged as a frontrunner in both data management and healthcare delivery, with one of the highest performing health sectors in India. For the past decade, the government of Tamil Nadu has put significant resources and effort into developing a computerized Health Management Information System (HMIS) and digitizing patient records within all levels of the healthcare system. The state has pioneered the development of the Pregnancy and Infant Cohort Monitoring and Evaluation (PICME), which has impacted maternal and child healthcare (MCH) quality and efficiency. The system tracks and records mother and infant information from the date of prenatal registration through the first year of the child's life. The data derived from the system allows policymakers to assess the state's status compared to global standards and its progress towards the Sustainable Development Goals (SDGs).

To ensure decisions are informed and accurate in a data-driven world, there has been a growing emphasis placed on data quality and data accuracy. The Johns Hopkins SAIS IDEV Practicum Team, partnering with Athena Infonomics, visited Tamil Nadu, India to complete field research assessing the collection of data by Village Health Nurses (VHNs) and ground-level health staff, particularly in connection to MCH data. After extensive secondary research and a review of existing literature, the team conducted observations, interviews, and focus group discussions in Primary Health Centers (PHCs), Health Sub-Centers (HSCs), and Anganwadi Centers in Tamil Nadu's Poonamallee Health District.

This report first highlights significant secondary research findings and background information on the Tamil Nadu healthcare system and HMIS. It then outlines key primary research findings and anecdotal evidence on the challenges associated with MCH data collection for frontline health workers. Following, the report proposes a viable mHealth solution to address several of the aforementioned challenges and provides details on the main features of the application.

Justification for the proposal is supplied in the form of key benefits and impacts on MCH in Tamil Nadu. The report concludes with a statewide rollout agenda, indicating preliminary financial plans and next steps.



2. Background Research

This background research provides preliminary information regarding the current situation of maternal and child health service delivery and health information management in Tamil Nadu. The following targeted literature summary sought to inform the SAIS IDEV Practicum Team of the prevailing issues in Tamil Nadu's maternal and child health improvement agenda prior to conducting fieldwork.

2.1. Maternal and child health in Tamil Nadu

Tamil Nadu is one of the most socially and economically progressive states in India with a population of 77.9 million people and a literacy rate of 81%. Alongside the achievements in living standards, the quality of maternal and child healthcare (MCH) in Tamil Nadu makes it a frontrunner in health in India. Commitment to providing quality healthcare for all has been key to maintaining Tamil Nadu's status amongst its comparator states in India.

Table 1: Infant mortality rates (IMR), 2015-16 and maternal mortality rates (MMR), 2011-13

	IMR (per 1,000 live births)		MMR (per 100,000 live births)
	Urban	*Rural*	
Tamil Nadu	18	23	79
Maharashtra	23	24	68
Kerala	6	5	61
Andhra Pradesh	20	40	92
South Asia*	*42*		*182*
OECD*	*6*		*14*

*(Source: IMR from NFHS-4, MMR from SRS — * South Asia and OECD composite estimates from World Bank World Development Indicators)*

Village Health Nurses (VHNs) are often the primary source of antenatal and postnatal care for rural women in Tamil Nadu. They staff Health Sub-Centers (HSC) which provide local coverage under the supervision of Primary Health Centers (PHC). VHNs are the frontline health workers. Their job role includes regular visits to the villages under their jurisdiction at regular intervals in order to provide general

MCH services. These VHNs also play an instrumental role in immunizations and provide treatment for minor ailments.

PHCs are a key part of the health system. Comparing different tiers of health service provision in Tamil Nadu, Jayanthi, Suresh, and Padmanaban (2015) report the reasons behind the four-fold increase in delivery of services at PHCs since 2006: "user-friendly ambience, courteous attitude and behavior of staff, good infrastructure, availability of qualified staff, and relative absence of informal payments have contributed to increased preference for birthing care in PHCs."

Tamil Nadu has made considerable achievements in health indicators such as life expectancy at birth, infant mortality rate, total fertility rate, and maternal mortality rate.

Health providers also have strong access to needed pharmaceuticals. Chokshi et al. (2015) compared Tamil Nadu with Bihar and found that "Tamil Nadu had suppliers for 100% of the drugs on their procurement list at the end of the procurement processes in 2006, 2007 and 2008, whereas Bihar's procurement agency was only able to get suppliers for 56%, 59% and 38% of drugs during the same period". Price-wise Tamil Nadu provides the same drugs for half the price as Bihar (Chokshi et al., 2015).

Tamil Nadu has made considerable achievements in health indicators such as life expectancy at birth, infant mortality rate, total fertility rate, and maternal mortality rate. Although significant progress has been made, 23.8% of children under 5 are underweight for their age, and only 30.7% of children between 6-23 months receive an adequate diet according to 2015-2016 National Family Health Survey Statistics.

A major reason behind the decrease in maternal mortality in Tamil Nadu is the prevalence of deliveries enabled by skilled health workers (99.3% in 2015) and the use of obstetric care when needed (Padmanaban, Raman, & Mavalankar, 2009). IMR significantly declined from 30 in 2006 to 21 per 1,000 live

Box 1: ***Before the adoption of eHealth***

Before the implementation of eHealth solutions, patients waited in long queues and endured slow processes to receive care. A mother we spoke with was a patient of an urban primary health care center for over 20 years. Each time she visited the PHC, she would have her details noted down as if she were a new patient. Though her records were maintained at every visit, accessing her information was not easy as it was stored away in an old notebook filed in a back room. Therefore, every time a doctor consulted her, she narrated her medical history, with the chance of forgetting critical details that she was unaware the doctor should know. On some days, she would wait in a long queue for more than an hour before she could see a doctor. Once her visit was complete, the doctor would give her a handwritten prescription for the pharmacy. When she arrived at the pharmacy, there would be a long queue too. After she finally reached the pharmacist, s/he would glance at her prescription, look for the medicine, and sometimes return telling her that her medicine was out of stock. She would then have to return a week later to pick it up. If it was an emergency, she would have to ask the doctor for an alternative medicine and again stand in the long queue to see the doctor. This was common practice in government healthcare centers before the inclusion of ICT solutions.

births in 2016. Likewise, MMR declined from 111 in 2005 to 63 per 100,000 live births in 2015. Major factors contributing to improvements in maternal and neonatal deaths have been women's greater use of public health facilities and the institution of a conditional cash transfer program called Janani Suraksha Yojana (JSY), which provides monetary incentives for certain care practices, including institutional deliveries. In addition, for all deliveries, the Central Government of India offers a cash transfer to support newborn nutrition and substitute mothers' lost wages (Vora, Koblinsky, & Koblinsky, 2015). Despite the fact that Tamil Nadu performs relatively better than comparator states in India, Vaidyanathan, (2015) an official in the Government of Tamil Nadu, lists the following challenges to be tackled: (i) maternal anemia, (ii) imbalance among genders for the use of contraceptive measures - excessive dependence on female sterilization (89.5% of contraceptive prevalence in the state), and (iii) lack of service expansion to tribal populations and migrants.

2.2. Health information management in Tamil Nadu

A reliable and secure system that can store crucial health information is necessary to monitor the population's health status. Tamil Compared to the earlier paper-based system, Mukherjee, Karuppiah, and Babu (2014) identified higher user satisfaction levels using Tamil Nadu's electronic HMIS system.

There are four main components of the statewide HMIS system:

1. Hospital Management System (HMS), which automates all clinical activities in public health care facilities;
2. Management Information System (MIS), which is an online reporting platform for clinical and ancillary support services, national health programs, and administrative information for all public health facilities;
3. College Management System (CMS)
4. University Automation System (UAS)

A reliable and secure system that can store crucial health information is necessary to monitor population's health status.

The first two of these components are the primary clinical components, while the latter two are targeted to academic users. The introduction of Tamil Nadu's HMIS facilitated the automation of workflow processes at hospitals. Manual paper registers and records are gradually becoming electronic. Additionally, this has facilitated real-time monitoring of hospital performance. The MIS component also produces reports on public health which are sent monthly to headquarters over the internet. Although Tamil Nadu has made significant progress, there is a disconnect amongst health policymakers and program managers on how to efficiently utilize this health information for effective planning and management. This has led to underutilization of available data and decreased demand for the system.

The software for the HMIS is a centralized web application built on an open source platform (Bansal, 2011). There is a need to review and revamp the security protocols including a "Hypertext Transfer Protocol Secure" (HTTPS).

Manual paper registers and records are gradually becoming electronic. This has facilitated real-time monitoring of hospital performance.

The HMIS follows an industry standard-three tier architecture, with presentation, business logic, and data layers. (Department of Health and Family Welfare, 2012) IT coordinators are placed in each district to handle infrastructure issues, application support, and training. The HMIS also employs three administrators for managing its core servers. Another IT initiative underway is the Pregnancy and Infant Cohort Monitoring and Evaluation (PICME) program, with software under development by the National Informatics Center (NIC).

Several issues confronting the HMIS system are related to structural, procedural, and human resources. First, several structural issues are due to the fact that many institutions, departments, and programs use their own data collection systems. This results in weak coordination in health information with duplicates and gaps in data collection, reporting error, and improper management of data. Second, collection of excessive information is unwarranted and much of the information collected goes unused. The extensive use of codes also makes the information difficult to read and understand. Additionally, it increases the risk of user error, data/code inaccuracy, or missing data. Thus, planners and policymakers are unable to interpret and use the data efficiently. Third, human resource related issues arise from insufficient training of the HMIS and user error.

3. Field Findings

3.1. Primary research findings from frontline health workers

Considering the challenges outlined in the team's background research, the SAIS IDEV Practicum Team conducted a field assessment of current conditions, challenges the VHNs face with respect to MCH data registration, and avenues for improvement through potential eHealth interventions. Our field research took place from January 9 to 26, 2017 in and around Chennai, Tamil Nadu.

Data management in any health care system can be broken into three sections: data collection, data integration, and data delivery for subsequent usage. The objective of our research was to assess on-the-ground maternal and child health (MCH) data collection by frontline health workers, namely Village Health Nurses (VHNs.) The rationale behind focusing on the data collection level was the notion that its improvement would directly influence the effective integration of data and thus the usage of data. With efficient and effective collection of MCH data by frontline health workers, policymakers will receive reliable information and be able to make informed decisions to improve maternal and child health.

Through interviews, observations, and focus group discussions we sought to uncover challenges in data collection for VHNs in rural, peri-urban, and urban settings. Our initial perception was that VHNs are well integrated into their communities and appeared to have high levels of motivation and commitment to their district residents. VHNs are dedicated to the wellbeing of mothers and children in their service areas. The health system of Tamil Nadu works effectively to filter patients as needed through nurses, primary health centers, and to higher-order treatment centers for more severe ailments or involved treatments. Nevertheless, VHNs face a number of challenges in their work, several of which could be mitigated through simple technological improvements.

Our primary research findings are categorized and explained below. Box 2 provides a quick list of our key observations.

Box 2: ***Key observations in MCH data collection and registration***

1. Due to growing population, VHNs are covering increasing numbers of households.

As outlined by the IPHS guidelines, there should be one HSC for every 5,000 people. Our interviews indicate that the average VHN covers a population closer to 7,500. Through reduced population coverage, VHNs efficiency could be improved.

2. VHNs rely on 8-9 different registers to cover all their weekly activities.

While MCH data has been compressed to a single register, VHNs cover a wide array of services, each with their own paper-based data recording system. As a result, filing systems are often disorganized and incoherent, physical space in HSC is limited, and record-keeping is time-consuming. In addition, heavy registers are inconvenient for VHNs' mobility. Instead, every VHN interviewed chose to carry a personal diary to record patient data while conducting field visits.

3. Repetitive data entry is taxing and time consuming for VHNs.

For an AN check-up, VHNs enter the same patient information in six places. We estimate that VHNs spend at least 9-15 hours weekly on data entry and management. This reduces time spent providing health services to patients and frequently affects nurse's non-working hours. To economize, VHNs may sometimes make estimations, resulting in lower data quality.

4. VHNs are comfortable with paper registers, finding computer data entry cumbersome.

Almost all nurses had personal smartphones and were adept at using them, often incorporating them into their work. They reported sending images or descriptions of medical cases to MOs for assistance in quick diagnostics. They also frequently use their smartphones to access PICME and HMIS when their laptops are not connecting to the internet. However, many nurses were concerned that a smartphone is too small to enter and view patient data and that they would prefer tablets.

5. Nurses often face challenges connecting to the internet and PICME/HMIS websites.

The servers for PICME and HMIS websites lack the capacity to accommodate the number of medical staff regularly accessing them. In addition, the internet connection in PHCs, HSCs, and nurses' homes is inconsistent. As a result, VHNs reported uploading PICME data late at night or very early in the morning when server traffic is low. It takes VHNs an average of 1-2 hours per night to enter and upload data, whereas, if there are no internet connection issues, it only takes them 30 minutes.

6. There are frequent backlogs of data verification and inadequate inspection of reports.

Medical Officers are responsible for inspecting at least 30 HMIS reports at the end of each month. This laborious responsibility takes away a great deal of time from MOs primary duty of providing health services to patients.

7. There is scope to improve the usage of data already existing within the system.

Nurses see the importance of collecting and maintaining patient records and records of their own operational performance, but often do not make use of the computerized information they have entered. PHC staff and nurses tend to rely on written data, both in formal registers and informal patient notes. District-level staff have access to aggregated reports of activities, however the process of acting on data is mostly ad-hoc and, at the level of the nurses, disconnected from the electronic systems.

3.1.1. Health center facilities

Within the health district of Poonamallee where we conducted our fieldwork, there are 23 Health-Sub Centers (HSCs) each staffed with one VHN. However, only 9 HSCs have a physical office and treatment space. The rest are conducted in family homes or rely solely on field visits. Without a physical office, VHNs face inadequate storage space, difficulty in maintaining confidentiality, and several other expected challenges.

Figure 1: The collection of paper documents at a Primary Health Center near Poonamallee

3.1.2. Reliance on paper registry books

Despite the ongoing transition to a computerized, paperless health management information system, VHNs still actively utilize 8-9 registry books for different health issues and patient information. While there is only one paper registry for MCH, when combined with the registries for non-communicable diseases, school programs, immunizations, fevers, etc., the paper load becomes quite high. Storage and maintaining an organized filing system for these registries is difficult and often not a priority for VHNs. The implication of this is a disorganized system for data collection and maintenance within the HSCs. Should VHNs require specific patient information, the time required to locate such information is drastically heightened, reducing nurses' time spent with patients.

3.1.3. Technology

All VHNs were issued laptops and mobile Wi-Fi devices in 2014. They are now outdated and need upgradation. In addition, all VHNs were given government-issued SIM cards and receive 110 rupees per month for calling and messaging patients. There are desktop computers at PHCs, but they are frequently not working or are unable to connect to the internet. During observations at PHCs, our team witnessed functioning desktop computers with internet connection 25% of the time.

The majority of VHNs also reported using personal smartphones to message medical officers and fellow nurses. They reported sending images via WhatsApp to their supervising medical officer when they are in the field and unsure of a patient's health concern. Many sub districts have formed WhatsApp groups and actively communicate with their cohort through this portal.

3.1.4. Weekly activities of Village Health Nurses

Each HSC is required to cover a population of 5,000 individuals. However, as populations rise across the State, the majority of VHNs we interacted with oversaw a population of over 7,500 people. One urban HSC even had a population of 11,000. As such, in several areas additional VHNs and HSCs are needed as population grows. VHNs' services vary each day of the week as follows:

- Monday: antenatal (AN) clinic
- Tuesday: review meeting at PHC
- Wednesday: immunization distribution
- Thursday: school visits
- Friday: visits to ICDS centers and village nutrition day

The wide variation in services delivered by VHNs adds to the complexity of their jobs and the high demand on their services. This reinforces the need for a flexible data system that is capable of accommodating the wide range of VHN activities and health care services.

3.1.5. Antenatal data collection

The average VHN sees between 100 and 120 pregnant patients per year and registers roughly 3 newly pregnant women per month. VHNs meet with each mother 7-9 times throughout the pregnancy and post-pregnancy. She spends about 15-20 minutes with the patient each visit, checking vitals and recording updated health information. For each visit, the VHN writes the patients' data in 6 different locations as follows:

1. The VHN writes the patient data in her personal diary
2. She transfers the data into the patient's PICME Mother Card
3. She writes it again on her PICME Counter Card which she keeps at the HSC
4. The VHN then fills out the Reproductive & Child Health (RCH) register with the patient data
5. Each night, the VHN enters the new antenatal data for each patient into the PICME system
6. At the end of the month, the VHN uses her diary or the RCH register to categorize and sum patient information, entering the summed data into the HMIS system

As noted, a new RCH register was introduced in January 2017. While this register consolidated AN information and data collection, it does not come without its challenges. To start, each registry book is about 1-inch-thick and only records 20 pregnancies per book with 5 pages allocated to each pregnancy case. As previously stated, each VHN has roughly 120 pregnant patients per year, meaning may be actively utilizing 6 registry books at any one time.

During observations, VHNs diligently recorded data and kept up with Mother Cards, RCH registers, PICME, and HMIS data registration. However, they generally had a limited view of the importance

of data collection. Most VHNs only considered data collection to be important on a case-by-case basis, indicating that they collected data so as to follow the progress of a mother and to know if a mother was having problems. Given this individualistic view, VHNs frequently voiced confusion over the need for a computerized data registration system. They felt they were able to adequately track a mother's progress using just the paper registry and saw no need for digitization into PICME. There was little appreciation for the importance of tracking overall health of pregnant women across the state, district, or country to assess improvements or setbacks in health. Additionally, at the VHN level, there was no understanding of how the data they collected was used by higher-level decision-makers to inform policy decisions. Priorities of policymakers and VHNs converge with respect to tracking high-risk mothers, but there is a disconnect between how the data is collected and how it is being used. For this reason, it is understandable that VHNs did not see the need for computerization of MCH data. Focus group discussions did reveal an awareness of the usefulness of data to compare different areas and communities. VHNs expressed a desire to use data to assess how their communities compared to other villages, however they voiced frustration over not being able to retrieve the HMIS data to do such comparisons.

3.1.6. Immunization distribution

Every Wednesday VHNs immunize infants. To determine which children require an immunization that week, the VHN looks at the PICME system and writes down which babies need which vaccines that day, as well as the phone numbers of the mothers. The VHN will then go to her PHC, pick up the necessary immunizations, and go to Anganwadi centers within her service area to distribute. If necessary, she will call the mothers and remind them to come in with their infant. As with an AN clinic visit, the VHN will record the administration of the vaccine in 6 different locations including the AN register, Mother Card, personal diary, and PICME system. She will usually complete about 30-35 immunizations each Wednesday. -- The VHN interacts with her information systems several times, often repeating the same information: the mother's PICME card, the HSC's counter card, the immunization register, the AN register, and often in ad-hoc journal (if, say, the VHN prefers to not carry around all the heavy register books she maintains). The VHN later enters the record of the vaccination on the mother's record in the electronic PICME system and includes it as one additional vaccine provided in her own operational reporting on the HMIS registers. Each of these information system entries records essentially the same single activity, however the system is highly vertical and measures activities around programs (e.g., MCH or immunizations) rather than holistic integration of individual health.

3.1.7. Key challenges in data collection

Our primary research revealed several key challenges that inhibit reliable and efficient MCH data collection, presented in table 2, below.

Table 2: List of key challenges facing VHNs in collecting and managing MCH data

Population growth	Increasing population without corresponding growth in HSCs means that VHNs face far too heavy workloads. Each HSC is supposed to cover a population of 5,000; however, in our sample population, VHNs coverage population ranged from 7,000 to 11,000.
Burdensome data collection materials	VHNs spend roughly half of their time visiting patients in their respective towns and villages. Many VHNs voiced that laptops and registers are too heavy for them to bring into the field during these visits. Thus, they opt to bring a small personal diary, record patients' information, and then transfer information into the proper registers upon returning to the HSC. This step adds an additional location where patient information could be incorrectly recorded, interpreted, or transferred. In addition, VHNs sometimes round data collected in the field which can lead to incorrect diagnoses or treatments.
Multiplicity of data entry	The majority of nurses voiced frustration over having to enter the same data in multiple places. There was a divide, however, between nurses who want to get rid of paper registers and enter data straight into PICME and nurses who want to get rid of the computerized system and just use the registers. As perhaps expected, older VHNs were more disposed to the paper registers.
Network speed and server connection	Every VHN stressed that network speed and difficulty connecting to the PICME server were the biggest challenges for them in data management. Internet connectivity issues and server capacity issues make it very difficult for VHNs to access PICME and HMIS to enter patient data. Most VHNs stay up very late or wake up very early to enter data electronically while server and internet traffic are down – the process usually takes 1-2 hours each night. This implies loss of sleep and an increased likelihood that exhausted VHNs will make mistakes in data entry. Oftentimes VHNs use their personal smartphones to enter data if the internet is not working on their laptops. While most VHNs seemed very comfortable doing this, the mobile interface is not user friendly. The website is not responsive to screen size, which makes it more likely that data will be entered incorrectly or rounded.
Complex data summation for HMIS entry	VHNs find it challenging to sum and record data into HMIS at the end of the month. They sum the data points via the RCH registry or their personal diary, and then enter the summed numbers into HMIS. There are a lot of data points and numerous sections to fill out, which VHNs reported to be cumbersome and frustrating.

3.1.8. Challenges with PICME and HMIS data systems

VHNs face a number of problems with the PICME and HMIS websites, usually due to either misuse or misunderstanding. It is a cultural tradition for pregnant women to move from their married home with their husband to their parent's home to give birth. This may mean moving from one district to another, and away from the VHN they have been seeing for months. The VHN from the original district will often call the VHN in the new district and tell her about the patient. The VHN who is seeing the pregnant patient for the first time will then register the patient as a "visiting mother" in the PICME system despite her already having a PICME registration with the previous VHN. PICME is supposed to follow the patient wherever she goes, but in our research it was apparent that this is not done in practice. This misunderstanding and incorrect use of the PICME system increases the chances of missing important pregnancy-related information or misreporting patient data.

Within HMIS, VHN reporting errors are said to be frequent, although there are no records kept of VHNs' mistakes. According to an HMIS technology manager from Poonamallee, mistakes are generally simple typing errors. There is no automatic flagging system within HMIS, so even simple typing errors can greatly affect data. While observing a randomly selected VHN report in HMIS, we observed a data entry error that had gone unnoticed. In this instance, a VHN had reported '-7' mothers with a hemoglobin level of 12-15 g/dl. Obviously, this data point makes no sense and yet it was not corrected by the responsible medical officer.

Additionally, both PICME and HMIS are not offline-capable. If data is entered into the webpage and then the internet or server connection goes down, the VHN will have to re-enter all of the data and try to upload it again. Connection challenges such as this cause PICME data registration to take roughly 1-2 hours per night and HMIS data registration to take 1-2 hours per month. As indicated,

Box 3: ***Potential for mHealth Solutions***

In Poonamallee, I sat with a village health nurse inside a primary health center as she demonstrated how she inputs data into her smartphone rather than her computer when there are network connectivity issues. After two minutes of waiting, a 'timed-out' notice appeared on the screen of the VHN's phone. This was not surprising to her. She mentioned that high volumes of users try to access the server during the day which causes the system to slow down. For this reason, she often waits to input data at home. With the family present and children in need, she explained that it was easy to grow frustrated while trying to both input data and care for her family.

The VHN is young and tech-savvy, so her smartphone acts as an alternative device when she cannot use her computer. Her smartphone also allowed her to use apps like Facebook and YouTube daily. Even though it takes this VHN less time to enter data compared to her counterparts, she encounters other problems such as screen-size adjustment problems on her mobile screen. The website does not adjust to fit the screen of her mobile phone, requiring her to zoom in to read text and access different data points.

On the other hand, nurses that have been in this profession for 20 or more years mentioned that it was difficult at times while transitioning to and learning the system. The fact that the system is written in English added to the transitional difficulty. In addition to writing in paper registries, they now also had to put this information online, a slow process with intermittent data connections.

the biggest challenge for VHNs is slow and frequently non-existent internet connection as well as overburdened and sluggish servers for both PICME and HMIS. VHNs also complained that the PICME server logs them out after 30 minutes; if the VHN spends greater than 30 minutes filling out the webpage form, the data will not be saved and the VHN will have to log back in and start over.

Finally, several VHNs voiced distrust of the online system. They mentioned that 8 or 9 years ago patient records were deleted by the government due to server overload, and they are afraid this will happen again. For this reason, they have more trust in their physical paper registers.

3.1.9. Challenges at the Primary Health Center level

Medical Officers at PHCs are responsible for checking HMIS reports monthly, a highly time-consuming task for already overburdened doctors. A medical officer at a rural PHC indicated that she has to read over 32 reports at the end of each month. This takes her a long time and, since her patients are her first priority, she has to do it after she has finished seeing all her patients for the day. She ends up quickly skimming the reports very late at night or early in the morning rather than rigorously auditing the data.

Additionally, in order to refer a pregnant patient to the PHC, the VHN must call the PHC and tell them they are sending someone over. This act takes up the valuable time of both the VHN and the nurse or doctor at the PHC. *Automatic referrals or flagging could help PHC nurses and medical officers save a great deal of time.*

Further insights from interviews with medical officers are provided below:

- It is important for VHNs to efficiently segregate high risk pregnancies from low risk ones. VHNs can easily take care of low risk pregnant mothers, but medical officers need to get involved when there is a high risk pregnancy. For this reason, accurate and timely data collection is highly important at the PHC level.
- Inquiring about the caste of pregnant women (or anyone, for that matter) is offensive. Medical officers requested that the HMIS not require this identifying information.
- Medical officers are aware of the pin number lifetime tracking system used in general hospitals. They believe that PHCs may use this system in the future and think it would greatly improve the functionality of their health centers.

Our primary research findings illustrated high levels of motivation and commitment by VHNs to their communities. However, it is also apparent that VHNs are overworked and thus unable to sufficiently and effectively complete their duties.

As Tamil Nadu Healthcare moves towards a paperless data recording system, it was apparent that this push has yet to come to fruition at front-line with health workers such as VHNs. We observed parallel paper-based and computer-based data recording systems, which took VHNs roughly 9-15 hours to complete each week.

3.2. Uses of health data

3.2.1. Primary findings related to government use of health data

The Government of Tamil Nadu is committed to strengthening its health system and focusing on maternal and child health, access to health care, prevention and treatment of non-communicable diseases, information and communication technology (ICT) developments, and private sector engagement in health. The state has a robust health infrastructure, skilled health professionals, and significant experience managing several state-based, as well as vertical, health programs. Prior to the introduction of computerized data management systems, there were repetitive and slow paper-based processes in place. However, the introduction of ICT allowed for the integration of three levels of health care management at the village, district, and hospital level. Furthermore, the State of Tamil Nadu is starting to incorporate the national biometric registry (Aadhaar) to civil registration, which would also be used to track patient history.

Our primary research findings demonstrated that the government health officials are committed to advancing the status of health and reaching targets and goals such as the Sustainable Development Goals (SDGs). For example, Tamil Nadu is heavily committed to reducing the maternal mortality ratio (MMR) from 62 to zero. For this reason, high risk mothers are rigorously tracked at multiple levels. If a maternal death occurs, an extensive review is conducted, tracking the mother from the point of death back to when she was first registered on the PICME system to ensure lesson may be applied moving forward. Government officials will use the PICME system to access the mother's information and extrapolate any potential explanations for her death.

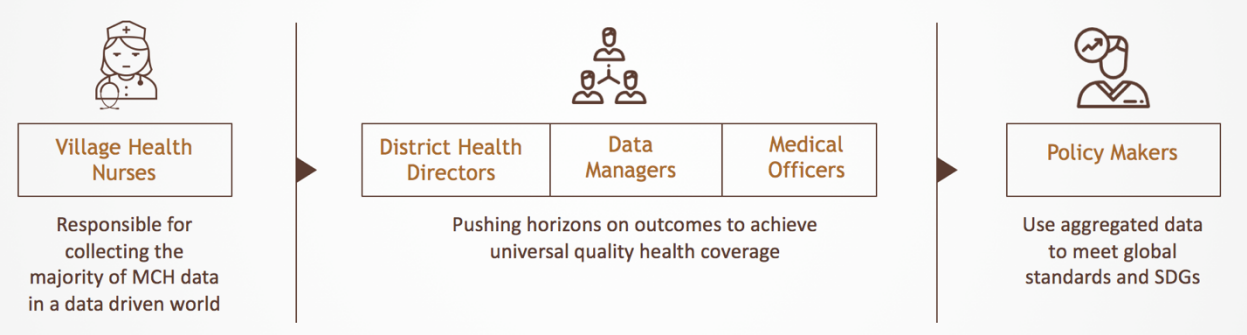


Figure 2: Work by higher-level health staff is directly influenced by data from frontline workers (Credit: R. Silva, Athena Infonomics)

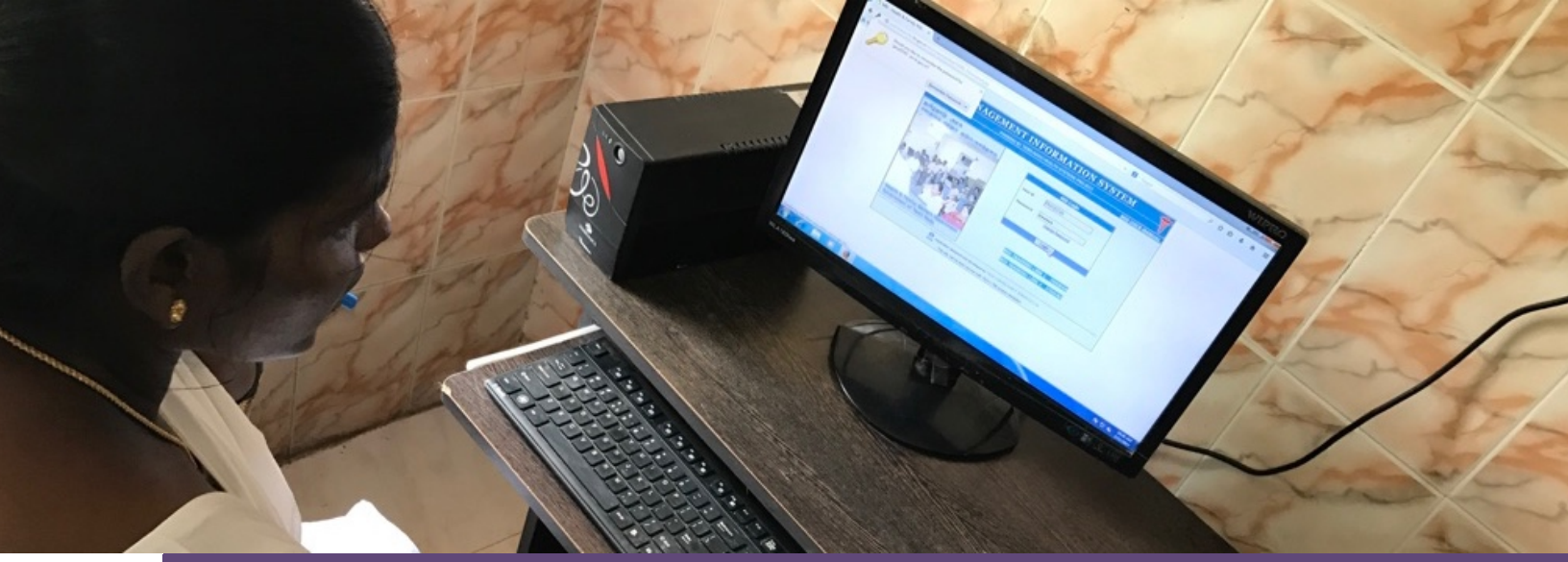
Because the HMIS is an aggregate of data collected from individual tracking systems, the team expected government officials to interact with the database and analyze total indicators from each district. It was evident that the village and district level interact with HMIS more than the state level, calculating total numbers from their villages, entering the total number from their community into

the system, and reviewing the numbers. However, state officials are more likely to access information through dashboard-style analysis, reports targeted at specific policies, and systems that generate predictive analytics to easily identify trends, anomalies, or warning signals. High-level health officials also receive daily emergency notifications through email, text message, and WhatsApp from mid-level government officials. This replaces the need for them to interact with HMIS daily. Government officials reported having less interaction with HMIS on a real-time basis because of time lags and the perception that some data take from ground-level health workers may be rounded and not accurate. Ground-level staff, outside consultants such as J-PAL, and research universities are more likely to interact with HMIS to provide policy recommendations and external research on how to efficiently allocate resources. The consultants also examine HMIS to track variation between and within districts, to identify underdevelopment, and track changes through time.

Box 4: ***Government officials' use of data***

With lives on the live, Tamil Nadu health officials know every moment is vital. Their busy schedule was apparent during a meeting with one official as he was frequently interrupted by assistants and phones calls. Every hour was critical towards achieving the SDGs or State goals. The official took us through different dash-boards that were available to him. We specifically looked at roadside accidents and were able to see how the dashboards and predictive tools were helpful for anticipating when and where accidents were more likely to happen. The official used this information to determine where to place ambulances during certain hours. In regards to MCH, officials are able to see disaggregated data by districts and identify which districts have low indicators and which are performing better than others. Although mid to senior-level officials have access to this data, aggregates or key outcomes are more likely to be reported to them rather than assessing and interpreting the data. These officials receive key alerts through WhatsApp rather than through seeing them on dashboards.

A ground-breaking measure that will soon be initiated is the linkage of the national biometric registry (Aadhaar) to civil registration, which will also be used to track patient history. It will first be implemented at the hospital level and then adopted through different health levels. This will greatly increase efficiencies when tracking patients, especially when patients relocate. With biometric capabilities, centers can identify and pull-up a patient's history through fingerprint or iris scan. This would substantially improve efficiency as a patient's information would be tied to the Aadhaar and not a number or national ID card that can easily be forgotten or lost. The biometric registry would eliminate the need to send patient information through fax, computer, or over the phone from other centers in different villages or states. It would also reduce multiple entries of patient history or loss of data. In addition, it would dramatically decrease the number of unregistered births. Currently, births at private health facilities are difficult to capture in the public system. The state has introduced some initiatives where mothers can easily register births, such as through call centers and an online self-register system. Registering mothers for the Maternity Benefit Scheme will also be easier when it is tied to Aadhaar rather than through the PICME system.



4. Health Data Management Application

Based on the fieldwork observations, the SAIS IDEV Practicum Team designed a blueprint for an offline capable tablet-based application, which will optimize MCH data management in Tamil Nadu. The proposed app seeks to enable remote and facile data registry for VHNs and will link PICME and HMIS systems. This tailored application streamlines VHNs interactions with patient information through a set of functionalities. The app's functions address the major challenges that the VHNs face in registering MCH data during their regular field visits.

Tamil Nadu is considering a wide-reaching overhaul to the current health information systems, allowing hospitals and clinics at various levels to more efficiently share data and integrate private sector providers. To complement these aims and build upon other digital health upgrades, the proposed VHN-level application will improve field-level data collection and service delivery throughout the state of Tamil Nadu. With this application, high-quality field data will be rapidly available to policymakers and administrators for monitoring and planning purposes. Additionally, information about individual cases will be more easily used by PHCs and VHNs to ensure the delivery of effective health services.

4.1. Application design and features

The app will be designed as a gateway between the VHN (data registrar) and the PICME and HMIS databases. Core functionalities are as follows:

- VHN-specific secure login credentials;
- Form-based navigation that feeds the data into PICME and HMIS databases separately;
- Offline data entry option and functionality to sync the new entries when connected to network;
- Built-in geotagging function, which records where the data was collected (even without internet connection at the moment of data entry);
- Ability to incorporate Aadhaar identification number into patient information;

- Ability to capture bar codes, QR codes, etc. for data registry;
- Ability to cache data pertaining to basic patient information such as name, address, Aadhaar number; and
- Automatically-generated notifications for VHNs as well as for mothers on a wide range of information including the regular visit schedule, medicine/vaccination availability, and "red flags" for high-risk pregnancies.

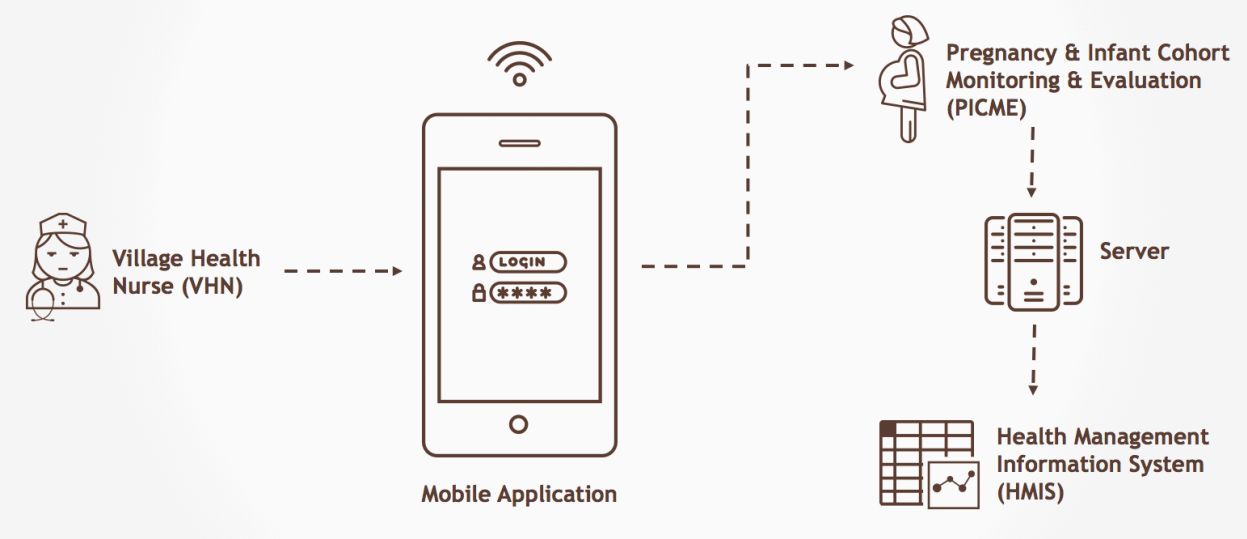


Figure 3: Basic structure of the proposed tablet-based application when used by VHNs (Credit: R. Silva, Athena Infonomics)

The App's core functions will therefore replace the VHNs' following constraints:

- carrying paper-based registers during household visits;
- computerizing the data after it is collected in the field instead of instant data entry;
- struggling with the server availability and internet connectivity while computerizing the data;
- aggregating daily data into weekly and/or monthly as requested by their supervising PHCs for HMIS statistical input purposes;
- filling the pregnant mother's card after each visit; and
- memorizing high risk pregnancies and other individual cases.

VHNs will be carrying their tablets to enter data immediately after they make home visits while they are in the village. Hence, the app does not only make data registry faster through facile form-based interface and cached data functionality but also ensures efficiency in minimizing data errors by replacing human-made calculations.

The proposed application also envisages a core functionality that PICME data feeds into HMIS through a server. This makes the MCH portion of the HMIS data to be automatically generated by the PICME data entries. This seeks to bridge the gap between community-based and facility-based data recording.

Since the proposed App is a gateway designed exclusively for VHN's MCH data entry, policy-makers' usage of existing HMIS and PICME systems will remain the same. However, this App's major contributions will be that the statistical data accuracy/consistency in HMIS will be enhanced and real-time pregnancy tracking will be improved by virtue of the enhanced PICME data.

The proposed App's user interface will be designed by taking into consideration other popular mobile applications prevalently used by the VHNs, such as WhatsApp. This seeks to optimize the user experience by ensuring the VHNs' familiarity with the App's basic functions. The specifics of how the user interaction will operationalize will be outlined in the system requirements specification (SRS), described below.

4.2. Opportunities from the proposed application

The proposed application will present health authorities with several opportunities to build upon Tamil Nadu's progress in successfully delivering data-driven health interventions. These opportunities broadly fall into three categories:

- Further improving data collection and service delivery at the level of the field health worker;
- Improving the quality of data reported in state information systems; and
- Expanding opportunities to apply the data collected to inform policy and caregiving decisions, ultimately leading to improved health outcomes.

With the proposed mobile/tablet application in comprehensive usage, we estimate that nurses' workloads on data entry would be cut from 9-15 hours weekly to approximately 3-5 hours weekly, equivalent to an entire working day.

4.2.1. Efficient data collection

The proposed app will improve the efficiency of the data collection and entry process for ground-level health workers, allowing them to dedicate more time to patients. With the proposed mobile/tablet application in comprehensive usage, we estimate that nurses' workloads on data entry would be cut from its current 9-15 hours weekly to approximately 3-5 hours weekly, equivalent to around an entire working day. These benefits can be translated into improved service quality and patient experience with shorter waiting times to see nurses.

4.2.2. Improved data quality through less duplication

The proposed application will reduce or eliminate the need for VHNs to enter data they have collected into multiple locations, whether digitally or on paper. This will substantially reduce the scope for unintentional errors, either in individual case files or in aggregate statistics. With a mobile tablet device, nurses will no longer need to carry and fill out multiple paper registers, an electronic information system, and their ad-hoc diaries. Nurses understand the importance of collecting

patient information and are committed to ensuring its accuracy, however data points are sometimes approximated for healthy-looking patients for expediency. With a more straightforward method of data entry, there will be fewer opportunities for errors and less need to improve efficiency on the fly.

In addition, the proposed application will allow for integration with various lab testing devices at PHCs to manage data that is currently collected by staff nurses or lab technicians and then reported to VHNs. With direct connection to lab test results, findings will be immediately inputted into patient case files, without technicians needing to first report them to VHNs. The app will then notify VHNs (or even the patients themselves) about the new results, and it will provide special alerts if the results are cause for concern — for instance, if they indicate a mother is in a high-risk group. These connections will provide for rapid reporting of more accurate information that can be acted upon at various levels within the health system.

4.2.3. Leveraging data for decisionmaking

The proposed application will allow all levels of the state health system to improve their use of health data, in part by better leveraging data that is already provided into the state's health information systems. Because of improved accuracy and timeliness of data collection, the app will allow for higher quality reporting outputs to be made available to staff at various levels in near-real-time. This information could include, for example, reports related to the performance of HSCs in an area, or information on a specific category of mothers, or even analysis of a specific case that is of interest. The app will also be able to provide improved inputs to the State of Tamil Nadu's Health Data Resource Center (SHDRC) Dashboards for use by state policymakers, including the ability to look at groups within district and block statistics and to look at individual or groups of cases. Policymakers and administrators will hence be able to make more use of information that is now coming from PICME and HMIS.

Additionally, we expect that the app will help nurses and medical officers to see critical information about individuals—for instance, high-risk mothers, or newborns needing immunizations—within their own coverage areas, allowing them to make appropriate responses. Some dashboard-style data will be available to local nurses as well as block- and district-level officials, allowing them to create plans and make decisions about their covered populations using data they have already created. This will ensure that data already in existence will be put to a more efficient use at the field level.

4.2.4. Enhanced data flows will improve MCH outcomes

The proposed application can contribute to improved maternal and child health outcomes through several channels. First, improved information, especially related to individual cases, will facilitate decreased maternal and infant mortality. Data quality and accuracy is key to segregate and focus on high-risk mothers. In addition, recent literature has suggested that birth complications, which can result in infant or maternal deaths, are often attributable to inadequate pregnancy tracking.

(Padmanaban, Raman, & Mavalankar, 2009) Closer surveillance of high-risk, antenatal mothers, which the app aims to facilitate, is crucial to prevent such complications. The app will be able to automatically flag high-risk mothers based on identified criteria and will be able to deliver notifications to VHNs (and potentially to mothers themselves) regarding special precautions.

Additionally, the app can be used to track post-natal families and infants' development and nutrition in ways that are currently not uniformly computerized. By bringing post-natal nutritional programs into the electronic system via VHNs, the app will help create real-time, disaggregated data on the nutritional status of children, enabling prioritization of areas for strategic planning.

Finally, by facilitating improved data analytics, the app will allow decision-makers to identify underperforming areas in Tamil Nadu and higher-burden districts, contributing to statewide convergence and more balanced growth. This will contribute to Tamil Nadu achieving the goals of the State Balanced Growth Fund (2012-2013), which is targeting a more balanced growth across all areas of the state.

4.3. Similar apps and approaches

Leveraging mobile applications and other ICT solutions in development has received a good deal of attention in recent years, especially in light of the 2016 World Development Report from the World Bank, *Digital Dividends*. (World Bank, 2016) We would also like to note the nine principles propagated by the Principles of Digital Development Working Group (see box 5; Waugaman, 2016) and recommend their integration when moving forward with the proposed application.

Box 5: ***Principles for digital development***

1. Design with the user
2. Understand the existing ecosystem
3. Design for scale
4. Build for sustainability
5. Be data driven
6. Use open standards, open data, open source, and open innovation
7. Reuse and improve
8. Address privacy and security
9. Be collaborative

Below is a brief sampling of relevant technological innovations working in the MCH space worldwide. We explored these examples both for their impacts and the process used in their development, which can be informative for the proposed approach in Tamil Nadu.

Table 3: Summary list of exemplar MCH mHealth applications

Reaching antenatal mothers	***Aponjon***, a product of the Mobile Alliance Maternal Action (MAMA) program, launched nationwide in Bangladesh in December 2012. (Haas, 2016) It provides actionable reminder messages on care practices and health visits to pregnant mothers, as well as for 'gatekeepers,' including women's partners, mothers, and mothers-in-law. The service provides both recorded content, with voice and text, and call-center based counselling to support healthy mothers and infants.

Real-time case tracking

Catholic Relief Services (CRS) Senegal piloted an mHealth system to improve diarrhea case management for children under five in rural areas. CRS partnered with over 2,000 community health workers (CHWs) to identify challenges in ensuring timely and relevant data was reported from health huts to CRS staff. Prior to the introduction of the app, data was often collected and analyzed monthly or quarterly, after which responses to spikes in incidence of disease—e.g., malaria rates—often proved ineffective. CRS and CommCare responded by developing and piloting a real-time mobile- and web-based application used by CHWs to managed child diarrhea cases. The app provided messaging to CHWs to improve service quality (i.e., downward reporting) and referrals and data to subsequent level health posts (i.e., upward reporting).

Job-aids for frontline health workers

The ***Mobile SAKHI Project*** assists frontline workers in remote data collection and provides visit reminders to improve adherence to visit schedules in Maharashtra, India. (CommCare, 2014) The CommCare application suite has also been used to provide audio files in local languages to assist in communicating certain care practices. It can also be used to communicate materials related to health behavior changes, including pregnancy spacing, maternal diet, nutritional supplementation, immunization, and appropriate infant and young child feeding practices.

Supervision of care visits

The ***ReMiND project*** (est. April 2011) included a series of components to target improved maternal, newborn, and child survival through improved coverage and frequency of visits by Accredited Social Health Activists (ASHAs) in Uttar Pradesh, India. (CRS, 2017) There are separate phone-based job-aid apps for ASHAs and their supervisors, as well as a program to improve training in interpersonal counselling skills and technical literacy for the ASHAs. CRS, in partnership with Dimagi successfully scaled the application suite to cover eight health districts and a population of 1.5 million. Content provided to ASHAs was field tested and is available offline for home visits. By improving the abilities of supervisors to monitor data coming into the system, overdue care visits decreased from an average of 10 days to 1.5 days. Overall, CRS has seen a doubling of care visits, improved frequency and quality of counseling, and improved access to antenatal care in the targeted blocks.

Data capture designed for scale

Integrated Community Case Management (iCCM) is used in hard-to-reach areas of Malawi as a complement to facility-based services. The iCCM mobile application provides several tools to front-line health surveillance assistants (HSA) who provide services to children under five. (Haas, 2016) It allows the HSAs to capture village registers, links to the logistics management system for management of drug supplies in rural clinics, and it improves supervision of HSAs throughout rural Malawi. The iCCM project is also interesting for its design process and scale. The service provider trained 6 HSAs in one district on a pilot version of the application and solicited feedback from them on its functionality and use over a period of 2 months. The Mangologic-based application running on Android platforms was then rolled out to all HSAs in that district. Next, the service provider trained Ministry of Health officials on the application and, to ensure sustainability, on how to train other HSAs to use the application. The service provider also remained in constant communication with the HSAs using the application at all phases of scale-up, largely through WhatsApp chat groups, a dedicated helpline, and scheduled project review meetings.

Inclusive design process

Henrique Shishido et al. (2014) designed a system to collect health data critical to monitoring chronic diseases called ***mHealth Data Collector*** (mHDC). The design process involved interviews with health professionals and a prototyping process to identify minimum requirements for the application. Health providers in Brazil were given tablets for using the application in a trial system. By carefully designing an attractive and intuitive mobile application and by including a data input validation system, the research team's app led to errors from handwritten notes. The authors found that the provided software was able to collect data on healthcare clients for future decisionmaking and to promote research of the existing health situation.

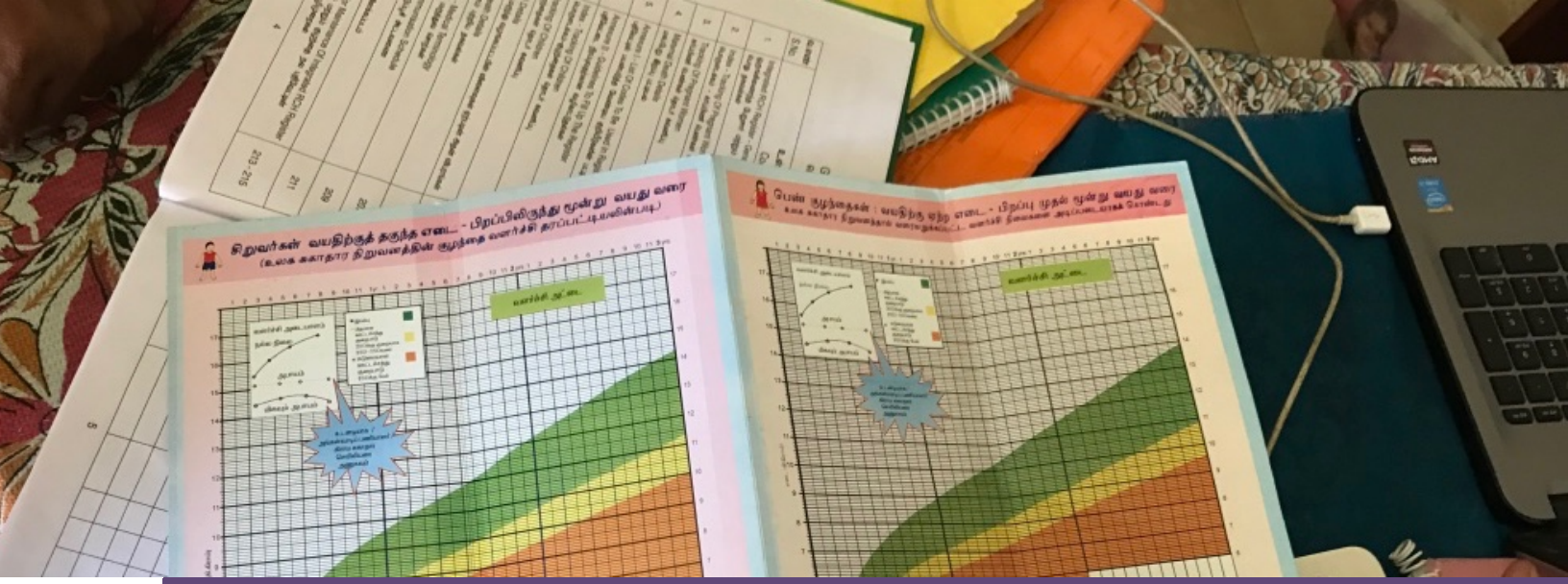
Open platforms

The ***Open Smart Registrar Platform***, OpenSRP, in Senegal is currently being piloted to become the primary platform by which frontline health workers report data to the national health systems. OpenSRP was developed with widely-deployed IT systems, including DHIS2, and can be used on any Android device. (Levine et al., 2015) OpenSRP is one of several open-source systems that can be explored to provide the basis for the proposed app.

Tracking antenatal care

RapidSMS is a phone-based technology approach being used in Rwanda to help CHWs track women's antenatal care visits, identify at-risk women, and

	help both women and health facilities with referrals. The system can provide rapid feedback between CHWs and other levels of the health system, as well as promoting contact between at-risk women and health workers at various levels. Launched by the Rwandan Ministry of Health and UNICEF in 2009, the system currently receives about 12,000 messages daily from CHWs. (Haas, 2016) The Ministry is currently exploring using RapidSMS to enhance other data-collection needs.
Broad access to health data	The Turkish ***Family Medicine Information System*** (FMIS) is a nationwide system for transferring primary care records among health practitioners and the Ministry of Health. (Dogac et al., 2014) Client applications used by providers can work online or offline to access, modify, and if necessary, sync patient data with the Ministry of Health's internet service. The offline capabilities have proven useful for providers on home visits in rural areas. Additionally, the system has allowed the Ministry to undertake performance evaluation of providers and to build a decision support system for Ministry officials to access aggregated primary care data throughout Turkey.



5. Statewide Rollout Agenda

It is anticipated that rolling-out the proposed application would involve a 12-month pilot in approximately three health districts of Tamil Nadu, followed by scaling to all districts in the subsequent year.

5.1. Pilot and scaling

The primary purposes of the pilot phase will be to determine how the app can be most effective when used by VHNs and other state health staff and to mitigate any potential problems with the application or its usage. A pilot period of 12 months is recommended to ensure that there is ample time to field the system, train staff and VHNs, and observe the app's impacts on the work of VHNs within the health system. It will also ensure that there is adequate time to identify and mitigate issues that arise before moving to scale statewide. To ensure that the pilot will be relevant for the entire state, the three districts selected should be a decent representation of the state environment, including urban and rural areas, and somewhat representative of the larger population.

5.2. Costing

Our preliminary cost model reflects the pilot year (Year 0) and a subsequent three-year project lifecycle at scale. Our overall cost estimate (present value at 7% interest rates) is INR 15.51 crore (US$ 2.4 million)[*] for the entire software and hardware lifecycle, subject to the assumptions described below. The annual breakdown is listed in figure 4.

Software development is expected to occur mostly for the pilot year, with some calibration and improvements as the program moves to scale to address issues identified by the pilot. We assume that the software will be developed in such a way that will allow it to be scaled statewide with little

[*] 1 crore is 10 million; 1 lakh is 100 thousand; exchange rate (April 2017) is approximately 65 Indian rupees (INR or Rs.) to 1 U.S. dollar (US$).

marginal cost. Nevertheless, estimates are included for routine systems maintenance throughout the life of the program. We also assume that the existing HMIS application service and backend hardware will be strengthened (and/or upgraded) by the state government — if the program will need to strengthen these systems as well, additional resources will be required.

Hardware purchases are based on the estimated number of new nurses using the application in the pilot and then in the first year, with allowances built in for device replacement needs. Tablets are assumed to cost INR 15,000 each to ensure that the purchased devices are of sufficiently high quality and durability, with adequate capabilities, storage, and batteries.

Figure 4: Estimated cost structure of developing and fielding the proposed application

	Pilot (3 districts) Year 0		Scale (TN statewide) Year 1		Year 2		Year 3	
	Units	Cost	Units	Cost	Units	Cost	Units	Cost
OpEx								
Software/hardware maintenance				Rs. 5 lakh		Rs. 5 lakh		Rs. 5 lakh
Training	6	Rs. 6 lakh	80	Rs. 80 lakh	10	Rs. 10 lak	10	Rs 10 lakh
CapEx								
Hardware: front-end	650	Rs. 97.5 lakh	10,000	Rs. 15 crore				
Application development		Rs. 40 lakh		Rs. 10 lakh				
Total		Rs. 1.44 crore		Rs. 15.95 crore		Rs. 15 lakh		Rs. 15 lakh
Total, PV (at 7%)	Rs. 15.51 crore							

5.3. Monitoring and evaluating

As a part of developing and fielding the proposed application, a robust monitoring and evaluation (M&E) framework will need to be developed and implemented. Fortunately, the efforts devoted to digital health programs worldwide in the past few years have yielded a set of recommendations, best practices, and toolkits to help implementers build upon prior experiences. (e.g., World Health Organization, 2017)

To begin, goals will need to be articulated. These are approximately as described above: to enhance service delivery and reduce VHNs' data workload; to improve the quality of reported health information; and to expand upon opportunities for leveraging data the health system creates for better outcomes. The monitoring system will need to focus on how well the technical system is working and how it is being used in the field. This will be critical in both the pilot phase, to assess impacts and identify areas for refinement, as well as in the scale-up phase, to ensure that the app is being fielded effectively throughout Tamil Nadu.

The evaluation system should focus on longer-run factors including user satisfaction (both among health system staff and service recipients), system responsiveness to needs, changes in data reporting processes and patterns, changes in health outcomes, and a cost-benefit assessment. Evaluation reports should be provided as widely as possible to allow other states to follow the example set by Tamil Nadu. Ideally, some evaluation outputs will be available to provide feedback to the program during implementation.

To guide the development of an M&E framework, an illustrative set of key performance indicators (KPIs) are listed in table 4, below.

Table 4: Illustrative KPIs for the health data management application

Category	**Illustrative Key Performance Indicators (KPIs)**
Reach	• Number (proportion) of VHNs reporting through the app • Number (proportion) of VHNs reporting through the app at the time/place of service provision • Percentage of time device/app is available to VHNs • Percentage of entries by VHNs into data systems through the app • Time spent by VHNs using the app
Data collection	• VHN satisfaction using the new app • Usage patterns of VHNs, including frequency and duration for various data entry forms, and geotagged location of data entry • VHN engagement through other channels, including WhatsApp, Viber, SMS, phone calls, etc.
Data quality	• Potential errors identified in HMIS records • Audis of selected PICME and HMIS records
Data usability	• Time lag in reporting critical health information (e.g., on high-risk AN mothers) to higher level health authorities • Usage patterns for data analysis, including most used outputs and statistics, among health authorities, medical officers, and VHNs

- Number (proportion) of reports including data collected through application

5.4. Risks and mitigation

Table 5 below presents a preliminary set of risks presented by the launch of the proposed application, and a very brief discussion of recommended mitigation efforts.

Table 5: Preliminary list of anticipated risks and mitigation measures

Risk	Impact	Mitigation
Nurses decline to use the new app, preferring paper registries	High	App will be designed in conjunction with nurses and will be as intuitive and familiar as possible; pilot will identify key usability constraints
Security of the data stored in or used by the app is compromised	High	All users will have individual credentials and limited access to necessary records; data will be transferred using secure protocols and stored on encrypted databases
Perception among health service clients about the app's ability to harms data security and/or privacy	Medium / high	Information flyers will be made available describing, among other things, the improved security of the new application (appropriate for general audiences)
Usage of app fails to change rate of errors made in state health data systems	Medium	M&E protocol will examine rate of data errors during the pilot; designing with users will help identify key points to decrease error rates
Level of training required for nurses to field the app is prohibitive	Medium	Tamil Nadu already has extensive training infrastructure for VHNs and other health workers; training will be provided by existing staff already aware of the technological familiarity of members of their team
Overruns in cost or time of building the app	Low / medium	SRS will detail elements needed, including a listing of priority levels of different components and an outline of the approach to development

5.5. Next step

To move forward with the proposed application, the first step will be to develop a s*ystems requirement specification* (SRS) detailing the functional requirements of the application as well as the interactions that different user classes (e.g., VHNs, AN mothers, block medical officers) will have with the application. To the extent possible, use cases should be developed in partnership with the target users—the nurses and state health staff—that will be employing the application at the field level. This and other measures should be used to ensure the application design conforms to the nine principles of digital development. (Waugaman, 2016) The SRS and the process of developing it will also facilitate further elaboration of the M&E framework and risks and mitigation measures described above. We estimate the SRS would require approximately 8 weeks to complete.

Based on the SRS, the application would then be developed and piloted. The 1-year pilot would begin after the development of the critical components of the tablet application, the procurement of necessary hardware, and the preparation of training materials. The SRS will also help to refine estimates on development costs, timeframes, and potential risks.

6. Annexure

6.1. Methodology

The purpose of this research project was to identify and assess the challenges associated with maternal and child health (MCH) data collection by ground-level health workers. Before conducting the field research in Tamil Nadu, the research team performed background research for four months in Washington, D.C in preparation for the trip. This involved meeting with the client and an expert health consultant weekly, completing a literature review, and developing pre-prepared observational and interview research templates to record data. Data was collected through qualitative interviews, observations, and focus groups. At the request of the host organization, the team conducted field research in the district of Poonamallee, located to the west of Chennai. The selection of Poonamallee was a convenience sample due to its proximity to Chennai, distribution of development blocks, and range of urban, semi-urban, and rural communities, the district is a good example of an area facing urbanization pressures in modern Tamil Nadu.

Interviews: The team conducted semi-structured, researcher-administered interviews that were primarily open-ended questions with health workers using discussion interview guides and questions that were prepared prior to the interviews. In Poonamallee a total of 11 interviews were conducted with five VHNs, three staff nurses, and three MOs. In addition, there were three meetings with government officials in Chennai to assess how they use the data collected from ground-level health workers to make policy decisions. Lastly, the team met with two informational technology (IT) specialist to gain technical advice for the proposed recommendation and details of what add-ons can be incorporated into the app.

Observations: There were nine observations- three HSCs, three ICDS, ad three PHCs- where the research team observed the presence and functionality of physical materials at health centers, such as computers, phones, and internet connection. The data collection and entry process was also observed, from both the beneficiary's perspective and the perspective of the frontline worker. Observations were recorded on observation guides in order to standardize observation procedures during the field work.

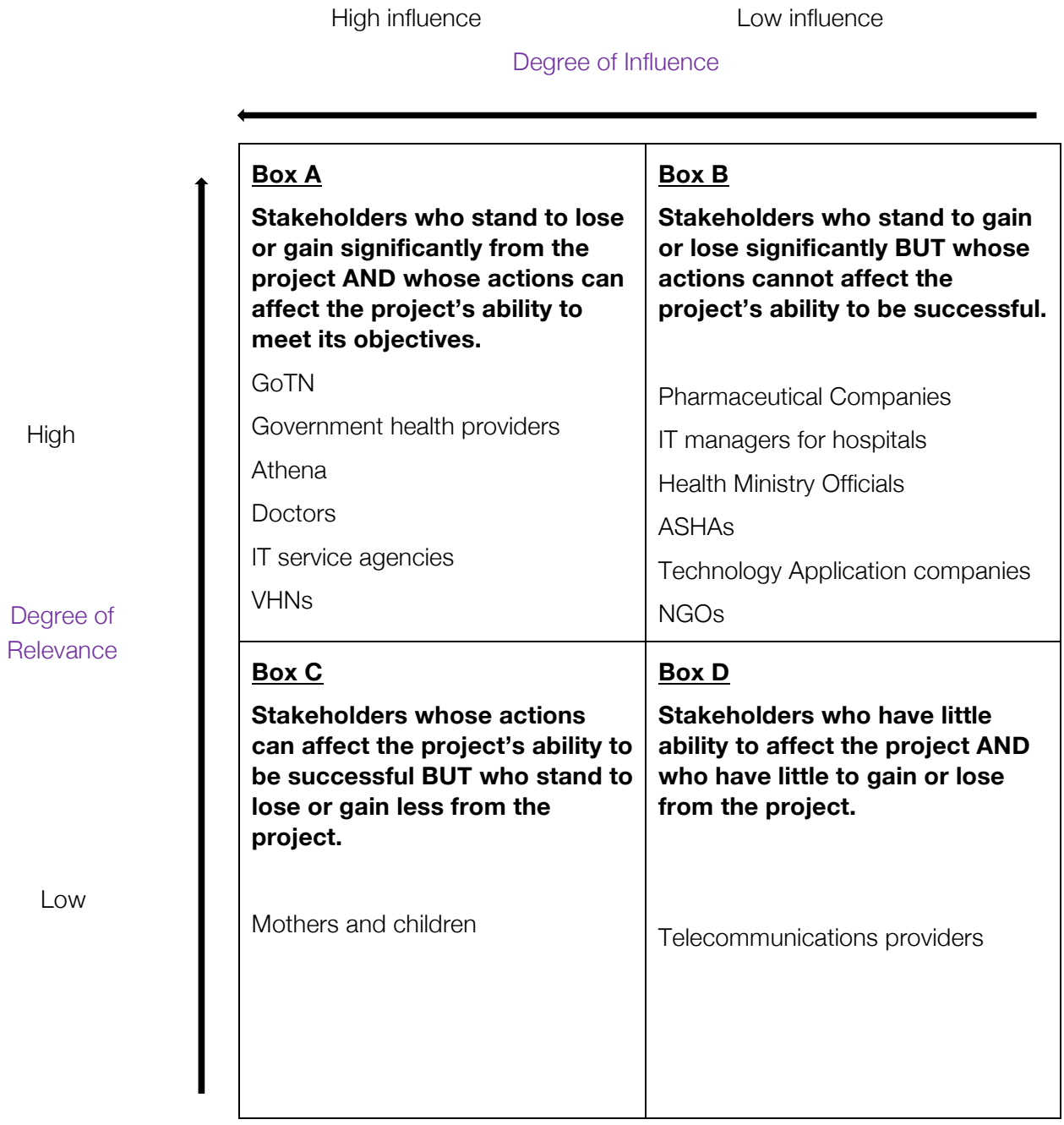
Focus group discussions: At the end of the field research, two focus group discussions were conducted in Poonamallee with a total of 20 VHNs, who were all female. The focus group data was triangulated with data received from interviews and observations.

Table 6: List of Interviewees

Category	***Body***
Government Agencies	Principal Secretary, Planning & Development, Tamil Nadu
	Director of Public Health, Tamil Nadu
	Director of National Rural Health Mission, Tamil Nadu
	Institute of Public Health, Poonamalee officials
	District Maternal and Child Health, Poonamalle
	Deputy Director of Public Health, Poonamallee
IT Specialist	HMIS Technical Director, Poonamallee
	Athena staff
Outside specialists	Abdul Latif Jameel Poverty Action Lab
	TN health sector specialists
Healthcare Workers	VHNs
	Staff nurses
	Medical Doctors and Medical Officers

6.2. Stakeholder matrix

Figure 5: Stakeholder matrix



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