Implementation of the Electronic Management Information System in Bangladesh

Experience and Lessons Learned

December 2019

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CONTENTS

ABBREVIATIONS

AHI	assistant health inspector
API	application programming interface
apk	Android package
AWP	advance work plan
BBS	Bangladesh Bureau of Statistics
BRN	birth registration number
CCDS	Citizen Core Data Structure
CHW	community health worker
CPU	central processing unit
CSBA	community skilled birth attendant
DGFP	Directorate General of Family Planning
DGHS	Directorate General of Health Services
DHIS 2	District Health Information System v. 2
EDD	expected date of delivery
ELCO	eligible couple
eMIS	electronic management information system
EPI	Expanded Program on Immunization
FPI	family planning inspector
FS	field supervisor
FSA	field support assistant
FWA	family welfare assistant
FWV	family welfare visitor
GIS	geographic information system
GNU	GNU's not unix
GOB	Government of Bangladesh
GP	general practitioner
GPL	general public license
HA	health assistant
HI	health inspector
HID	health identification number
HPNSP	Health, Population and Nutrition Sector Program
HRIS	human resource information system
HSS	Health Systems Strengthening
icddr,b	International Centre for Diarrheal Disease Research, Bangladesh
ICT	information and communication technology
IT	information technology
JDBC	Java Data Base Connectivity
LMIS	logistics management information system
M&E	monitoring and evaluation
MCH	maternal and child health
MCI	master client index
MIS	management information system
MNC	Maternal and Newborn Care [eRegister]
MOHFW	Ministry of Health and Family Welfare

MTEPI	EPI technician
NGO	nongovernmental organization
NID	national identity card number
NRC	nonregistered client
OSS	open-source software
PII	person identifiable information
PRS	Population Registration System
PVC	polyvinyl chloride
QA	quality assurance
RAM	random access memory
RD	rural dispensary
SACMO	sub-assistant community medical officer
SHR	shared health record
SPA	single-page application
TOT	training of trainers
UFPO	upazila family planning officer
UHFWC	Union Health and Family Welfare Center
UHID	unique health identification number
UI	user interface
USAID	United States Agency for International Development
USC	union subcenter
UX/UI	user experience and user interface

EXECUTIVE SUMMARY

In 2015, the Ministry of Health and Family Welfare (MOHFW) of Bangladesh undertook an initiative to develop and implement an electronic management information system (eMIS) to benefit community health service delivery. The initiative was implemented through a collaborative partnership among the United States Agency for International Development (USAID)-funded MEASURE Evaluation project, the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b), MaMoni Health Systems Strengthening (now MaMoni MNCSP), and SIAPS (now MTaPS) and was supported by USAID.

The intent of the initiative was to replace cumbersome paper instruments, reduce data burden for health providers, improve data-driven service delivery and quality of care, and make management of health and family planning activities at the grassroots level more efficient and effective. The resultant eMIS provides comprehensive and interlinked electronic tools for use by community-level healthcare and family planning workers (health assistants [HAs] and family welfare assistants [FWAs]), union-level service providers (family welfare visitors [FWVs], sub-assistant community medical officers [SACMOs]), their supervisors (health inspectors [HIs], assistant health inspectors [AHIs], and family planning inspectors [FPIs]), and their managers at the upazila level. Data from eMIS get linked to the mainstream reporting system for use by managers, planners, and policymakers at the directorate and ministerial levels.

All tools created for the eMIS were vetted and approved by the Directorate General of Family Planning (DGFP) and the Directorate General of Health Services (DGHS). The district and upazila managers had overall responsibility for implementing the eMIS, while technical assistance was provided by the eMIS initiative through software development, the provision of equipment, and capacity building. Systems for Improved Access to Pharmaceutical and Services (SIAPS), another USAID project (now MTaPS), contributed in the area of logistics management.

This document describes in detail the information technology (IT) structure of the eMIS and the experience of implementing it across several upazilas and districts in Bangladesh.

Types of Tools in the eMIS

The eMIS initiative sought to automate the data collection processes employed by community-level health workers in Bangladesh through the introduction of information and communication technology (ICT). This took the form of comprehensive and interlinked electronic tools[1] organized in three layers:[2]

1. Population registration app
2. Service apps, which include community and facility modules
3. Supervisory apps and web-based monitoring and management tools (for upazila-/district-level managers or central-level decision makers and system administrators)

All eMIS tools are loaded onto mobile devices (i.e., tablet computers). Tablets are convenient for use in rural areas and low-resource settings because community health workers (CHWs) can easily carry them during their field visits, the devices have a relatively long battery life and do not need to be recharged frequently during long hours in the field, and they can be easily connected to the Internet. eMIS tools also operate on the tablets both online and offline. CHWs can store data on the tablet while it is offline and later upload the data to a central server once an Internet connection is available.

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[1] Throughout the document, the term "tools" encompasses apps, applications, and modules.

[2] Icddr,b, with MEASURE Evaluation support, developed systems for family welfare assistants (FWAs), health assistants (HAs), FPIs, assistant health inspector (AHIs), health inspectors (HIs), the upazila family planning officer (UFPO), and the upazila health and family planning officer. MaMoni HSS project (now MaMoni MNCSP) developed the systems for FWVs and SACMOs working at the union-level facilities (Union Health and Family Welfare Centers [UHFWCs]), as well as community skilled birth attendants (CSBAs). Web-based monitoring tools were also developed by both organizations. SIAPS (now MTaPS) supported the integration of logistics data under the Supply Chain Management Portal.

Architecture of the eMIS

The eMIS tools were modeled on the paper-based tools already in use by the government CHWs. They were created as modular applications within the eMIS so that service providers could have access to the modules relevant to them and to allow easy addition of new data elements or features, as needed. Built using an open-source software (OSS) platform, the eMIS tools were designed to be flexible enough to suit the needs of the two MOHFW directorates, as well as sufficiently robust to handle the large volume of data being input by the public sector health workforce. The system architecture has been kept simple so that further development and maintenance of the eMIS do not become critical issues for the government.

Lessons Learned

- Digital forms of the eMIS tools were modeled on their paper-based counterparts.
- The volume and frequency of transactions and the local working environment were considered when selecting infrastructure for the eMIS.
- To develop software and manage database servers, a multidisciplinary team is needed with knowledge of Android and web technologies, database and server management including user interface (UI), and quality assurance based on different platforms and programming languages.
- CHWs need high-quality, durable equipment suitable for running resource-hungry apps.
- When choosing an operating system for the central server, consider how widely used it is, as well as its cost, manageability, security, robustness, and reliability.
- Server and database requirements should be finalized at an early stage.
- When selecting a database system, consider the comprehensive needs of the system, such as population size, geographical coverage, and frequency of use.
- The use of an SQlite database in the Android devices was highly effective, but it also had some limitations.
- Regular syncing between CHWs and facilities is desirable to keep the central database up-to-date, but this does not happen due to poor Internet connectivity.
- System performance is a continuous process that must be addressed regularly, as data volume increases over time.
- Because of downloading issues associated with poor Internet connectivity, tools were developed to compare the device and central databases for inconsistencies.
- To maintain the security of the system, tools and protocols such as strong password management, two-factor authentication, and a risk mitigation plan were needed.
- An urgency to start the implementation process prevented the development team from having strong requirement analysis at the initial stage and led to frequent changes.
- When the systems are handed over to the government, to maintain them the government must ensure that it has the required manpower either on staff or through outsourcing.
- Because the central database is updated regularly, it needs to be functional at all times and managed by dedicated staff.
- Automation of system management activities is important for sustainability.
- eRegisters are needed to mirror existing paper-based registers, forms, and official procedures or instructions to encourage user acceptance and facilitate learning how to use the system.
- It was not practicable to develop a desktop version of the mobile app; therefore, only mobile apps were used.
- The naming convention should be finalized at an early stage of development so as not to adversely affect the development timeline.
- While the user interface can be in a local language, programming languages require knowledge of English.
- System integration was necessary across community and facility systems to enable data sharing and access to real-time data.

- Integration of community modules of the DGHS and DGFP, as well as of facilities, enables sharing of data.
- Data from the eMIS can benefit other MOHFW systems if the systems are integrated.

Population Registration System (PRS)

The first app to be developed under the eMIS was the PRS. The PRS is used to collect individual and household data from the catchment areas of the FWAs and HAs.

Demographic data of all individuals and socioeconomic status of the households in the catchment area are captured through the PRS. Each household and individual within that household are assigned a unique health ID upon registration and are provided with ID cards by the CHWs. Population data are stored in the centralized server and are accessible to FWAs, HAs, FWVs, and their supervisors and managers.

In the pilot districts, population data were collected through a special drive engaging both the FWAs and HAs who worked in the same ward (local government unit). Later, in other expansion districts, FWAs were encouraged to carry out the data collection first, as it was difficult to maintain coordination between the FWAs and HAs. Further, in the MaMoni districts, the registration modality was changed so that whoever was visited by an FWA during her regular household visits registered that household and the individual members within it. In cases where individuals visited an FWV at the Union Health and Family Welfare Center (UHFWC) but were not registered in the PRS at the time of the visit, the FWV did partial registration of the individual, to be completed by the FWA at a later date during her household visit.

Lessons Learned

- Piloting PRS data collection in two districts informed expansion of data collection to include household socioeconomic data.
- The organizational units from both the DGHS and the DGFP, as well as the option for one CHW to work in multiple catchment areas, had to be accommodated within the PRS.
- The numbers generated to make up for the absence of government-assigned numbered street addresses for households in the rural areas were arbitrary and not known to the household members or the CHWs.
- Given the absence of a national-level human resource information system, a provider database of CHWs was created for PRS user authentication at DGFP.
- The PRS had to be modified to accommodate the long list of occupation codes.
- It was imperative to work with local government to update the geo codes.
- Different identity documents show different name spelling and date of birth for the same person, which complicates the registration process and database search function. Early marriage is also problematic for obtaining the correct date of birth of women.
- As women were not always able to provide their mobile phone numbers, the CHWs were trained to find out the number using special codes if the phone was available.
- Some architectural issues should be finalized before full-scale implementation of the system, such as issues around health identification numbers (HIDs).
- Socioeconomic data need to be updated regularly to make them usable for decision-making purposes.
- As the PRS is not implemented in urban areas, migration may not be captured accurately.
- PRS tables feed data to the service-related apps and hence are fundamental to the eMIS ecosystem.

- Because the PRS is conducted at the household level, facility-based registration is partial and needs to be completed in the community.
- Public sector CHWs performed data collection better than the outsourced personnel because they already knew the community members and visited them regularly in the course of their work.
- Population registration began as a separate module but was later integrated into community modules, allowing the CHWs to conduct registration during routine visits.
- Seasonal weather and work patterns may affect the performance of CHWs.
- The value of PRS data becomes apparent when used by other programs.

Conclusions

Population registration through the PRS has opened up many possibilities for health service delivery. It allows the CHWs to generate lists of target groups, such as eligible couples (for family planning), children (for immunization or other services), births, and deaths. PRS data need to be updated on a regular basis, and supervisors and managers can play a role in this process. Experience with the PRS also calls for engagement or collaboration with national standard-setting organizations.

Community and Supervisory Systems

Service modules implemented at the community level are the FWA eRegister and the HA eRegister, which are modeled after the paper registers and used by the FWAs and HAs to collect data on all the activities they perform.

Data are recorded in one large, bound volume of the paper registers, which contain many different sections. The electronic format eRegisters have made it possible for the CHWs to conduct all their work digitally. eRegisters have been introduced in a few districts, where the CHWs are using both paper and electronic registers. In the future, CHWs will only be using eRegisters. Modules for the FWA eRegister include the Eligible Couple (ELCO), "Woman Injectable," and Death modules. There are similarities in the work performed by the HAs and FWAs in the areas of maternal and child health, under-five child care, and death reporting; therefore, the modules for these areas are similar for both. The HA eRegister also includes the Expanded Program for Immunization for Child and Woman.

Lessons Learned
- Integration of community and facility systems was required to keep track of women receiving their first contraceptive injectable dose at a facility and the subsequent doses from a CHW.
- Integration of the Maternal and Child Health (MCH) facility and community modules resulted in enhancements from the paper register.
- Integration of the FWA and HA modules was required for the reporting of births and deaths.
- Notifications about past events and job aids alerting CHWs about services due were made possible because of the digital data available in the system.
- The HA eRegister tracks individuals registered with HID and nonregistered client (NRC) numbers, as well as those not registered anywhere.
- It was possible to expand the functionalities of the supervision modules over time.

Conclusions

Digitization under the eMIS is bringing many benefits to the organization. The DGFP introduced the eighth version of the FWA Register in 2016 and the ninth version in January 2019. The digitization of the community modules has brought synergies to the sharing of data in an area assigned to different cadres of

health and family planning workers. It has also contributed new tools for the CHWs, which improves their ability to perform their duties well.

Facility Modules

Both the DGFP and DGHS have union-level facilities that provide a wealth of services. The UHFWCs under the DGFP are equipped with paramedics for maternal, childcare, and family planning services (i.e., an FWV) and other general patients (i.e., a SACMO). The SACMO is responsible for providing general medical care in the UHFWCs. All UHFWCs are equipped to provide maternal and child care, including family planning services.

The tools developed for the union-level facilities for use by FWVs and SACMOS are composed of three modules, namely maternal and child care, family planning methods, and the general patient module. To produce these tools, the developers needed an understanding of the bifurcated health system of Bangladesh. They accomplished this through consultation with domain experts and review of available documents, registers, and guidelines. They also learned through interaction with the practitioners and by frequent field visits.

Lessons Learned

- Consultation with domain experts, practitioners, and users helped ensure that the application was user friendly and adapted to the field context.
- Providers should be trained to use multiple search criteria to search for the records of clients unable to provide HIDs.
- A system for monitoring referrals between union- and higher-level facilities was needed to update the data in the electronic system.
- Users required guidance on how to input their correct login information.
- Providers were initially assigned only one facility in the eMIS reporting system, but this was later changed to accommodate providers with multiple facility assignments.
- More analytical tools were added to allow for review of provider performance in real-time.

Conclusions

The union-level facility eRegister has improved the work at facilities, as well as the reporting. In addition, new tools have the potential to ensure quality of care. Under the eMIS, managers are now able to monitor the quality of care and pursue referral cases.

Monitoring and Administrative Tools

Web-based tools were developed to perform system management functions by system administrators and monitoring and administrative functions by supervisors, managers at the district and subdistrict levels, and decision makers at the national level. Data relating to service delivery may be viewed and management tasks performed by accessing different tools.

The monitoring tools webpage hosts a set of tools for managers, supervisors, and decision makers, as well as CHWs and other providers. The following actions can be performed from this website:

- View population registration, including status of registration and some key identifiers
- View community statistics, by activities or functions
- View facility statistics, including status of services provided by UHFWCs and satellite clinics
- View submitted reports
- View advance work plan (AWP) submission status
- View activities in paper register format

- Perform management and administrative functions
- Download resources such as user manuals and other documents
- Submit eTickets for any issues requiring resolution

Lessons Learned

- The monitoring tools website came at a later stage of eMIS development in response to requests from users to see the results of workers' performance and service delivery, as discussed in the monthly meetings at the district and upazila levels.
- Data visualizations were useful for reviewing data entry and progress, including during the monthly meeting at the subdistrict level.
- Initially, providers were assigned to areas manually. However, as the number of users began to increase, web-based tools were introduced through the monitoring page.
- Monitoring tools make it possible to view the performance of the facility providers, including services provided to individuals having NRCs or HIDs.
- Creating replicas of paper registers in web view helped convince management to go paperless and also provided a backup.
- A system of eTicketing allowed users to communicate directly with the eMIS developers when issues arose.
- Using a repository and version numbers helped the team of developers manage version changes.
- The sync checker enables monitoring of the status of synchronization between the device and server databases.

Conclusions

A ministry-wide human resources information system (HRIS) is needed to authenticate users on the webpage and perform functions such as provider assignment. Web-based monitoring tools should be comprehensive enough to engage all levels of managers and decision makers and should have data visualizations. The site should also evolve to address new requirements, and maintenance and continuous development of this site should be a priority. The monitoring webpage allows implementers to monitor the status of ongoing registration by providing tools managers can use. The developers and field implementation team can also monitor different aspects of the system.

Implementation Arrangements

The experience of implementing the eMIS tools in Tangail and Habiganj districts informed later scale-up of the eMIS in other districts. The eMIS tools were developed for users in the DGHS and DGFP, the principal stakeholders of the initiatives. The development of software solutions followed government-approved formats and guidance or clearance from the relevant authorities.

- Regular supervisory visits from management at the national and local levels play a significant role in motivating the workers at the community level.
- During the preparatory phase of the five-year sector program of the MOHFW, the potential of the eMIS was highlighted, resulting in the inclusion of scale-up of the eMIS in relevant operational plans of the 4th Health, Population and Nutrition Sector Program (HPNSP) under the DGFP.
- During national rollout of the eMIS, the catchment area should be thoroughly checked with HAs/FWAs, supervisors, and managers, and the Bangladesh Bureau of Statistics (BBS) should be notified if any discrepancies are found in the geo code.
- Internet connectivity should be checked prior to conducting the training in the field.
- Identifying the challenging participants and focusing on them differently is more effective for training, while older participants may need special attention.

- The printing of the HID card required careful planning, including the distribution of the card by the CHWs, the status of which is shown in the app.
- It was necessary to exercise caution when using the generator (due to power failure), as it caused damage to some of the equipment.
- Although telecom operators rolled out high-speed Internet service nationally, this was not available in the rural areas, and there were issues with the quality of the services provided.
- An Internet data use policy was issued by the government to address issues with CHWs' personal use of the tablets that exhausted the data quota.
- A local-level technician could be helpful for resolving device-related problems.
- A buffer stock of tablets should be maintained at the district level, and an extended replacement warranty could be included in the bidding document.

Conclusions

The wide variation in the demographics of the health workforce in the rural areas created challenges during implementation. Not all CHWs had been exposed to modern technologies. Therefore, there were apprehension and concerns about the adoption of technology by the range of CHWs. The results have varied, with some CHWs showing extraordinary aptitude and others not as proficient. However, the managers and supervisors helped to overcome any negative impact and made the implementation smooth, from assignment of catchment areas to training on care and use of tablets. The implementation experience was rich and helped to scale up eMIS tools in new areas.

Looking Forward

The digital tools developed for the CHWs have helped to bring changes in the way the CHWs work in rural areas. These tools have benefited the field supervisors and their managers. There is now emphasis on data quality and visualization of data for performance management. There is also the potential to establish an accountability framework, as was evident from the upazila managers' monitoring the CHWs' work. The progress of work was reviewed by managers and CHWs during monthly meetings at the upazila level. Lower-performing CHWs could easily be identified in these forums, which encouraged them to improve (so as not to be called out at these meetings).

While technical assistance played an important role in designing the tools and also in implementation for the better part of the program, it should be noted that the government has begun taking responsibility for implementation, and in the future this will become mostly a government activity. However, there is a greater need for support and maintenance of the system, and in the longer term, some form of technical assistance will still be necessary. Although this document did not address sustainability issues in detail, a sustainability plan is under preparation and will address such issues.

CHAPTER 1. INTRODUCTION

Government of Bangladesh Health Service Provision

In Bangladesh, government health services are provided through the MOHFW. Since 2017, the MOHFW has been made up of two divisions, the Health Services Division and the Medical Education and Family Welfare Division. In turn, the Health Services Division houses the DGHS, and the DGFP falls under the Medical Education and Family Welfare Division.[3]

Both the DGHS and the DGFP provide essential health, population, and nutrition services throughout Bangladesh, frequently via CHWs. The two directorates have a strong focus on rural areas, where CHWs provide services through home visits and at health facilities (e.g., community clinics) in their catchment areas. CHWs in the DGHS consist of HAs, while those under the DGFP are known as FWAs. Figure 1 shows the organizational structure of service delivery under the MOHFW.[4]

Figure 1. Organizational structure of the Ministry of Health and Family Welfare
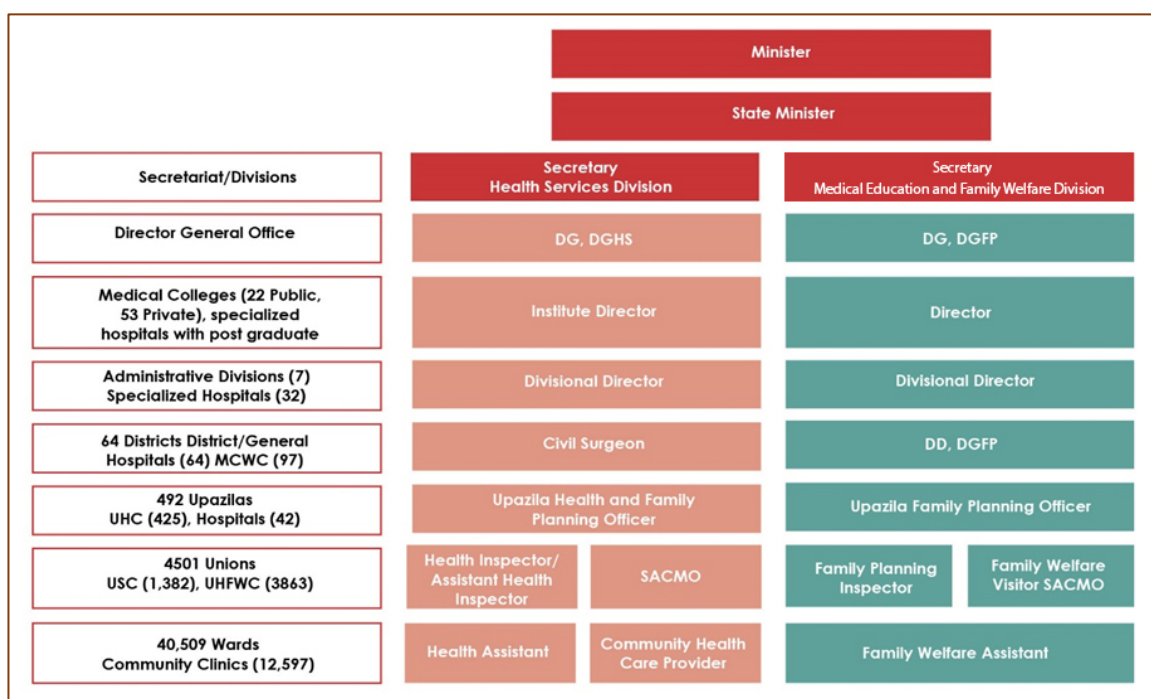
Electronic Management Information System (eMIS) Initiative

In 2015, the MOHFW undertook an initiative to develop and implement an electronic management information system (eMIS) to benefit community health service delivery. The initiative was implemented through a collaborative partnership among MEASURE Evaluation, icddr,b, and MaMoni HSS and was supported by USAID.

The intent of the initiative was to replace cumbersome paper instruments, reduce data burden for health providers, improve data-driven service delivery and quality of care, and make management of health and family planning activities at the grassroots level more efficient and effective. The resultant eMIS provides comprehensive and interlinked electronic tools for use by community-level healthcare and family planning

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[3] There are other departments under the two Divisions which are not mentioned here.

[4] The MOHFW was partitioned into two divisions in 2017. Agencies and departments were reorganized under these two divisions, and new organizations may also be created. This figure primarily presents the health service delivery structure of the MOHFW.

workers (HAs and FWAs), union-level service providers (FWVs, SACMOs), their supervisors (HIs, AHIs, and family planning inspectors), and their managers at the upazila level. Data from eMIS get linked to the mainstream reporting system for use by managers, planners, and policymakers at the directorate and ministerial levels.

All tools created for the eMIS were vetted and approved by the DGFP and DGHS. The district and upazila managers had overall responsibility for implementing the eMIS, while technical assistance was provided by the eMIS initiative through software development, the provision of equipment, and capacity building. Before it phased out, SIAPS, another USAID project, contributed in the area of logistics management.

Organization of This Report

This document describes the development and implementation of the eMIS in Bangladesh. The eight chapters that follow cover the following topics:

- Chapter 2 provides an overview of the eMIS tools that were developed and implemented for use at different levels of the health system.
- Chapter 3 presents the system architecture and process for developing the eMIS and includes brief descriptions of the operating system, central database, choice of database for the device, and other tools used to develop the system.
- Chapter 4 describes the PRS, which is the foundational app for the eMIS.
- Chapter 5 describes the development and testing of community modules and supervisory systems.
- Chapter 6 covers the development of facility modules.
- Chapter 7 describes the monitoring and administrative tools of the eMIS.
- Chapter 8 presents the challenges of implementation and how challenges were addressed to successfully implement eMIS in the field.
- Chapter 9 discusses what is next for the eMIS.

CHAPTER 2. OVERVIEW OF EMIS TOOLS

Types of eMIS Tools

The eMIS initiative sought to automate the data collection processes employed by community-level health workers in Bangladesh through the introduction of ICT. This took the form of comprehensive and interlinked electronic tools organized in three layers:

1. Population registration app
2. Service apps, which include community and facility modules
3. Supervisory apps and web-based monitoring and management tools (for upazila-/district-level managers or central-level decision makers and system administrators)

eMIS Data Collection

All eMIS tools are loaded onto mobile devices (i.e., tablet computers). Tablets are convenient for use in rural areas and low-resource settings because CHWs can easily carry them during their field visits, the devices have a relatively long battery life and do not need to be recharged frequently during long hours in the field, and they can be easily connected to the Internet. eMIS tools also operate on the tablets both online and offline. CHWs can store data on the tablet while it is offline and later upload the data to a central server once an Internet connection is available.

Architecture of the eMIS

The eMIS tools were modeled on the paper-based tools already in use by the government CHWs. They were created as modular applications within the eMIS so that service providers could have access to the modules relevant to them and to allow easy addition of new data elements or features, as needed. Built using an OSS platform, the eMIS tools were designed to be flexible enough to suit the needs of the two MOHFW directorates, as well as sufficiently robust to handle the large volume of data being input by the public sector health workforce. The system architecture has been kept simple so that further development and maintenance of the eMIS do not become critical issues for the government (Figure 2).

Figure 2. eMIS architecture
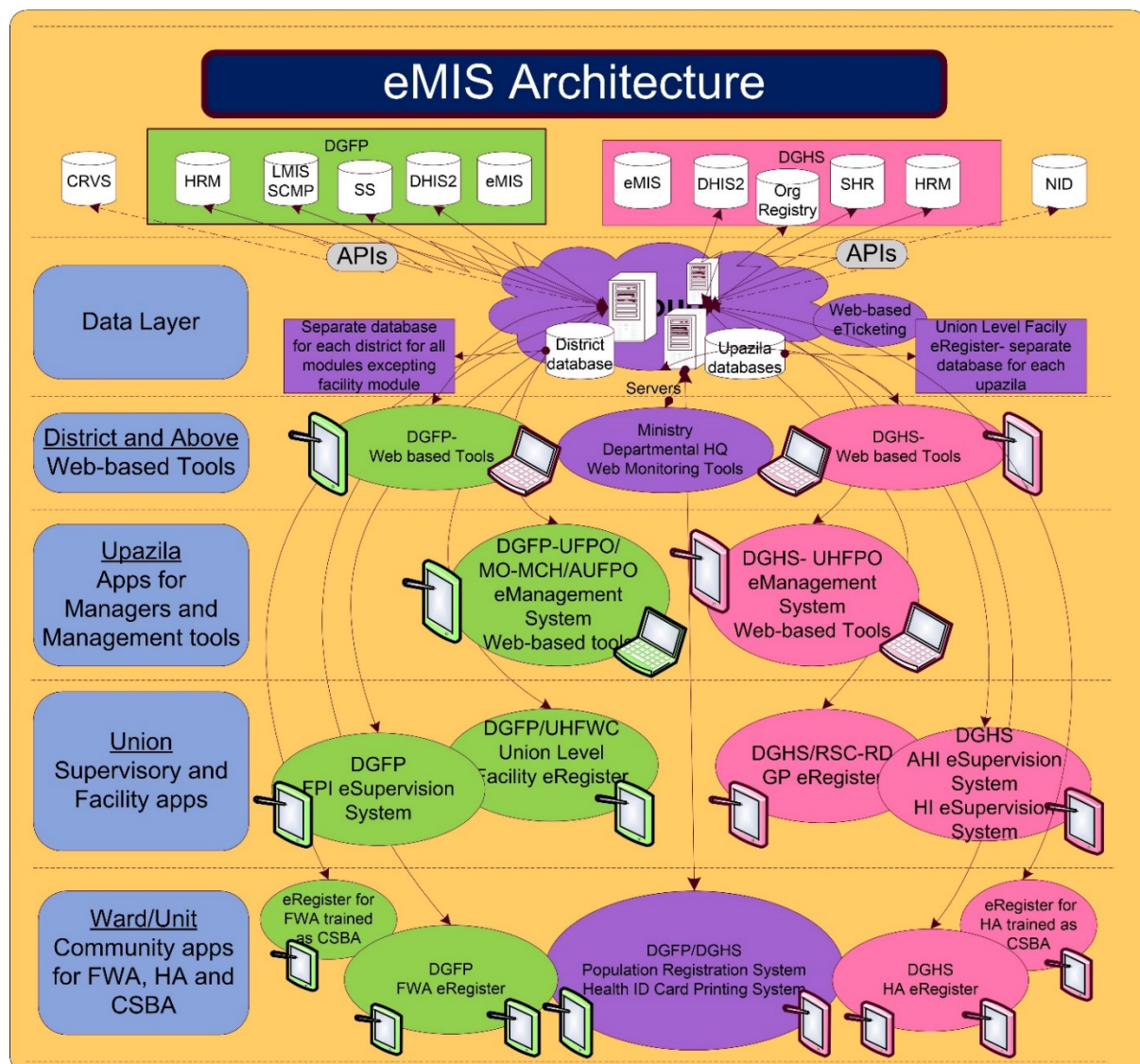
Tools for CHWs and Primary Care Facilities

Population Registration System (PRS)

The PRS is the foundational system used by FWAs and HAs to collect individual and household socioeconomic data from their catchment areas. Upon registration, FWAs and HAs assign each individual within a household a unique health ID and provide ID cards. If an individual seeks healthcare services from a health facility and has not previously been registered in the PRS by a CHW, that person will be partially registered at the health facility, and a CHW will complete the registration during a subsequent home visit. Population data are stored in the centralized server and are accessible to FWAs, HAs, FWVs, and their supervisors and managers.

Community and Facility Apps

The service and facility-based modules implemented at the community and health facility levels capture the health services CHWs provide in community settings, such as during home visits or at rural facilities. The CHWs record the services they provide in the relevant eRegisters. Because the eRegisters mirror the paper-based data collection forms, CHWs recognize and are comfortable with the electronic data entry into the tablet. The app can generate aggregate reports that are compiled at the upazila level and submitted to national headquarters at the end of the month.

Service modules used at the community level include the FWA eRegister and the HA eRegister. The HA eRegister is based on the paper-based registers used for the Expanded Program on Immunization (EPI) for children and women and other activities.

Other apps for use at community health facilities, such as those at the union level, include the Maternal and Newborn Care (MNC) eRegister, the Community Skilled Birth Attendant (CSBA) eRegister,[5] and the Union Health Facility eRegister. The Facility eRegisters, comprised of the MNC eRegister, the Family Planning eRegister, and the General Practitioner eRegister, are meant for use by FWVs and SACMOs at UHFWCs under the DGFP or by SACMOs at the union subcenters (USCs) and rural dispensaries (RDs) under the DGHS.

Supervisory and Management Tools

Supervisory Modules

Supervisory modules for union- and upazila-level supervisors and managers are designed to monitor the activities and performance of CHWs (Figure 3). These apps include the FPI eSupervision System, AHI eSupervision System, HI eSupervision System, and Upazila Family Planning Officer (UFPO) Management System. Links to the guidelines for supervisors issued by relevant health departments are included in the apps.

Figure 3. District health management structure

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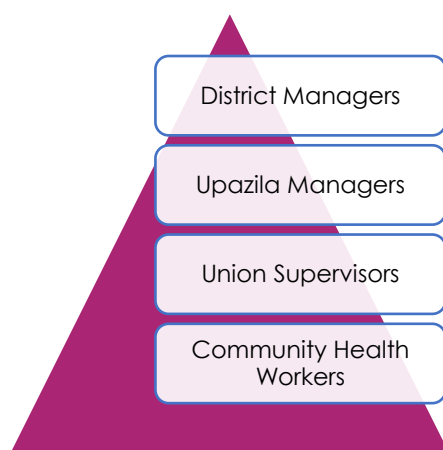
[5] CSBAs are FWAs and female HAs who have received a six-month training in pregnancy and childbirth.

Monitoring and Management Modules

Monitoring, administrative, and management tools comprise the fourth group of tools. These include apps on tablets and web-based tools to guide administrative and management tasks. A web-based interface allows authorized users to access these tools online.

Monitoring tools can generate or view reports. System maintenance tools are used at the central level by developers, system administrators, and other authorized users. Both can be used to assign access to users, prepare reports, assign work areas, review performance, and manage providers.

eMIS Data Storage and Use

eMIS data are stored in a central database that allows supervisors and managers to view or download aggregated data through web applications as needed for decision making. Supervisors and managers also share the data with CHWs and the union-level health facilities to facilitate coordination of service delivery and ensure continuity of care.

Conclusions

The tools of the Bangladesh eMIS for the community and union-level health facilities, on the one hand, and supervisory and management functions, on the other, have the advantage of being interlinked, enabling integrated use by the different types of CHWs, their supervisors, and managers. CHWs' tools are based on paper tools already in use and are loaded onto mobile devices, with the apps accessible for use both offline and online. Importantly, system architecture was designed such that maintenance of the eMIS, as well as additional development later on, do not become problematic for the government in the future, thereby contributing to the sustainability of the system.

CHAPTER 3. LESSONS LEARNED FROM THE SYSTEM ARCHITECTURE AND DEVELOPMENT PROCESS

Several lessons were learned during the design and development of the eMIS system architecture. These are described in this chapter.

Digital forms of the eMIS tools were modeled on their paper-based counterparts.

The electronic modules in the eMIS were modeled after the paper-based tools already being used by the government community health and family planning workers and their supervisors. They were also designed to enable the incorporation of new data elements or features, as needed. Previously, if the DGHS and DGFP wanted to add new data elements to the paper-based system, the registers had to be reprinted, which had significant cost implications.

The volume and frequency of transactions and the local working environment were considered when selecting infrastructure for the eMIS.

Based on previous experience with development of digital infrastructure and the working environment of the CHWs and their supervisors, the eMIS initiative prioritized the following points:

(a) Make use of the full potential of mobile technologies so that infrastructural limitations, including interruptions in power supply and Internet connectivity, can be circumvented.
(b) Ensure that system architecture is simple enough that further development and maintenance do not become burdensome for the government.
(c) Create modular applications so that new components can be added when required.
(d) Use OSS so that there is no burden on the government to pay for licensing fees or any other costs when the eMIS is transferred to the government.
(e) Ensure that the system is sufficiently flexible and robust to handle a large volume of daily transactions, given the size of the public sector health workforce.
(f) Align national standards with global standards for geo locations and names and health-related data, where appropriate.
(g) Take into consideration issues of capacity within the public sector workforce.

To develop software and manage database servers, a multidisciplinary team is needed with knowledge of Android and web technologies, database and server management including UI, and quality assurance based on different platforms and programming languages.

The eMIS grew out of the need to automate the business processes of the CHWs and their supervisors. To design and maintain a robust routine health information system, a skilled development team was needed with proficiency in different development platforms and programming languages, in addition to knowledge of health service delivery.

Development of the eMIS began in January 2015 with the existing developers of icddr,b and MaMoni HSS/Save the Children in Bangladesh. No new personnel were hired immediately, but some new positions were created at icddr,b, and personnel were brought on board to fill them at a later date. Community-level systems were developed by icddr,b and facility-level systems by the MaMoni HSS. SIAPS contributed in the area of logistics management, especially for the logistics management information system (LMIS).

As there was an urgency to roll out some modules immediately in the field, the first app—for population registration—was developed within three months of initiation of the project. The developers of this app were either trained or working in Java and SQL Server databases and had knowledge of managing Android-based apps. However, the development team was too small and lacked some needed multidisciplinary skills, such as in user experience and user interface (UX/UI) design, quality control and

quality assurance, database management, computer security, geographic information system (GIS), and web technologies. In particular, expertise in languages (and/or frameworks[6]) such as JavaScript and PHP became essential to realize the full potential of the eMIS apps and web-based tools and to expand its functionalities.

The implementers of the initial app—people knowledgeable about field-level practices of the DGFP and the DGHS, including physicians and those who had worked with both departments on health service delivery and data management—had in-depth knowledge of the business processes of the DGHS and the DGFP, which was essential for developing a functional app. In addition, DGFP and DGHS headquarters and field officials provided guidance during the development phase, and the digital solutions were vetted with them before the app was introduced in the field. There was notable enthusiasm from these key stakeholders from the beginning of the implementation process.

System Architecture

CHWs need high-quality, durable equipment suitable for running resource-hungry apps.

The main considerations in developing the digital tools and selecting the hardware and software were the following:

- To have the ability to capture transactional data continuously, including all instances of service provision and commodity distribution, updating the central database whenever any services are given or any data are input in the field
- To improve the digital tool user experience
- To ensure that quality data are generated, leading to innovative use and performance improvement

Tablets and laptops had already been provided by the government to some field staff to encourage the use of ICT-based systems. The DGHS had provided tablets to the CHWs, while the DGFP had provided laptops to the facilities and upazila offices. The eMIS project solicited feedback from the CHWs who were using the tablets and found some of the equipment to be not very durable, have a shorter battery life, be prone to crashing, and to have overall weak performance. Given that the specifications of the tablet played an important role in its ability to properly run the apps, tablets with the high-end configurations shown in Table 1 were procured. The government should procure tablets with similar or higher specs as they become available on the market.

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[6] In computer programming, a software framework is an abstraction in which software providing generic functionality can be selectively changed by additional user-written code, thus providing application-specific software. A software framework provides a standard way to build and deploy applications. A software framework is a universal, reusable software environment that provides particular functionality as part of a larger software platform to facilitate development of software applications, products, and solutions. Software frameworks may include support programs, compilers, code libraries, tool sets, and application programming interfaces (APIs) that bring together all the different components to enable development of a project or system. Source: https://en.wikipedia.org/wiki/Software_framework

Table 1. Suggested specifications for tablets

1.	Network	GSM, HSPA, LTE
2.	Operating system	Android OS, v5.0.2 or above
3.	CPU speed	1.3 GHz or above
4.	CPU type	Quad core
5.	Sensors	GPS, gyroscope, accelerometer, compass, ambient light
6.	Display	Type: TFT; Size: 7-inch; Resolution: 1024x600 pixels (minimum)
7.	Memory	RAM: 1GB or higher; Internal: 8 GB or higher; External: Up to 64 GB
8.	Wi-Fi	802.11 b/g/n 2.4GHz, Bluetooth version: BT 4.0
9.	Camera	Primary: 5 MP (minimum), secondary: 2 MP (minimum), video: 1080P
10.	Battery capacity	Minimum: 4000 mAh (above preferable if available)
11.	Multimedia	Audio playback, video playback; Ringtones: MP3
12.	Features	Messaging, Java, HTML5
13.	Warranty	Minimum 2 years (preferably with a replacement warranty)
14.	Certification	FCC, CE (a must for ensuring quality of hardware)

Central Server

When choosing an operating system for the central server, consider how widely used it is, as well as its cost, manageability, security, robustness, and reliability.

The eMIS resources at the central level are stored on a Linux server, version CentOS Linux. Linux is more widely used than Windows, and it is free, easily manageable, highly secure, robust, and reliable. The rationale for choosing Linux server was the following:

- CentOS Linux is open source and comes with a general public license (GPL) (a type of OSS license). The GNU GPL is a widely used free software license, which guarantees end users the freedom to run, study, share, and modify the software.[7]

- Linux has been reported to have better performance related to hardware functions (workstation) and managing requests from clients (networks) than other operating systems. This operating system is also less likely to be affected by viruses and malware.

- Unlike other operating systems, Linux does not become slow after long-time use; thus, there is no need to reboot it periodically to maintain performance. It can handle a large number of users, and does not hang up or slow down due to memory issues.

- It is used for high-performance applications, desktop applications, and embedded applications. Disk space can be saved by installing selected components required for a particular use. Access to the server can be easily managed.

- Linux consumes very few resources (i.e., CPU, RAM, hard disk), which makes it suitable to be run on low-specification hardware, as well.

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[7] Source: https://en.wikipedia.org/wiki/GNU_General_Public_License

Central Database

Server and database requirements should be finalized at an early stage.

A Microsoft SQL server (a proprietary relational database) running on a Windows server environment was used for storing eMIS data during the initial phase of the eMIS initiative, primarily because of convenience—icddr,b was already using it for other tasks, it was available in the existing system, and the developers were familiar with it. However, it was proprietary and platform dependent (i.e., it only runs on Windows operating system), and its use was inconsistent with the avowed goal of the eMIS initiative to use OSS. It was later changed to PostgreSQL, which runs on the Linux operating system. The team also considered interoperability with other national systems, such as the District Health Information System v.2 (DHIS 2). After overall assessment, PostgreSQL database was chosen for the central database.

When selecting a database system, consider the comprehensive needs of the system, such as population size, geographical coverage, and frequency of use.

PostgreSQL is a powerful, open-source object-relational database system.[8] As reported on its website, "It has more than 15 years of active development and a proven architecture that has earned it a strong reputation for reliability, data integrity, and correctness. It runs on all major operating systems, including Linux, UNIX (AIX, BSD, HP-UX, SGI IRIX, macOS, Solaris, Tru64), and Windows. It is fully ACID[9] compliant, has full support for foreign keys, joins, views, triggers, and stored procedures (in multiple languages). It includes most SQL:2008[10] data types, including INTEGER, NUMERIC, BOOLEAN, CHAR, VARCHAR, DATE, INTERVAL, and TIMESTAMP. It also supports storage of binary large objects, including pictures, sounds, or video. It has native programming interfaces for C/C++, Java, .Net, Perl, Python, Ruby, Tcl, ODBC, among others, and exceptional documentation. It supports international character sets, multi-byte character encodings, Unicode, and it is locale-aware for sorting, case-sensitivity, and formatting. It is highly scalable both in the sheer quantity of data it can manage and in the number of concurrent users it can accommodate."

Some general PostgreSQL limits are included in Table 2.

Table 2. PostgreSQL limits

Limit	Value
Maximum database size	Unlimited
Maximum table size	32 TB
Maximum row size	1.6 TB
Maximum field size	1 GB
Maximum rows per table	Unlimited
Maximum columns per table	250–1600, depending on column types
Maximum indexes per table	Unlimited

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8 Source: https://www.postgresql.org/about/

9 "In computer science, ACID (Atomicity, Consistency, Isolation, Durability) is a set of properties of database transactions intended to guarantee validity even in the event of errors, power failures, etc. In the context of databases, a sequence of database operations that satisfies the ACID properties (and these can be perceived as a single logical operation on the data) is called a transaction. For example, a transfer of funds from one bank account to another, even involving multiple changes such as debiting one account and crediting another, is a single transaction." Source: https://en.wikipedia.org/wiki/ACID_(computer_science)

10 SQL:2008 is the sixth revision of the ISO and ANSI standard for the SQL database query language. It was formally adopted in July 2008. Source: https://en.wikipedia.org/wiki/SQL:2008)

Other convenient features of the PostgreSQL platform are the following:

- Graphical user interface (GUI) database design and administration tools: PgAdmin III, Database .NET
- PostgreSQL rarely crashes during normal use.
- CSV[11] is the de facto standard way of moving structured (i.e., tabular) data around. PostgreSQL's CSV support is of high quality.
- Regular expressions[12] (called *regexen* or *regexes*) are as fundamental to analytics work as arithmetic— they are the first choice (and often the only choice) for a huge variety of text processing tasks.
- PostgreSQL can be driven entirely from the command line. PostgreSQL can be configured from a mobile phone by sending SSH[13] to a server.
- PostgreSQL's dump utility[14] is extremely flexible, command-line driven (making it easily automatable and scriptable), and well documented.
- PostgreSQL comes with a set of extensions called *contrib* modules. There are libraries of functions, types, and utilities for doing certain useful things that do not quite fall into the core feature set of the server.

The population of Bangladesh is huge. Storing data from a large geographical area and using them regularly pose significant challenges. Therefore, instead of maintaining all data in one single database, several databases are maintained based on the district for community systems and upazila for facility-based systems. The distributed databases are run in virtual machines and so do not require huge numbers of physical servers.

Device Database

The use of an SQlite database in the Android devices was highly effective, but it also had some limitations.

The development team chose SQlite for the device (tablet) database, as it seems to be the most preferred for Android devices. According to the Android authority:[15] "SQLite is a relational database management system, similar to Oracle, MySQL, PostgreSQL and SQL Server. It implements most of the SQL standard, but unlike the four database engines mentioned above, it is not a client-server database engine. Rather, it is embedded into the end program. What this means is that you can bundle a SQLite database with your application, and get access to all the power of a relational database within your application. SQLite is native to both Android and iOS, and every app can create and use an SQLite database if they so desire. In fact, in Android, device contacts, and media are stored and referenced using SQLite databases. An exciting tidbit of

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[11] "A comma-separated values (CSV) file is a delimited text file that uses a comma to separate values. A CSV file stores tabular data (numbers and text) in plain text. Each line of the file is a data record. Each record consists of one or more fields, separated by commas. The use of the comma as a field separator is the source of the name for this file format." Source: https://en.wikipedia.org/wiki/Comma-separated_values

[12] "A regular expression, regex or regexp[1] (sometimes called a rational expression)[2][3] is, in theoretical computer science and formal language theory, a sequence of characters that define a search pattern. Usually this pattern is then used by string searching algorithms for "find" or "find and replace" operations on strings, or for input validation." Source: https://en.wikipedia.org/wiki/Regular_expression

[13] "Secure Shell (SSH) is a cryptographic network protocol for operating network services securely over an unsecured network. Typical applications include remote command-line login and remote command execution, but any network service can be secured with SSH. SSH provides a secure channel over an unsecured network in a client–server architecture, connecting an SSH client application with an SSH server. The protocol specification distinguishes between two major versions, referred to as SSH-1 and SSH-2. The standard TCP port for SSH is 22. SSH is generally used to access Unix-like operating systems, but it can also be used on Windows. Windows 10 uses OpenSSH as its default SSH client." Source: https://en.wikipedia.org/wiki/Secure_Shell

[14] "A database dump is a major output of data that can help users to either back up or duplicate a database. This can be considered part of the more general term data dump, which involves revealing a set of stored data from a given technology." Source: https://www.techopedia.com/definition/23340/database-dump

[15] Source: https://www.androidauthority.com/creating-sqlite-databases-in-your-app-719366

information is that SQLite is the most used database engine in the world, and quite possibly the most widely deployed software ever."

According to the SQlite website:[16] "SQLite is used extensively in every smart phone, and there are roughly 3.5 billion smart phones in active use, each holding hundreds of SQLite database files, it seems likely that there are over one trillion SQLite databases in active use."

SQLite is open source, does not require a license, and bears the Public Domain Mark.[17] The use of SQlite proved highly effective for the apps developed under the eMIS. Large databases in the devices run smoothly without any problems arising, which demonstrates the capability of the SQlite.

However, limitations were also found with SQlite—earlier versions could not handle some constraints applied in relation to data type (e.g., fields identified as integer were accepting characters as well). This created issues with data quality. When constraints were applied at the server level, data were not synchronizing, creating problems for building validations and maintaining the integrity of the data between the device and server tables. These limitations were addressed to a large extent in due course, though not all could be resolved.

Middleware

Web services used as middleware were ineffective for syncing.

The local SQLite database in the hand-held device (i.e., tablet PC) of the end users connects to the central server for data syncing through the Internet. This syncing is done through middleware. Initially, web services were used for managing syncs. However, because of performance issues, the developers shifted from web services to web APIs (application programming interfaces[18]). Key points are:

- Web services that were used as middleware were found to slow down the syncing performance and proved ineffective.
- Web APIs sped up the syncing process and provided satisfactory performance.

APIs and web services serve as a means of communication for the app and central database. A web service facilitates interaction between two machines over a network, whereas an API acts as an interface between two different applications so that they can communicate with each other. Web services may not perform all of the operations that an API can perform.[19] The APIs for the eMIS were written using JSON, followed by Python gradually introduced at later stages.

Syncing

Regular syncing between CHWs and facilities is desirable to keep the central database up-to-date, but this does not happen due to poor Internet connectivity.

Managing syncs between the device and the server databases is an essential routine component of the eMIS system. It does not happen in real time due to Internet connectivity problems. Apps work offline but connect when the Internet connection is available. Both customized and third-party tools have been

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[16] Source: https://www.sqlite.org/mostdeployed.html

[17] Source: https://en.wikipedia.org/wiki/Public_domain

[18] "In computer programming, an API is a set of subroutine definitions, protocols, and tools for building application software. In general terms, it is a set of clearly defined methods of communication between various software components. A good API makes it easier to develop a computer program by providing all the building blocks, which are then put together by the programmer. An API may be for a web-based system, operating system, database system, computer hardware or software library. An API specification can take many forms, but often includes specifications for routines, data structures, object classes, variables or remote calls." Source: https://en.wikipedia.org/wiki/Application_programming_interface

[19] Source: http://www.differencebetween.net/technology/internet/difference-between-api-and-web-service/

used to manage sync activities. For community systems, customized tools were developed, whereas third-party tools have been used for facility systems (Symentic DS).

Both types of tools have advantages and disadvantages. Customized tools are easily manageable but need rigorous testing at every step when there are changes in the data tables. Third-party tools have some constraints or restrictions that cannot be overcome, given that customization can only be done by the original developers and not by other users. Since community and facility systems are interlinked, it may have been better if the same syncing tools had been used across all systems under the same architecture. Syncing sometimes posed difficulties at various stages of implementation, which were overcome by continuous improvement of the app and data sync mechanisms. Syncing issues, including the need to sync seamlessly at a desirable speed, will need to be addressed at the current stage of development or in the future as the system gets larger and reaches further maturity.

System Performance

System performance is a continuous process that must be addressed regularly as data volume increases over time.

Enhancing (and maintaining) system performance is a continuous process. At the early stage of implementation, when the data volume was small, the system performed at the desired level. Over time, as the volume grew, performance began to be a cause of concern. Search responses became slow, and synchronization became time-consuming due to too many inner queries/subqueries (e.g., searching for husband's name, father's name, and mother's name from different tables). To solve this problem, performance was improved by:
- Removing inner query/subquery, where possible
- Applying table joining over inner query
- Introducing an indexing mechanism
- Using database functions and views over complex and commonly executed queries
- Using database commands (namely, Analyze and Vacuum table and database) to increase the performance of database system
- Optimizing OS and database parameters

This is a longer-term matter of system maintenance and will have to be monitored on a continuous basis.

Apk Download and Database Rebuilding

Because of downloading issues associated with poor Internet connectivity, tools were developed to compare the device and central databases for inconsistencies.

Whenever any updated version of the app is released, it has to be downloaded onto the CHWs' tablets using the Internet. If the version change is a major one and affects the central and local databases, it becomes necessary to check the status of synchronization or the similarities between the device database and server database. After ensuring correctness, the device database is deleted after the download of the apk (i.e., an executable file on Android devices), and the database is rebuilt with data from the server database. This is a cumbersome process, and if the Internet connection is poor, it may not be possible to download the apk, let alone rebuild the database. In such cases during implementation, the field-level staff contacted the CHWs or their supervisors and helped them download from a location where the Internet connection was better. Because of such difficulties, tools were developed to compare the device and central databases for inconsistencies, and instead of rebuilding the database's running complex queries in the device, copies were created on the server and downloaded to the device. If the connection was stable, the downloading of the rebuilt database could be smooth. The cloud-based management of the process ensured that data integrity was maintained and that those data were of high quality.

System Security and Data Backup

To maintain the security of the system, tools and protocols such as strong password management, two-factor authentication, and a risk mitigation plan were needed.

Various methods need to be employed to ensure computer security, from user-level methods to hardware. Cyber security has become very important and is required for "the protection of computer systems from the theft and damage to their hardware, software or information, as well as from disruption or misdirection of the services they provide. Cyber security includes controlling physical access to the hardware, as well as protecting against harm that may come via network access, data and code injection. Also, due to malpractice by operators, whether intentional or accidental, IT security is susceptible to being tricked into deviating from secure procedures through various methods."[20]

Health data, particularly individual-level data, are highly confidential and sensitive, requiring robust system security. Security features such as introduction of a data access layer, web API authentication, development of a data access policy were gradually added under the eMIS initiative as the development moved ahead. It was also decided to implement different tools and protocols in due course, such as strong password management, two-factor authentication, and a risk mitigation plan.

Data backup is necessary to reduce the risk of losing data. It involves copying and archiving computer data so as to be able to restore the original dataset after a data loss event. Data loss can be a common experience of computer users. Though backups represent a simple form of disaster recovery, backups by themselves do not ensure complete recovery. Electronic data could be transient, and in case of accident could be wiped out without leaving any trace. Often, even if lost data are retrieved, they become unusable. Therefore, all systems need to have a backup policy that is robust and allows for full retrieval. It is essential to have processes in place for recovering data from a backup.[21] The eMIS data are collected in the device, and when the syncing operations are completed, the data become available in the server database, allowing further use at different levels of organizational hierarchies. A data backup policy for eMIS data is followed to regularly back up data in different locations.

Sync Management

The execution process of the JSON data format in both client (tablet) and server (API) was optimized. Interactions between the Android System/API and the database were reduced to optimize the concurrency in a multi-user environment. The SQL query was optimized to reduce the execution time for data searching.

Database lock and error Issues occurred at times during saving at the server side, where the database displayed error message saying, "Database got locked." During concurrency in multi-user access, the only solution to unlock the database for user access is restarting, which is not desirable. Users were attempting numerous times to access the database, creating great difficulties. For example, when the database needed to be rebuilt in the provider database, the rebuild process had to start from the beginning. In other instances, during execution of the "Show" or "Search" commands, data took a long time at the application level, or the app did not respond. In order to solve the problem, the execution process of the JSON data format in both client (tablet) and server (API) was optimized. Interactions between the Android System/API and the database were reduced to optimize the concurrency in a multi-user environment. The SQL query was optimized to reduce the execution time for data searching.

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[20] Source: https://en.wikipedia.org/wiki/Computer_security

[21] Source: https://en.wikipedia.org/wiki/Backup

Null Handling

Null handling issues needed to be resolved at the application level, including replacing an existing string null with a database null.

Users need to input values in the app. Ideally, there should be constraints that allow only certain inputs, such as characters, numeric, or alphanumeric. However, null values are instead generated because of various factors. Since both community and facility modules connect to a common database at times, if any data item is not present in one system, a null value is created in the database (weight in maternal and newborn care, but not in community module). Null data in the database is difficult to handle—the string null cannot be interpreted in a corresponding value. This may lead to system failures when queries generate errors. The issues were resolved at the application level. In addition, special provisions were made to the database where the existing string "Null" was replaced with database null.

Application Development Process

Introduction: Selecting a Suitable Platform

Central to eMIS architecture is the use of mobile technology in a cloud-based environment. mHealth apps designed for a mobile platform (smartphones, tablets) are easy to use, cost less, and remain functional even without a constant supply of power or an Internet connection. Tablets are also capable of handling a more sizable volume of data processing and storage than smartphones. A cloud-based system ensures that data are available from a central location, and regular syncing between handheld devices and the cloud database ensures integrity and availability of data to all the users, whether community-level workers or managers. Mobile devices have clearly opened up many avenues for capturing health service delivery data, as well as performance management in Bangladesh's health sector.

The main requirement for the eMIS was to have a comprehensive and interconnected system supported by a robust central database across the 64 districts of Bangladesh. The work of eMIS is embedded in the formalized structure of government health service delivery structures supported by official registers, procedures, and instructions. Bringing all of these into an electronic system was an immense, comprehensive task. The eMIS first looked for ready-made solutions, including OpenSRP and other tools, many of which lacked documentation and access to comprehensive code libraries. Upon evaluation of the available documents/codes, it was decided that the system had to be built from scratch.

Standards of Development Process

An urgency to start the implementation process prevented the development team from having strong requirement analysis at the initial stage and led to frequent changes.

Software design and implementation need to follow a standard development process for effective and efficient performance. During in-house sessions and field visits, the development team (IT team) members were oriented to union-level healthcare delivery, data collection, and reporting tools used at the local level to help them gain an in-depth understanding of the context and requirements. However, time limitations to complete the development and start implementation sometimes did not allow adequate time for the development team to plan out the complete business logic. Moreover, a lack of uniform practices at the local level led to frequent changes in logic. To overcome these challenges, "agile" methodologies for collaborative management of the software development process were adopted. As end users are the most appropriate people from whom feedback should be obtained, rapid prototyping of ideas was adopted so that the feedback from the end users could be incorporated as early as possible in the development cycle. Prioritization of requests for modifications followed weighing potential benefits and associated risks of implementing each request.

mHealth development needs a multidisciplinary team approach comprised of people from different domains of IT and health.

The development of the eMIS followed a multidisciplinary team approach, which was key to the success of the process. Throughout the development phase, the multidisciplinary teams met regularly, and individuals from national-level programs and local-level end users were also consulted.

Approaches to Software Development

The two teams of developers, for the community and facility systems, used different approaches to handle distinct issues they faced.

The eMIS developers consisted of programmers working in two separate organizations (DGFP and DGHS). Each team faced distinct problems that required different approaches to solve. For example:

- *There was a need in the community system to locate the registered individuals easily.* The opening screen of the community tools shows the names of villages, and the CHWs can go straight into the village list during home visits. Search options are used to find the specific person in the household or village setting using the device database for the catchment area. All the records are available in the device, and all registered clients' records remain in the system unless they have migrated out or are new to the community. After migration status is updated, the migrated person shows up in the database for the new area.

- *The facility system users need more elaborate search tools to identify the large number of service recipients. The catchment area for facilities is quite large.* People from outside the catchment area also visit facilities for services, and if they have registered previously for services, their records need to be available in the database,[22] although non-availability of records cannot be used to deny services. Those who are not registered are served as NRCs (with a limited data element). The upazila database is maintained in the device and contains records of all people served. For the facility health provider, the first step is to use the search function using a number of parameters to identify the person seeking services.

Competencies in Coding Languages

When the systems are handed over to the government, to maintain them the government must ensure that it has the required manpower either on staff or through outsourcing.

The eMIS apps and applications run on mobile devices and desktop computers, while all data reside in the central server. To accommodate this, a multidisciplinary team of developers with a wide range of competencies was required for developing the eMIS, based on the following considerations:

- Java is used for developing all mobile applications on the Android platform.
- Web-based applications were initially based on ASP.net, but this coding language is not open source, is platform dependent (does not support a Linux server), and has licensing fees. Therefore, subsequent development was done using a Java servlet.
- Skills in web development were required.
- For maintaining the database, knowledge of PostgreSQL was required.
- Development of APIs in different languages was also needed. For managing the sync between the device and central database, a JSON data format was used initially; however, later it was transitioned to Python.

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[22] This would not have been a problem if the eMIS was implemented nationwide and records of all service seekers could be retrieved from a central database.

- Skills were also required for programming in JavaScript and DHIS 2.

As the goal of eMIS is to cover the whole of the DGFP, it is necessary to include developers with varied skills and competencies. System maintenance is a long-term issue and calls for a broader vision. When the system is handed over to the government, the government must ensure that it has the required manpower within its staff or through outsourcing.

Server and Database Management

Because the central database is updated regularly, it needs to be functional at all times and managed by dedicated staff.

A key activity of the technical people involved in the eMIS is to manage the software for continuous use. All eMIS apps are downloaded from the server. The central databases need to be updated regularly in a Linux server. Managing system software updates for the Linux operating system-based server (i.e., operating system and associated application like Tomcat, PostgreSQL update in Linux) require a dedicated skilled person.

A database administrator responsible for managing the relevant servers and databases joined the team at icddr,b much later than other programmers. The need for the position increased over time as the number of servers and databases increased, but it would have been better if the position had been created at the beginning of the development process. The database administrator helps to maintain and troubleshoot the system, as needed, as well as performs other activities, including access control, backup, and database restoring.

Automation of system management activities is important for sustainability.

Under the eMIS initiative, dependence on the manual interventions was reduced by automating part of the server and database management. This was done by incorporating system management functions previously done manually into the web-based tools and scripting.

User-Centric Design

eRegisters needed to mirror existing paper-based registers, forms, and official procedures or instructions to encourage user acceptance and facilitate learning how to use the system.

Although the initiative sought to replicate the existing paper-based tools, it was not always easy to do so. Paper-based tools have some flexibility in terms of the ability to write comments and highlight particular information. Considering the potential literacy levels and the user experience, each component of the eRegisters/tools was made as user-friendly as possible—e.g., minimal text inputs requiring a keyboard, expanded predefined options, less scrolling, easy navigation from one section to another, data import though unique identifiers, and intelligent search options. Advance features of digitization such as navigation drawer[23] and material design[24] were also added.

The elements[25] of user-centric design that were employed were the following:

- *Specify the context of use.* Identify the people who will use the product, what they will use it for, and under what conditions they will use it.

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[23] The navigation drawer is a panel that displays the app's main navigation options on the left edge of the screen. It is hidden most of the time but is revealed when the user swipes a finger from the left edge of the screen or when the user touches the app icon in the action bar while at the top level of the app. Source: https://developer.android.com/training/implementing-navigation/nav-drawer.html

[24] Material Design is a design language developed in 2014 by Google. Material Design makes liberal use of grid-based layouts, responsive animations and transitions, padding, and depth effects such as lighting and shadows. Source: https://en.wikipedia.org/wiki/Material_Design

[25] Source: https://www.usability.gov/what-and-why/user-centered-design.html

- *Specify requirements.* Identify any business requirements or user goals that must be met for the product to be successful.
- *Create design solutions.* In stages, build from a rough concept to a complete design.
- *Evaluate designs.* Ideally, conduct usability testing with actual users.

At the early stage, the developers had limited knowledge of the context in which the applications would be used. Before the design expert could evaluate the design, the requirements for proper documentation needed to be identified, with review and feedback provided by the technical team. One difference between paper-based and electronic registers was that paper-based registers allowed for rectification of mistakes within a reasonable period, while the eRegister restricted modifications to a limited time period (e.g., within three days). Users complained about this and changes were eventually made to the application.

Desktop Version of Android Apps

It was not practicable to develop a desktop version of the mobile app; therefore, only mobile apps were used.

The choice of device (laptop vs. tablet) was important, given the capacity of the end users and the available IT infrastructure. Although it was easy to choose tablets for CHWs, the selection of a device for facility-based service providers was more difficult. In line with the government's plan to provide either laptops or tablets or both to the service providers, the development team attempted to develop the system for both tablet and laptop/desktop. There were two ways to address the issue: (1) develop the desktop version on the Windows operating system, and (2) use emulation programs to run Android programs on a Windows laptop/desktop. However, the programmers were not prepared to undertake these tasks because of the volume of programming and because ensuring consistency between the two versions of the tools on a regular basis would have created an extra burden. In addition, Android apps cannot be installed on Windows PCs, and when the desktop versions were emulated on the laptop, the results were unsatisfactory. Open-source tools were also not able to perform the tasks required. Further, desktop versions of mobile apps have limited memory access to support offline use. Therefore, mobile applications turned out to be the only feasible option.

Ensuring Quality

Maintaining quality at every step of development by having a dedicated quality assurance person is needed to create an efficient, effective, and sustainable electronic system.

Dedicated quality assurance (QA) personnel are required to make sure that developments reflect the desired quality. All developments should be deployed only after passing rigorous quality testing. Initially, there was no dedicated QA person, which meant that a standard process based on constructive QA, analytical QA, and quality control was not maintained at every step of development.

Naming Convention

The naming convention should be finalized at an early stage of development so as not to adversely affect the development timeline.

A naming convention is a set of rules for choosing the character sequence to be used for identifiers, such as variables, types, functions, and other entities, while writing codes. Examples include CamelCase and SnakeCase. A naming convention helps to reduce the effort needed to read and understand source code, enables code reviewers to focus on more important issues than syntax and naming standards, and ensures that code quality review tools focus their reporting mainly on significant issues instead of syntax and style preferences.[26]

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[26] Source: https://en.wikipedia.org/wiki/Naming_convention_(programming)

Initially, no case convention was followed to create database tables. Later, the decision was made to follow CamelCase. However, CamelCase was found to have limitations when frequent changes are made. Therefore, the developers later started using a naming convention of small letters with an underscore between the words (i.e., Snake_Case). This required additional work at a later stage to make the names consistent, and all CamelCase names were converted to Snake_Case. Finalizing the naming convention at the initial stage could have saved time on development to the benefit of the system.

User Interface and Language

While the user interface can be in a local language, programming languages require knowledge of English.

The DGFP and DGHS registers and documents being recreated in electronic versions were in Bangla, the national language of the country and the language the government requires in all official communication. As a result, the user interface of all eMIS Android apps was to be in Bangla. However, programming languages use English. Therefore, the front-end screen interface was designed in Bangla, and the back-end tools were in English. The numeric and date fields were captured in English but could be reproduced in Bangla fonts.

System Integration

System integration was necessary across community and facility systems to enable data sharing and access to real-time data.

Initially, a client's service history was not linked across different levels of providers. For example, services provided from union-level facilities were not visible to CHWs. Despite apps being used autonomously, data sharing was needed to ensure accurate reporting, requiring system integration during the development of the various eMIS apps and applications. When the system was introduced at the beginning stage, data could not be shared properly within the same catchment area among providers, possibly due to slow synchronization or other problems. In addition, the catchment areas of two types of CHWs were different, and additional queries had to be executed to update records. Also, the catchment areas of FWAs and HAs in unit and block levels were not well defined, and issues with integration were noted during manual syncs. These issues were resolved by implementing automatic sync and accurately defining the catchment areas. During registration, the provider had to identify all households in the catchment area, which helped to run queries efficiently.

Database integration did not receive sufficient attention initially. The synchronization process was manual, which restricted the availability of real-time data. The CHWs were not aware of the need to synchronize data on a continuous basis, leading to use of automated tools via Cron,[27] a software utility. Cron is a time-based job scheduler set up to run at fixed times, dates, or intervals. It automates system maintenance or administration and is suitable for scheduling repetitive tasks.

Database-related changes, such as in the database tables, affect all of the apps, including the community system, facility system, and monitoring tools. When any change of database was made, it could not be confirmed in the local database, as the functionality of the ALTER statement[28] is limited in SQlite. Changes in any table structure, whether at the level of community or facility systems, required consultation among developers.

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[27] Source: https://en.wikipedia.org/wiki/Cron

[28] The ALTER DATABASE is a structured query language (SQL) command. This statement is used to modify, maintain, or recover an existing database.

Integration between facility modules and community modules

Integration of community modules of the DGHS and DGFP, as well as of facilities, enables sharing of data.

There is overlap in the work of FWAs and HAs, who serve the same communities and provide some of the same services. FWAs record data using the FWA eRegister and HAs the HA eRegister, while integration of the two allows for data sharing. Records of clients served within the same catchment area are mutually visible by FWAs, HAs, and facilities, and records are kept updated in all apps.

Integration with Logistics Management Information System (LMIS)

Data from the eMIS can benefit other MOHFW systems if the systems are integrated.

The eMIS data can be shared with other MOHFW systems. For example, the DGFP developed an LMIS that became part of the Supply Chain Management Portal of the MOHFW and had links to procurement and supply at the service delivery point level. The system relies on upazila-based monitoring of stocks, and solutions are based on data collected manually from FWAs. When eMIS tools were introduced, the FWAs were collecting data on distribution of reproductive health commodities on their devices. Integration with the LMIS was planned in order to supply service delivery point data in real time. However, the architecture of the Supply Chain Management Portal did not require such updating, being geared more toward monitoring the availability of stocks based on month-end reports. The developers on both ends worked to develop the API to share data on stock transactions.

Shared Health Record (SHR) Integration

Issues with authenticating each HID resulted from the high volume of data.

The HIDs provided by the SHR were originally intended to be authenticated upon each transaction within the DGHS's Master Client Index (MCI), for which the eMIS team wrote an API. The eMIS was supposed to send a single request for each HID in the SHR. However, the eMIS data volume grew bigger, and as there had been a huge backlog, it seemed impossible to authenticate each HID in a single transaction. As a result, the eMIS developers collected the API of the SHR from the DGHS and developed another API for batch processing from the eMIS server. Note that the SHR was not ready at the time when this document was being finalized, and previously allocated HIDs have not yet been authenticated through the MCI.

System Enhancement

System enhancements were needed to improve the search function and capture migrations to and from the catchment area.

After introduction of the eMIS tools, feedback was received on UX/UI, searching, data synchronization, and migration of people in the catchment area. UX/UI was not intuitive enough, which prevented the users from smoothly navigating from one module to another. Searching was difficult, e.g., in order to find a person, the user would have to go to the village list and then browse the households to find the specific client. A search could not be done from the register (view pages), e.g., ELCO, Pregnancy Register, Nutrition, Adverse Effects Following Immunization, and Immunization modules. To mitigate this problem, an advance search function was introduced. The later versions allow searches using extended parameters, such as household number, name, husband's name, father's name, mobile number, national identity card number (NID), birth registration number (BRN), and administrative boundaries. Search, including the advance search function, was included within each module or register.

In addition, there was no means to capture in- or out-migration, i.e., to record the new current address if a member moved to a new location. Therefore, migration was added to the system so that a user could easily transfer a member from one location to another.

After the digital system had been introduced, additional tools were needed for the CHWs. For example, tools allowing CHWs to prioritize visits were needed, such as prioritization based on expected date of delivery (EDD), whether expired or set to expire within the next few days.

Conclusions

Technological preferences for developing an eMIS should be guided by the purpose, the country's technological and financial capacities, interoperability with existing systems, cost effectiveness, and the availability of skilled staff. Other considerations are the need for a multidisciplinary development team from the inception of the development process, the desirability of user-centric design given the low literacy and high work burden of the system's users, and the need for robust hardware. Finally, a multidisciplinary IT team is essential to maintain and sustain the system in the long term.

CHAPTER 4. POPULATION REGISTRATION SYSTEM (PRS)

CHWs use the PRS to conduct censuses in their catchment area. The HAs (under the DGHS) and FWAs (under the DGFP), who perform domiciliary work, are responsible for the PRS because of their familiarity with the community. Using the PRS, they register all members of a household in their catchment areas, collect demographic data of individuals, and the socioeconomic status of the household. Unique HIDs are provided to individuals after registration.

This chapter on lessons learned around PRS covers design issues faced by the developers during various stages of development, the implementation of PRS in the field, data collection mechanisms, challenges in maintaining the quality of data, and expanding the functionalities of the system.

PRS Development

Development of the PRS took into account the following assumptions:

1. Population-level data are essential for creating an elaborate health information system.
2. CHWs working in the DGHS and DGFP have already been collecting data.
3. Data entry using mobile devices offers increased opportunities for collecting population-level data.
4. Denominator-level data would help determine the extent of coverage needed for effective health service delivery.

Piloting PRS data collection in two districts informed expansion of the data collection to include household socioeconomic data.

Initially, it was assumed that data collection would place an additional burden on the CHWs; therefore, the PRS was limited to a few important data elements/variables. After pilot implementation in two upazilas, additional data collection seemed feasible, and the scope of the PRS was expanded.

The PRS now stores individual-level demographic data and household socioeconomic data, which CHWs collect during routine home visits. Data collection for the PRS builds on and replaces previous data collection efforts, including the geographic reconnaissance collected by the DGHS on a yearly basis[29] through 2010, and household data collected on the FWA Register at the beginning of each year. The PRS incorporates these data elements and in addition adds household socioeconomic variables.

Design, Development, and Implementation

The developers at icddr,b had previous experience conducting registration of households and individuals for health and demographic surveys. This experience informed the design of the PRS, which took approximately three months to develop. During the implementation stage, some issues arose, including overlap in catchment areas and service responsibilities between the two types of CHWs.

Catchment Areas of CHWs

The organizational units from both the DGHS and the DGFP, as well as the option for one CHW to work in multiple catchment areas, had to be accommodated within the PRS.

DGHS and DGFP are large organizations. Their organizational structures at the grassroots level are based on the administrative boundaries of headquarters at the national capital, followed by divisions, districts, and upazilas (subdistricts). The CHWs are located within the lowest tier of local government units, i.e. the union. In the past, there were three wards per union, but this was later increased to nine. However, the organizational structures of the DGHS and DGFP are still based on the old system of three

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wards rather than the nine wards, and the terms "old ward" and "new ward" are used to distinguish them. In the old wards, there are two or more FWAs under the DGFP, depending upon the size of the population, and the location where they work is called the FWA unit. They are supervised by the family planning inspector (FPI) based in the union. On the DGHS side, one HA is typically assigned to any old ward, and they are supervised by an AHI and a health inspector (HI) from the union.

The target population is larger for the HAs than for the FWAs. All households are allocated to both the FWA unit (served by FWAs) and the EPI sub-block (served by HAs). As noted previously, there is some overlap in services provided by FWAs and HAs, such as maternal and child care.

In the first version of the PRS, data on FWA unit and EPI sub-block were not available as options, so CHWs could not enter those data when they registered individuals/households. FWAs and HAs can both record household data, but if the FWA unit and sub-blocks are not attached to the data, the data will not be downloaded properly from the server.

Catchment areas were added to the PRS later. During the distribution of tablets, the data for the specific catchment area are required to be downloaded onto the respective tablets of FWAs and HAs.

Data entry for the PRS is done by both FWAs and HAs. Providers are authenticated for their own catchment areas. Initially, catchment areas were assigned manually upon verbal verification from the CHWs. When the PRS was expanded for use in new upazilas, automated systems were introduced, and some issues arose. For example, not all of the FWA units or HA wards were staffed, and there were vacancies in CHW positions; thus, the CHWs were given additional households, and the same person could be working across multiple units or wards. However, only one unit or ward was permitted per tablet. As a result, design changes were required in the PRS to accommodate data entry for multiple units or blocks on the same tablet.

In addition, as there was overlap in the catchment areas of the FWAs and HAs, some data ended up being entered twice. Later, the PRS design was changed to allow the CHWs to divide their catchment areas for registering households and members without overlapping. This was helpful to avoid any duplication.

Responsibility for registering households was divided among the CHWs, with up to 5,000 people allocated per CHW. The CHWs were permitted to enter the data for any household, and the CHWs registered households at their own pace. Regardless of which CHW collected data from the ward, the PRS data were organized according to the specific CHW's catchment areas. However, the catchment area as defined in the system sometimes conflicted with the actual catchment area of the HA/FWA due to adjustments made by local managers. This issue was resolved after discussion with local managers and supervisors by modifying the catchment areas.

Household Numbers

The numbers generated to make up for the absence of government-assigned numbered street addresses for households in the rural areas were arbitrary and not known to the household members or the CHWs.

Because there are no government-assigned numbering schemes for the households in the rural areas, it is not possible to track houses by a definitive identifier. As a result, arbitrary household numbers have to be assigned to the households. However, the system-generated numbers have limitations, as they are not known to either the CHWs or the household members. Instead, the CHWs use an informal system to identify the households based on their familiarity with the households and clients.

User Authentication

Given the absence of a national-level human resource information system, a provider database of CHWs was created for PRS user authentication at DGFP.

User authentication is important to be able to access the features of the PRS app. Because there is not a national HRIS in place for the DGFP, user credentials consisting of an ID and geo-references or administrative units were created for each FWA, and a database was created. The IDs of HAs were taken from the DGHS database. Having a database of PRS users allows the CHWs to use the app and perform data entry. When a national system is eventually established, authentication will be done from that national HRIS.

Incorporating National Standards

The PRS adheres to a number of national standards for different identifiers, such as Citizen Core Data Structure (CCDS), geo codes, NID, and birth registration number (BRN). This helps to ensure interoperability. Experience using these is described below.

Citizen Core Data Structure (CCDS)

The PRS had to be modified to accommodate the long list of occupation codes.

The Cabinet Division of the Government of Bangladesh (GOB) mandates that all ministries, divisions, departments, and directorate and subordinate offices follow the standards set forth in the CCDS[30] for the collection of population-level data. There are 20 variables in the CCDS,[31] 12 of which are mandatory and are included in the PRS.

In order to accommodate some of these mandatory variables in the tablet, innovations were required. For example, the list of occupation codes is too long to appear all at once on the small screen of the tablet. Users were having difficulty locating a particular occupation on the list. To address this, occupations found frequently in the rural areas were sorted to appear at the top of the dropdown list. Some new occupations were also added at the request of users.

Geo Codes

It was imperative to work with local government to update the geo codes.

Geo-spatial references developed by the BBS were used to identify the villages. Specifically, the BBS had developed geo codes, a geo-spatial reference scheme that identifies all geographical and administrative areas down to the village level. The use of the geo codes in the PRS ensured interoperability with other systems for potential data sharing. However, some challenges arose in the field, including the following:

- In some cases, the name of the village specified in the geo code did not match the actual village name, with the name and spelling (both Bangla and English) sometimes differing.
- Some villages were missing from the geo code.
- When administrative boundaries were changed or redrawn, changes were required in the Geo code, but updates were not available immediately.

Feedback from the community was essential to address the challenges. For example, the actual name of some villages had to be confirmed from the upazila/union parishad. These issues were raised with the local government units, who then communicated with the BBS. Close coordination between the BBS, as the repository of the geo codes, and users is imperative to address such issues quickly. The standards may

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[30] Bangladesh Gazette Extraordinary, September 20, 2012.

[31] Source: http://www.cabinet.gov.bd/site/page/ed80fa01-4477-4d43-99ac-5d836dadb3a1/CCDS-%E0%A6%A8%E0%A6%BF%E0%A6%B0%E0%A7%8D%E0%A6%A6%E0%A7%87%E0%A6%B6%E0%A6%BF%E0%A6%95%E0%A6%BE

require regular updates, and there should be a feedback mechanism between the users of the standards and the authorities who set them, the latter of whom should address issues as quickly as possible.

National Identity Card Number (NID) and Birth Registration Number (BRN)

Different identity documents show different name spelling and date of birth for the same person, which complicates the registration process and database search function. Early marriage is also problematic for obtaining the correct date of birth of women.

Some innovative features were added in the PRS to facilitate the registration process and searches, whereby the eMIS is able to capture data from different documents without human input. Barcode scanners are able to read the NID barcode (which is a PDF 417 standard barcode), the HID, etc. and capture the name, date of birth, and so on from such records. Additionally, the age as reported by the respondents is also included in the ELCO module.

In the PRS, the identification of a person is based on documents issued or authorized by the government. The national identity card and birth registration certificate with BRN are used as the primary documents for validating the date of birth and the name of the citizen. The voting-related particulars of each Bangladeshi citizen[32] are entered into a national database, and then citizens are given a national identity card bearing the NID number. The NID is issued by the Election Commission Secretariat under the Bangladesh Election Commission.

During registration, the CHWs request the NID card to capture personal details. However, collection of the NID posed significant challenges. Many citizens were unable to produce the card and reported that they had lost or were unable to find it. Recording the accurate date of birth and the name with correct spelling became problematic, as there were discrepancies in documents such as the NID and birth registration certificates in the spelling of names. The CHWs may have also recorded names using spelling that did not match that in any of the documents. Differences in spelling of the names could lead to problems identifying the person while using the database search functions.

In addition, given the practice of early marriage among girls, which may motivate some girls to lie about their age to circumvent laws regarding the age of marriage for girls, the documents may not contain the correct date of birth. This creates problems for providing services, especially with ELCOs, because service providers cannot provide some services when there are discrepancies in recorded age. No easy solutions were available in such situations.

Mobile Phones

As women were not always able to provide their mobile phone numbers, the CHWs were trained to find out the number using special codes if the phone was available.

Mobile phone use is very high in Bangladesh. Nonetheless, the CHWs faced problems collecting the numbers of the mobile phones from women, as many were using the phones owned by male members of the household and were unable to provide the number. It was difficult to collect the number if the owner was not present during registration. However, the CHWs were trained to find out the number using a special code if the phone was available. They were also made aware of the need to collect mobile numbers for communication purposes, which improved data collection significantly in scale-up areas.

Health ID (HID)

Some architectural issues should be finalized before full-scale implementation of the system, such as issues around HIDs.

As a unique identifier was essential for the health domain, an HID was generated for all registered household members through the PRS. At the initial stage, some duplicate values were generated. The

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[32] The minimum age to vote is 18 years. However, the NID Act allows the Election Commission Secretariat to enroll people below the age of 18. However, this remains to be implemented.

pattern of the temporary HID was changed from random numbers to a pattern (combination of geo code, household number, member serial number, and registration timestamp) to minimize duplication. The duplicate IDs were removed both using an automated process and manually. Duplicate service records were also eliminated, and constraints were imposed against some data fields. Proper data types were enforced according to column value.

DGHS started developing the SHR system, a health data repository for each citizen in Bangladesh, in 2015. One component of this system is MCI, from where each registered individual gets their unique HID. At the initial stage of PRS, the MCI was conceptualized but not functional. Temporary IDs were then planned to be provided, to be later replaced by pre-generated real HIDs from the MCI of the SHR system. Thus, SHR-generated HIDs were adopted for the PRS database. Seven million pre-generated HIDs were received in two batches. According to ThoughtWorks, the unique health identification number (UHID) is generated following the rules below[33]:

- Check-sum formula is done on the basis of the Luhn algorithm.[34] The initial digit (9) is not within the check-sum digit, check-sum digit being the last digit.
- HID is composed of 11 digits, and it always starts with 9.
- The next nine digits are random numbers without leading 0.
- There are no repeating numbers for more than three consecutive digits.
- There are no numbers with three consecutive digits of two sets in one number (e.g., 111 222 345 not allowed; 111 345 222 not allowed; however, 111 234567 or 123 222 454 is allowed).

The pattern matching validations are done while creating the HID and also later when a "*create patient request*" comes in the SHR.

ThoughtWorks also noted that the UHIDs were unique and not sequential. This was done deliberately as a part of the person identifiable information (PII) guidelines and to ensure that no one could guess another person's HID. For example, a member of one household should not be able to guess the UHIDs of the next household. They advised that during allocation, HIDs should not be distributed in a sorted manner. Instead, best practice would be to randomize the UHIDs during distribution.

The UHIDs are tracked against the facilities in the SHR system of the DGHS. To enable tracking, eMIS implementers were registered as organizations in the DGHS Human Resource Management System. In the MCI (patient registry), the HIDs could be allotted. In spite of this, however, duplication of temporary HIDs occurred due to gaps in data entry and syncing between the server and the device. Connectivity, over which there was little control, could have been an issue as well.

Difficulties were later faced while replacing the temporary HIDs given through the PRS with SHR UHIDs, as the population database became very large and copies were residing both on the device and the central server. It would have been better if the decision on HIDs had been made at an early stage of the project.

After completing registration in the PRS, HID cards are distributed to the household members. HID generation is discussed in this chapter, while printing and distribution is covered in Chapter 7.

Socioeconomic Status of the Household

Socioeconomic data need to be updated regularly to make them usable for decision-making purposes.

The initial version of the PRS collected data for variables relating to the individuals within a household. After introduction of the PRS in Basail upazila and upon review of CHWs' use of tablets for data collection,

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[33] Email communication between Angshuman Sarkar of ThoughtWorks and Md. Humayun Kabir on May 20, 2015.
[34] Source: https://en.wikipedia.org/wiki/Luhn_algorithm

it became apparent that the data collection did not place a substantial additional burden on the CHWs. The scope of data collection was then broadened to include socioeconomic data.

The rationale for collecting socioeconomic data for the household was that these data affect health outcomes and relate to socioeconomic determinants of health. The questions on socioeconomic variables were shortened from the Bangladesh Demographic and Health Survey questionnaire and include explanatory variables identified in simple descriptive analysis. Some of the socioeconomic status data elements, such as education and assets, are prone to change with time. Therefore, CHWs must update the PRS upon notice or on a yearly basis. Managers need to ensure that such data are kept updated at all times.

Migration

As the PRS is not implemented in urban areas, migration may not be captured accurately.

Migration is driven by the necessity to move due to vocation or events such as marriage. Anyone who has moved out of the household needs to be deleted from the list of household members. Similarly, anyone moving into the household should be added as a member. These data involve multiple CHWs, as migration involves moving from one catchment area to another. When one CHW changes the status of the individual or marks someone as having migrated, a flag is issued. Any changes are reflected in the both the HA and FWA databases. If the movement happens in an area where the PRS has been implemented, the CHW in the relevant area gets a notification to add the individual to their catchment area. Capturing migration data poses some challenges when someone moves into an area without such registration. Rolling out the eMIS in all areas, including urban areas, is not likely to happen; in these cases, migration will go unrecorded.

Use of PRS Data in Service Modules

PRS tables feed data to the service-related apps and hence are fundamental to the eMIS ecosystem.

The PRS provides denominator-level data, and the information in the PRS database forms the basis for all services provided to a particular individual, either at the community or facility level. Population registration is an ongoing activity for the CHWs but not for the facility-based providers. Therefore, the system developers needed to ensure a robust system of sharing the data collected by the CHWs or facility-based service providers. The PRS can be accessed by both the CHWs and facility-level providers, whether to collect or access any service data.

Partial PRS

Because the PRS is conducted at the household level, facility-based registration is partial and needs to be completed in the community.

The PRS houses data collected at the household level. Records of any individual registered through the PRS are made accessible to both CHWs and facility-based providers, helping to ensure a continuum of care. However, the registration process requires time to complete. While the CHWs can immediately register a person, the facility-level providers are not able to do so—there are queues in the facilities, and when there is rush, serving clients quickly becomes the top priority. There may be people from areas not covered under the PRS or who have yet to be registered in the communities. When such people visit the facilities, they are considered NRCs in the facilities, and some data are captured to keep track of them, such as name, address, date of birth, and mobile phone number. The NRCs need to be followed up by the CHWs in the future to complete registration, or duplication of records may result. Duplication occurs if the same person is registered by the CHW at the household level as a new member without any linkage to previous registration at the facility.

In some situations, the facility system may be introduced prior to the community system. Facility and community systems are designed to run independently. To register those presenting in the facility without registration, NRC was broadened to include partial registration. That way, a person registered in a facility

can easily be registered later in the community. The partial PRS feature is implemented in the facilities. Instead of doing complete registration of the household, the names and some particulars of other members of the household are collected. While previously only the name of the client was recorded in the facility and the NRC number assigned, the system was changed to capture some additional variables, such as names of all members of the household, number of members in the household, and name of household head. This should help to identify the correct household for complete registration. When the community component is functional in the area, the FWA/HA gets notification of the people registered through partial PRS. Such notifications also help CHWs prioritize registration of these households.

Data Collection through External Data Collectors and CHWs

Public sector CHWs performed data collection better than the outsourced personnel because they already knew the community members and visited them regularly in the course of their work.

In the initial phase of the PRS, data were collected by both GOB CHWs and private data collectors in order to test different methods and assess their scalability. In Basail, GOB personnel (HAs, FWAs) were used, while in Madhabpur, GOB community-level workers collected data for three unions and the remainder were covered by private data collectors appointed by Shimantik on behalf of the MaMoni HSS.

It was initially assumed that PRS data collection would be additional work, and GOB providers would be slow to complete registration, while external data collectors would be able to complete registration quickly. However, this did not turn out to be the case. As outsiders, the external data collectors faced difficulties, and data collection did not reach expected levels. For the CHWs, on the other hand, data collection was easy, as they were accustomed to visiting households during the course of their work and were already acquainted with the community members. External data collectors were also costly and not considered feasible for national scale-up.

Data Collection Skills of CHWs

Population registration began as a separate module but was later integrated into community modules, allowing the CHWs to conduct registration during routine visits.

As the PRS was developed first, it was introduced as a stand-alone program. Other modules were introduced later. When the PRS is done separately, the CHWs have to perform it as extra work in addition to their regular duties. Later, population registration was integrated into community modules, allowing the CHWs to conduct population registration when required and while performing other routine tasks. This has eased the implementation process.

Considering users' knowledge about mobile apps, literacy, and their existing workload, it was anticipated that collecting PRS data might greatly increase the workload and time burden on CHWs. However, after deployment of the PRS in one upazila, it became apparent that time required for registering one household was minimal. The CHWs were registering 10 to 15 households (50 to 60 people) in a day. However, the speed of data entry is not the main consideration for the PRS, as data collected by the CHWs need to be of high quality as well.

Some issues with data quality were observed. For example, the values for some variables, such as NID and BRN, were missing. Collection of mobile phone numbers was also not optimal. Ensuring accuracy involves training and effective communication of data definitions to those who collect the data. Some validations were built into the system, and data verifications are included in the supervisors' module.

The value of the PRS was quickly understood by the CHWs. It has freed them from repetitive work (in different sections of the paper-based forms, some variables were copied repeatedly) and has made it easy to identify patients for service-related data.

Seasonal Effects on Performance

Seasonal weather and work patterns may affect the performance of CHWs.

Most of the areas of Basail upazila is low lying, and if rainfall continues for several hours, these areas are submerged. This makes it difficult for the CHWs to visit houses and hampers their work. HAs and FWAs may also be reluctant to work during rainy seasons due to accessibility issues. During March through May, most household members remain busy with harvesting and are not at home, which affects visits and in turn slows down registration in the community. This was brought to the attention of upazila managers, who instructed the CHWs to continue their work using umbrellas. The district managers were also aware of the issue and instructed the CHWs to continue their work.

Expansion of Functionalities

The value of PRS data becomes apparent when used by other programs.

When the Health Economics Unit of the MOHFW initiated their pilot health insurance project (*Shastho Surokkha Karmasuchi*) in three upazilas of Tangail (Ghatail, Modhupur, Kalihati), they needed data on the economic status of all households to identify those that were below the poverty line. Since the PRS was in the process of being implemented in all upazilas of Tangail, the variables they requested (household economic data on three additional variables) were included in the socioeconomic status section. The flexibility inherent in the PRS is noteworthy in the sense that it offers insight into what can be accomplished using the PRS in other modules of the eRegister. There have also been discussions on using PRS data for NCD screening in rural areas.

Conclusions

Population registration through the PRS has opened up many possibilities for health service delivery. It allows the CHWs to generate lists of target groups, such as eligible couples (for family planning), children (for immunization or other services), births, and deaths. PRS data need to be updated on a regular basis, and supervisors and managers can play a role in this process. Experience with the PRS also calls for engagement or collaboration with national standard-setting organizations.

CHAPTER 5. COMMUNITY AND SUPERVISORY SYSTEMS

This chapter describes the lessons learned through deployment of the community service and supervisory modules (i.e., the FWA eRegister and HA eRegister, including eSupervision Systems for FPI, AHI and HI, UFPO and the upazila health and family planning officer). The development challenges were significant, given the overlap in some activities performed at the community level by both DGHS and DGFP staff, administrative arrangements at the local level (which deviated from instructions given from the central level), and sensitivity to cultural behaviors and norms. The chapter describes how these issues were addressed during the development and implementation phases and how a comprehensive and interlinked system was established through eRegisters.

Converting the FWA Register to an eRegister

The FWA Register, the document on which the FWA eRegister is based, is used by the FWAs for collecting data on all activities they perform, except the monthly AWP. Data can be recorded in one large, bound volume of the FWA Register, which contains many different sections. Currently, the eighth version of the paper FWA Register introduced in 2016 is being used in the field, and the ninth version will be introduced in 2019. In addition, the FWA Register has been transformed into an electronic format eRegister, which has made it possible for the FWAs to conduct all their work digitally. eRegisters have been introduced in a few districts, where the FWAs are using both paper and electronic registers. In the future, they will only be using eRegisters. Where the paper FWA Register only is used, the FWAs manually prepare the end-of-month reports known as management information system (MIS) Form 1. These can also be generated using FWA eRegister.

FWA catchment areas are known as FWA units. Assigning catchment areas was difficult initially, as discussed in Chapter 4. The CHWs maintain their list of clients and record transactions or services provided in the relevant section of the FWA Register, including:

- Eligible couples
- Children 0–18 months (for vaccinations) and children 0–5 years (for other health services)
- Adolescent health care
- Pregnant mother and neonate
- Death list
- Daily activities
- Acceptors of injectables
- Monthly stock and distribution
- Household population list
- Village population list
- Acceptors of family planning methods

All of these are available for use in the electronic version. In addition, the preparation of the monthly AWP, an activity performed before each month, is also included in the eRegister.

The developers faced the following challenges during app design:
- **Configuring the catchment area of the FWA unit or HA ward**: Implementation of the eMIS began with the PRS. Registration work was conducted by both HAs and FWAs. The unit used for the PRS was the village. However, the FWAs actually work in FWA units, which can be an entire village, part of a village, or larger than a village. Those could be located in one ward or be composed of parts of different wards. For the HA, the unit is always a ward. This variation in catchment areas created challenges after introduction of the service modules. In the PRS, unit data were not entered. If units were not clearly identified, data would not download correctly onto the FWA's device, and some records would be missing. As the FWAs also share data with

the HAs, the correct ward needs to be identified in their device. In order to eliminate the problems of assigning the FWA unit or local government ward, all data were managed centrally in a database (extended facilities registry), and areas could be assigned by the managers to individual CHWs in the monitoring web page. This issue is discussed in detail in Chapter 8.

- **FWA's identification of the household numbers, which were generated randomly by the system, and consequently, finding the members whose registration was done by the HA, and vice versa for the HAs about the households registered by FWAs.** Search parameters were later expanded to make searches more effective.

Eligible Couple (ELCO) Module

A field was created in the ELCO module to record actual age, as dates recorded in the PRS were preventing generation of the correct list of ELCOs.

The FWAs compile or update the list of ELCOs in their respective catchment areas or administrative units in the FWA Register at the beginning of each year. ELCO refers to a currently married woman of reproductive age (15–49 years) whom the FWA visits during door-to-door calls and counsels on different family planning methods and health and hygiene, or to whom the FWA distributes reproductive health commodities. While designing the eRegister, developers faced the following challenges:

- **People were missing from the register due to household configuration**: All service modules/registers used the population database when providing services or collecting the data of any person within the catchment area. The membership criteria are applied for entering a given person in the household. Members who do not reside in the household at night (e.g., employed outside of their village) or who eat from a different kitchen are not recorded for the household or are not registered to a particular household. The household table in the eMIS does not show the name of the husband. For this reason, when the ELCO list was generated based on the household table, those names were missing. The identity of the husband is important for identifying the ELCO. An incomplete ELCO list meant that some clients were likely to be missed for services from both the community and facility systems. Additional queries were written to pick up the name of missing persons.

- **Mismatch between actual and reported date of birth**: Some individuals were not appearing in the ELCO list. One reason was the age limit. There are a number of sources for recording the date of birth of any individual. Most Bangladeshis are not included in the Civil Registration and Vital Statistics. The primary source document for the PRS is the NID card and/or birth registration certificate. Marriage documents are not considered a source, since some parents backdate the date of birth in order for the child to reach legal age earlier and avoid legal complications arising from child marriages. This becomes a problem for the providers when providing services. The age-related problems were solved by adding a separate field for age of the ELCOs in the ELCO module.

- **Practice of reserved numbers in the paper register**: The FWAs copied historical data from the paper register and entered them into the eRegister. However, many mismatches were found between the paper register and the list generated in the eRegister. For example, in the paper register, FWAs set ELCO numbers based on village. At the end of the list, they left some rows blank so as to be able to add new couples who would be registered later in these consecutively numbered rows. But in the eRegister, they were not able to continue that practice. The FWAs retrieve the list of ELCOs from the PRS database. An advance search mechanism had to be implemented to find the correct client with ease and speed.

"Woman Injectable" Module

Integration of community and facility systems was required to keep track of women receiving their first contraceptive injectable dose at a facility and the subsequent doses from a CHW.

The list of women who have received injectable contraceptives forms part of the FWA Register. The design of the "Women Injectable" module needed to address the issue of integration of the FWA eRegister and Union Facility eRegister (Family Planning eRegister), as the initial dose of the injectable could only be administered by the union-level providers or above at a facility, and the second and subsequent doses could be administered in the community either by an FWV or FWA.

Maternal and Child Health (MCH) Module

Integration of the MCH facility and community modules resulted in enhancements from the paper register.

Development of the MCH facility and community modules required the integration of systems used by different levels of providers for documentation. However, the developers faced problems resulting from insufficient information about the two registers; the integrated electronic system was subsequently modified when the content in the Register was found to be incomplete. For example, in the MCH Register, the sex of the child is not recorded, but this has been incorporated into the eRegister. In addition, the providers are required to collect the height of each pregnant woman. If height data is available from the facilities database, the community systems are able to identify the pregnant women at risk, as height under 145 centimeters is considered a danger sign requiring referral to the facilities.

Death Module

Integration of the FWA and HA modules was required for the reporting of births and deaths.

Birth and death events are captured at the community level by both the FWAs and the HAs. There is a section in the paper registers to record the name of the person with the date of his or her death, while the birth events are recorded in the MCH module. Both the FWAs and HAs capture these events. The tables in the database were amended to enable integration of the HA and FWA tables in the database). For birth, there is no separate module. It is integrated with the MCH module. The birth notification is generated using that module.

Notifications and Job Aids

Notifications about past events and job aids alerting CHWs about services due were made possible because of the digital data available in the system.

Notifications and job aids help CHWs be proactive about the tasks for which they are responsible. Notifications remind them about events in the past that should have been attended by the CHWs, while job aids alert the CHWs that particular services or data collection are due in the coming days or weeks. These are generated automatically and remain available in the app interface. For example, a notification will alert the CHWs that the EDD of some clients is overdue and that their delivery outcome data should be collected as soon as possible. A job aid button shows the names of women likely to deliver their babies within next seven days (again, based on the EDD) and the action(s) that should be initiated. These tools are novel and made possible thanks to the digital data available in the system.

Developing the HA eRegister

There are similarities in the work performed by the HAs and FWAs in the areas of maternal and child health, under-five child care, and death reporting. Therefore, the modules for these areas are similar for both.

Expanded Program for Immunization (EPI) for Child and Woman Module

The HA eRegister tracks individuals registered with HID and NRC numbers, as well as those not registered anywhere, including through partial PRS or NRC.

The EPI module was developed for the HAs, who maintain a list of children ages 0–23 months for the purposes of immunization. This list is generated using the PRS database and requires data about the sub-block. However, when FWAs conducted the PRS, they were not able to input any values into the sub-block field. In some instances, the HAs were also not entering sub-block values. The issue is that if this value is not entered, the result is that some children may be omitted from the EPI list. Although initially not mandatory, HAs were later required to enter a value.

At one point, the system was not showing the correct dates for the next vaccination due, which needed to be retrieved from the system based on session dates. Therefore, the EPI session value had to be captured by the HAs. The EPI session is organized on the basis of ward, whether in the rural areas or in municipalities. However, generating the list became a problem when the session was in a municipality. Instructions were given to monitoring and evaluation officers to identify whether the wards where the EPI sessions took place were in the municipality or not. In reality, the EPI technician (MTEPI) located in the Upazila Health Complex is responsible for creating EPI sessions. The EPI sessions were then added to the monitoring tools and can be assigned when the device is set for the HA. They will be assigned to MTEPI in the future.

When a child or a woman is registered for EPI, a card is issued which is retained by the immunized person. They usually bring this card when presenting for the next dose at the EPI center. These processes are emulated in the HA eRegister. However, in the eRegister, all individuals also need to be tracked through their HID or NRC ID. Managing NRCs in the eRegister became a challenge, because people who were given NRCs could not be instantly identified in the eRegister. The NRCs of those registered under the PRS could not be matched against HIDs, nor could they be downloaded for the specific session.

Report Generation and Submissions

Developing Systems for Supervisors and Managers

It was possible to expand the functionalities of the supervision modules over time.

In the district set-up, the upazila functions as the key administrative unit and works through unions. The union-level structures have first-line facilities, as well as CHWs who perform domiciliary visits and are supervised by union-level supervisors. There is a lack of documentation on the work of supervisors. Business processes and the content of each register could not be analyzed properly before starting the development process, e.g., a clear description of business processes for the eSupervision system (FPI, AHI, HI, UFPO, upazila health and family planning officer) was not available. Frequent demands for changes in content, logic, and design layout made the development of eSupervision system complicated.

The lack of proper documentation for developing eSupervision systems hindered the development process. The app includes some novel features included as a result of discussions with the field-level staff. The supervisors approve the AWPs of those they supervise and also prepare their own work plans submitted to the upazila manager or UFPO. The AWP submission and approval process was made interactive—the system can validate AWP submission and assist the CHWs to prepare AWPs. The supervisors can approve them without any changes or request modifications. The approved AWP becomes available to the next level of officials.

During supervisory visits, the supervisors inspect materials carried by the FWA, such as their bag or tablet. These were added in the interface with radio buttons. As there was no paper form to record supervisory visits, the addition of this function has added value to the system.

The supervisors are required to approve the end-of-month reports submitted by the field workers. This could not be added to the app interface and rather has to be done through web-based tools, as it requires retrieval of the reports and aggregating the reports at the union level.

It is possible to expand the functionalities of the supervision modules over time. The system depends on synchronization of data, as well as on downloads when necessary, which requires connectivity and the app being online. The supervisors can verify the data collected by the field workers and download the data for verification purposes.

Conclusions

Digitization under the eMIS is bringing many benefits to the organization. The DGFP introduced the eighth version of the FWA Register in 2016 and the ninth version in January 2019. The digitization of the community modules has brought synergies to the sharing of data in an area assigned to different cadres of health and family planning workers. It has also contributed new tools for the CHWs, which improves their ability to perform their duties well.

CHAPTER 6. FACILITY MODULES

This chapter addresses the issues faced in designing and implementing solutions for the union-level facilities providing services to local communities.

Facilities Under DGFP and DGHS

Both DGFP and DGHS have union-level facilities. The facilities under the DGFP are referred to in this document as union health and family welfare centers (UHFWCs), and those under the DGHS, while also called UHFWCs, are referred to here as USCs or RDs to differentiate them from the DGFP facilities. These facilities provide a wealth of services. . The UHFWCs under the DGFP are equipped with paramedics for maternal, childcare, and family planning services (i.e., an FWV) and other general patients (i.e., a SACMO). The SACMO is responsible for providing general medical care in the UHFWCs. All UHFWCs are equipped to provide maternal and child care, including family planning services.

The readiness of UHFWCs to provide services was assessed by Save the Children in Bangladesh in 2016. Based on this assessment, the UHFWCs were categorized as A, B, and C.[35] The facilities in category A, also called upgraded UHFWCs, provide 24-hour delivery services. These UHFWCs also maintain a network of satellite clinics in all the wards under the union. These clinics are situated in a household visited by FWVs on specified dates, typically monthly, to provide services. The facilities under the DGHS are manned by a paramedic and serve the general patients, i.e., those presenting for reasons other than pregnancy. Occasionally, a trained physician also visits the USCs/RDs.

The FWVs and SACMOs record the results of the encounters with those seeking services in the relevant registers. A monthly report is prepared on the activities from the facilities and submitted to the medical officer (FP-MCH) using a paper form called Form 3.

Application Design

Consultation with domain experts, practitioners, and users helped ensure that the application was user friendly and adapted to the field context.

The tools developed for the union-level facilities for use by FWVs and SACMOS are composed of three modules, namely maternal and child care, family planning methods, and the general patient module. To produce these tools, the developers needed an understanding of the bifurcated health system of Bangladesh. They accomplished this through consultation with domain experts and review of available documents, registers, and guidelines. They also learned through interaction with the practitioners and by frequent field visits.

Gaining a better understanding of the field realities and practices allowed the developers to make the system more adaptable and user friendly, but development took longer than anticipated due to frequent changes in the contents, logic, and design layout. For example, the facilities often lack critical equipment and due to financial constraints cannot replace it when it no longer functions. As a result, some fields (e.g., the weight[36] variable) were changed from mandatory to optional in the app interface. Discrepancies between national-level guidelines and field-level practices were also observed, which needed to be accommodated in the system. In addition, developers received frequent requests for changes by the technical team, GOB experts, and end users. Multiple changes also had to be made in the medical history panel, in part because the developers had difficulty understanding the medical terms and found some of the terms ambiguous. Finally, all medicines were not equally available for both SACMOs and FWVs to administer; thus, when managing

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[35] The breakdown of categories are: A=446, B=2,173, and C=650, totaling 3,269. Source: Directorate General of Family Planning (DGFP). (2016). *Strengthening Union Level Facilities to Improve Institutional Delivery*. Bangladesh: DGFP. Retrieved from https://www.healthynewbornnetwork.org/event/national-meeting-strengthening-union-level-facilities-improve-institutional-delivery/.

[36] The weight machines are supplied centrally, and many facilities lack this machine.

the inventory of pharmaceuticals, adjustments had to be made or the list had to be updated as per the provider.

One realization from the design phase was that the developers relied upon the written documents (e.g., guidelines, official circulars, and registers), but these documents are not always followed stringently in the field. Field situations varied compared to what was specified in the guidelines, and software design had to change to accommodate the field realities. Therefore, field visits and interaction with users were essential parts of development. It was also found that demonstration of tools helped to generate ideas and formulate new requirements for the system.

Setup of a server required setup of the database, application server, and synchronization server, which was very time-consuming. The issue was resolved by an automated scalable server system based on virtual technology. The database design was modified to be able to be replicated from the monitoring tool with a few clicks.

Nonregistered Clients (NRCs)

Providers should be trained to use multiple search criteria to search for the records of clients unable to provide HIDs.

Anyone who comes to a facility has the right to obtain health services, but the eMIS requires the clients to be identifiable in order to access previous records and ensure a continuum of care. Because the facilities do not perform population registration services for the community, data from the PRS are supposed to be used to identify the service seekers. However, people who have not yet been registered at the community level may present at the facilities for services, and their subsequent records nonetheless have to be maintained. As they cannot be provided with an HID at the facilities, a nonregistered client (NRC) module was created to maintain their records at the facility. Limited personal data are captured in this module, the objective being to merge them later in the PRS once the CHWs have conducted proper registration at the household level.

The creation of the NRC module led to some problems over time, particularly that duplications or multiple NRC IDs were sometimes created for the same client. As a result, it became difficult for the provider to retrieve the person's previously recorded data. There were also clients who had been registered either in the community or at the facility but did not bring their HID card or NRC number.

To ensure that clients brought or disclosed their ID number while seeking services at the facilities, the following actions were taken:

- Some FWVs (as in the UHFWC of Shajahanpur upazila in Habiganj district) would delay attending to clients without cards if not in need of emergency care and serve those with cards immediately. Such behavior motivated the clients to bring their ID numbers during future visits.
- To help the end users of the app, options in the search tool were expanded. Multiple options were included to make it easy to search for the person using multiple parameters.
- The ability to generate lists was added. Automatic generation of the pregnant women list in the selected area greatly reduced the need to use NRC numbers for finding someone from the database. The most frequently used option had become the filtration of pregnant women within the geographical boundary.
- The option for a service-specific search within a given period and location was also developed to narrow down the list generated.

The app design should be sufficiently flexible and intuitive to address the behavior of service recipients. While search tools were being modified to enable pre-defined searches, providers insisted that clients bring their ID cards when appearing for services, thereby motivating clients. The app features multiple search options to find the people registered as NRCs, and providers should use these search options

consistently to reduce duplication. When clients are unable to provide HIDs, the providers should be trained to search for their records using multiple criteria.

Client Referrals

A system for monitoring referrals between union- and higher-level facilities was needed to update the data in the electronic system.

Client referrals are another area addressed by the eMIS system. The providers at union-level facilities are not able to provide all family planning methods; therefore, they must refer clients requiring some methods, such as long-acting methods, to higher-level facilities (e.g., a maternal and child welfare center) or physicians. These referrals are required to be tracked through communication between the referring and referred facilities. The referring health care worker provides a referral slip, and the referred facility captures the results, including services provided. However, the lack of a system for monitoring the referrals meant that the data in the electronic system could not be updated. As a result, a system was developed to establish communication channels through the app interface.

Once the digital system was introduced to track referrals of clients seeking other health services, the data showed that there was an increase in referrals of high-risk mothers from union facilities at Habiganj district. This was verified by the number of deliveries and their outcomes. However, in order to see the results of a referral, a message has to be generated by the referred facility through email, call, or text message, as it is not yet possible to see whether the clients visited specific upper-level facilities, as these facilities do not use the eMIS.

Login Failure and Online Login Tracker

Users required guidance on how to input their correct login information.

When the facility registers were introduced in the field, users were inputting incorrect passwords, possibly due to lack of familiarity with computer systems or confusion about the keyboard layout. As a result, the app would not load, and the error message "Login failure" appeared, resulting in total system blackout. However, the online login tracker on the server side also captured users' login attempts, and providers and their supervisors were later provided guidance on how to access the system correctly.

Report Preparation and Submission

Providers were initially assigned only one facility in the eMIS reporting system, but this was later changed to accommodate providers with multiple facility assignments.

The providers working at the facility prepare an end-of-month report called MIS-3, which is sent to the upazila manager and aggregated nationally in the MIS-4/5 report. The MIS-3 report is generated through a single click. Initially, one device was allocated per facility for use for that particular facility. However, as providers are assigned more than one facility in an administrative arrangement known as "additional charge" to address provider vacancies, an option was added to the facility registry to allow the providers to use the same device if they had multiple assignments. For example, in Chunarughat upazila of Habiganj district, two FWVs from the neighboring unions were attending satellite sessions in a third union. The FWVs were allowed to submit separate MIS-3 forms for each facility, according to their assignments.

In the current paper-based reporting mechanism being used concurrently with the eMIS, there is a delay in the union-level data reaching the national level. For instance, the MIS-3 form is submitted at the end of the month to the upazila manager. Then it is compiled at the upazila level and entered as aggregated numbers in the digital system. In the eMIS system, as soon as a client's encounter is recorded, the full data set is accessible to the next level based on which reports are generated.

Performance Quality

More analytical tools were added to allow for review of provider performance in real-time.

Service quality cannot be determined from aggregated routine data, but this information could be useful to managers to improve performance and quality. Therefore, more analytical tools were added to review the performance of the providers. As data are collected at the most granular level, adherence to the quality of the service can also be monitored at the supervisor level in real-time, e.g., whether blood pressure is recorded appropriately or urine was analyzed during an antenatal care session.

Conclusions

The union-level facility eRegister has improved the work at facilities, as well as the reporting. In addition, new tools have the potential to ensure quality of care. Under the eMIS, managers are now able to monitor the quality of care and pursue referral cases.

CHAPTER 7. MONITORING AND ADMINISTRATIVE TOOLS

This chapter discusses web-based tools developed to perform system management functions by system administrators and monitoring and administrative functions by supervisors, managers at the district and subdistrict levels, and decision makers at the national level. Data relating to service delivery may be viewed and management tasks performed by accessing different tools.

The monitoring tools webpage hosts a set of tools for managers, supervisors, and decision makers, as well as CHWs and other providers. The following actions can be performed from this website:

- View population registration, including status of registration and some key identifiers
- View community statistics, by activities or functions
- View facility statistics, including status of services provided by UHFWCs and satellite clinics
- View submitted reports
- View AWP submission status
- View activities in paper register format
- Perform management and administrative functions
- Download resources such as user manuals and other documents
- Submit eTickets for any issues requiring resolution

User Access

The monitoring tools website came at a later stage of eMIS development in response to requests from users to see the results of workers' performance and service delivery, as discussed in the monthly meetings at the district and upazila levels.

The eMIS monitoring website was designed to allow different levels of users to access the site to monitor the progress of activities from their own location. Access is restricted to users authorized by the system and is provided to users based on criteria related to their roles and responsibilities or hierarchies in the administrative setup. Managers, supervisors, providers, and other users are accorded levels of access based on their roles. For example, a manager has access to all data in the district, whereas the supervisor in a union and a CHW in the unit would have access to data for their catchment area only.

Granting access and ensuring security were a challenge for developers. A single-page application (SPA)[37] was used to ensure the security of webpages. To make the system robust, the "prepare statement" system of the Java Data Base Connectivity (JDBC) was used, which checks for whether incoming user requests are valid. Authentication through the Human Resource Management database was the desired option for departmental users. In addition, eMIS developers advocated for allocating email address to all staff, especially in DGFP, as DGHS had already allocated email addresses to its staff.

Data Visualization

Data visualizations were useful for reviewing data entry and progress, including during the monthly meeting at the subdistrict level.

Data visualization is necessary for supervisors or managers at district and upazila levels and above. Users also requested developing tools to view work carried out by the providers in the field. The eMIS monitoring site presents data in tabular and chart views. Different types of charts are used to present data, such as bar

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[37] A single-page application (SPA) is a web application or web site that interacts with the user by dynamically rewriting the current page rather than loading entire new pages from a server. This approach avoids interruption of the user experience between successive pages, making the application behave more like a desktop application. Interaction with the SPA often involves dynamic communication with the web server behind the scenes. Source: https://en.wikipedia.org/wiki/Single-page_application

charts, stacked bars, columns, and pie charts. DataTables[38] was used for tabular presentation of data. In tabular format, data could be presented with pagination[39]—which controls how many entries are available in a single page—multi-column ordering, and table sorting. For the graph data view, initially Highcharts and later Chart.js[40] were used to create simple and complex charts. A GIS option is also available, although not yet fully functional at the time of this writing, to map data to a specific area. It is possible to download data in pdf or csv format or to print. Leafletjs[41] has also been used to present a map with the data. GIS-based tools are planned for this page in the future. DataTables has also been used to export data easily. Data from this webpage are used in monthly meetings or for general monitoring purposes.

National Reports

While it takes time to generate the MIS-1 report of the current month due to the need for complex calculations, reports for previous months are readily accessible, as they are stored in a separate table.

National reports are generated using the app interface or through the webpage. Initially, some data were not copied from the paper form to the eRegister, resulting in slow generation of the MIS-1 report; unless all data from the paper registers are copied into the app, it is not possible to complete the report. For example, the status of the last family planning method adopted by the client has to be tracked each month by the FWA. The total number of visits or rounds in the area are also noted in the MIS-1 report.

Generating the MIS-1 form requires a complex calculation on the server side, for which queries were optimized. The developers required better understanding of these processes to design the form or write the codes, which took significant time to complete. Due to the number of cells and complex calculations involving many tables within the database, significant reductions of time in generation of the report seemed difficult for the current month.[42] However, reports relating to previous months could be viewed easily, as these are accessed from a table generated during the supervisor's approval of the FWAs' reports; once approved, the action is complete and final.

Management Tools

Provider Management and Catchment Area Assignment

Initially, providers were assigned to areas manually. However, as the number of users began to increase, web-based tools were introduced through the monitoring page.

Area assignment is done through the monitoring webpage. In this process, unit and ward data are assigned to the provider. There are geo-location codes for all of the facilities under the DGHS that also extend to the DGFP facilities (UHFWCs). Initially, areas like a village, single unit, and single ward could be assigned to a provider, but the area assignment posed some difficulties. Initial design of the eRegister allowed only one unit in one device, but some providers work in multiple units. Later, the scope was broadened to assign multiple units, wards, and unions simultaneously for the same device. Therefore, providers who work in multiple unions are assigned to multiple unions.

The eMIS apps are for use by the FWAs, FWVs, FPIs, and SACMOs of the DGFP, and the HAs, AHIs, HIs, and SACMOs of the DGHS. As public servants, they are subject to transfer, promotion, and retirement, which could entail changes in their position. The database needs to be updated regularly to

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[38] DataTables is a plug-in for the jQuery JavaScript library.

[39] Pagination is the process of dividing a document into discrete pages.

[40] An open-source solution for charts. In Chart.js it is easy to include animated, interactive graphs on the website and available for free with the MIT license. Source: https://www.chartjs.org/

[41] Leaflet is the open-source JavaScript library for mobile-friendly interactive maps.

[42] This has been addressed in the current version of the software.

capture such events. The importance of having a full-fledged human resource information system was emphasized since the inception of the program.

Report Generation in the Facility

Monitoring tools make it possible to view the performance of the facility providers, including services provided to individuals having NRCs or HIDs.

The MIS-3 report is prepared from the facility side. In the manual system, the providers and their supervisors could not produce the MIS-3 report quickly, and the process usually required 40–45 days. There was no real-time aggregated data management tool to monitor data at all levels of the health system. There was also no tracking system to monitor the services provided to NRCs and people with an HID.

To address these issues, a facility registry was created for the DGFP. In the registry's Geo code, values such as the latitude and longitude and unique facility ID were recorded to allow more flexibility in provider assignment. The registry can handle multiple facilities in a union, as there is a unique ID for each facility. In the GIS map, there are different levels of aggregated data of MNC, Family Planning, and General Practitioner registers. This makes it possible to see aggregate data relating to a particular upazila, district, or the whole country at a glance, enabling the supervisors to monitor more efficiently. There is also a tracking system to monitor services rendered to the NRCs and clients with HID cards.

Register View

Creating replicas of paper registers in web view helped convince management to go paperless and also provided a backup.

The eMIS tools, which are digital and used with tablets, replace the paper-based registers. However, during initial implementation of the tools, the CHWs continued to use both tablets and paper registers. This was so that the paper registers could serve as a backup in case of failure of the system. In addition, the managers had to be convinced that all activities could be performed using tablets before paper registers could be eliminated. Ultimately, the eMIS implementers negotiated for paperless records, and register views were developed to convince management that elimination of paper did not mean that register views could not be replicated. The register views are replicas of the paper register and allow for generation of pdf files based on selected months or a date range. The replica of register pages created enough confidence to start paperless piloting in two upazilas at a later time.

eTicketing

A system of eTicketing allowed users to communicate directly with the eMIS developers when issues arose.

eTicketing is a tool that allows users to report electronically any issues related to implementation, software use, or bugs in the system. Previously, providers reported problems to their field supervisors or monitoring officer in person or over mobile phone. The problems were then relayed to the eMIS implementers/developers. The users were often not able to report details of the problem and were not informed of the actions taken, as the history of the solved issues was not available. To make it possible to connect users directly to the developers and implementers and to collect users' inputs quickly, a web-based eTicketing system was developed. The issues identified are easily categorized, and similar issues are grouped.

Source Code and Version Management

Using a repository and version numbers helped the team of developers manage version changes.

Because the eMIS team was comprised of different groups, there was a need to share codes for the repositories used, as well as the need to manage versions. Version management requires controlling the

changes done by multiple developers; otherwise, it is difficult to track the changes in code over time. A rollback feature is also required to allow the team to go back to a previous version if major problems occur in the version introduced later. Developers working in teams are continually writing new source codes and changing existing source codes. The codes for a project, app, or software component is typically organized in a folder structure or "file tree." One developer on the team may be working on a new feature while another fixes an unrelated bug by changing code; each developer may make changes in several parts of the file tree. Using the repository helped them manage team work. For version changes, giving incremental numbers (whole number or decimal, depending upon the extent of the modification) was made mandatory.

Sync Status Tool

The sync checker enables monitoring of the status of synchronization between the device and server databases.

Data sync is an essential component of the eMIS that ensures that there are always similarities between the database residing in the device and the central server. If data were not uploaded correctly, discrepancies arise between the device and server data. A tool to view sync status compares data between the device and server based on important tables. Perfect synchronization shows in green, and for discrepancies, the color turns red or yellow depending upon the extent of discrepancies. Managers can take appropriate actions after evaluating the sync status.

Conclusions

A ministry-wide HRIS is needed to authenticate users on the webpage and perform functions such as provider assignment. Web-based monitoring tools should be comprehensive enough to engage all levels of managers and decision makers and should have data visualizations. The site should also evolve to address new requirements, and maintenance and continuous development of this site should be a priority. The monitoring webpage allows implementers to monitor the status of ongoing registration by providing tools managers can use. The developers and field implementation team can also monitor different aspects of the system.

CHAPTER 8. IMPLEMENTATION ARRANGEMENTS

The experience of implementing the eMIS tools in Tangail and Habiganj districts informed later scale-up of the eMIS in other districts. This chapter discusses the role of eMIS implementing partners in engagement with all stakeholders, collaboration with central- and local-level officials, organization of training programs, and coordination among multiple implementing partners.

Collaboration with Government

eMIS implementation coincided with the phasing out of the Millennium Development Goals and the introduction of the Sustainable Development Goals on the global stage. The government's vision for a digital Bangladesh generated great interest among government workers regarding digital solutions at different levels of the public sector. Development partners were also ready to align with the government in this area through financial and technical support. The eMIS tools were developed for users in the DGHS and DGFP, the principal stakeholders of the initiatives. The development of software solutions followed government-approved formats and guidance or clearance from the relevant authorities.

Regular Monitoring and Visits by Managers

Regular supervisory visits from management at the national and local levels play a significant role in motivating the workers at the community level.

During the implementation phase of the PRS, senior officials of the DGHS and DGFP made regular supervisory visits. The director-MIS of the DGFP and the deputy director of MIS, DGHS, along with development partner representatives, visited the implementation sites where district- and upazila-level managers were present. They interacted with the CHWs and observed them collecting data, while for their part the CHWs offered suggestions and alerted the officials when they encountered difficulties. The monitoring and evaluation officers attended the regular DGHS and DGFP meetings at the field level. They monitored the tab-based work on a regular basis. Central team members regularly attended monthly meetings at the upazila level.

Alignment with Government Programs

During the preparatory phase of the five-year sector program of the MOHFW, the potential of the eMIS was highlighted, resulting in the inclusion of scale-up of the eMIS in relevant operational plans of the 4th HPNSP under the DGFP.

The objectives of the eMIS were aligned with the country's vision for a digital Bangladesh. Implementation of the eMIS was organized in light of program objectives of the MOHFW and aligned with the MOHFW sector program. During development of the Fourth Health, Population and Nutrition Sector Program (4th HPNSP) for 2017–2022, the potential of the eMIS was highlighted. The eMIS partners advocated for including the scale up of eMIS tools in other districts in the 4th HPNSP. Buy-in from the DGFP was demonstrated in the design of two operational plans for community and health facility systems . The DGFP proposed to scale up eMIS all over the country. However, due to issues with resource allocation, the scope was narrowed to two divisions, or 15 of the 64 districts of the country.

Human Resource Issues

Credentials are required to use the eMIS apps. The DGHS MIS had been using a human resource information system to assign a unique ID to each staff member. However, there is no equivalent system in the DGFP (i.e., CHWs and their supervisors are not identified through a unique ID). Therefore, after discussion with the DGFP, provider IDs were assigned. Later, the DGFP started developing the HRIS as a part of an MOHFW initiative. Once the HRIS has been developed, the issue with credentials will likely be resolved, and the HRIS will be helpful in national rollout of eMIS.

Many FWA units in Tangail district were vacant. In some of the vacant units, FWAs working in the adjacent areas were given additional assignments. During implementation of the eMIS, a number of FWAs retired

and turned in their tablets to their managers. To keep the work continuing, additional areas were assigned to the CHWs. However, some CHWs raised objections, as they were supposed to conduct registration in more than one unit. It was strongly felt that vacant areas need to be filled when scale-up of eMIS is taken up in new districts.

Frequent transfer or turnover of GOB personnel also created difficulties, especially when it occurred for senior-level positions. These new staff needed orientation to and an understanding of the system.

Role of Implementing Partners[43]

The eMIS teams included people with knowledge of business processes who represented all implementing partners and who worked intensively with the developers. These team members thoroughly reviewed the then-current data collection system of the CHWs and provided guidance to the developers for designing the tools.

Implementing partners played several other roles on the eMIS project. The icddr,b and MEASURE Evaluation team had supported the DGFP and DGHS previously on data management issues, and it supported the DGFP through revision of the FWA eRegister (eighth edition, introduced in January 2016) during an earlier phase. The implementing partners also helped prepare an HA Register that was not introduced in the field.

In addition, the eMIS team worked with government officials and liaised with DGFP and DGHS officials at the headquarters and local levels during all phases—from software development to implementation. The DGHS and DGFP provided clearance for the use of the original paper tools on which the electronic tools were modeled. MIS directors of the DGFP and DGHS issued government orders (GOs).

District and upazila management was also involved. Prior to implementation of the eMIS system, meetings were conducted with district- and upazila-level managers in Tangail and Habiganj districts, including those from the DGFP and DGHS, to inform them and create awareness. Engagement of the DGFP and DGHS management had a positive effect on district and subdistrict staff and resulted in the following actions:

- **GO issued in support of the program**: A letter was issued from DGFP/DGHS headquarters informing the district- and local-level managers of the system before it was introduced.
- **Inception meetings held:** These are held at the local level and attended by local government representatives and district administration officials.
- **Training of trainers (TOT) organized**: A TOT was provided at the national level before formal training at the local level.
- **Letter to the participants issued**: A call-up letter was issued from headquarters instructing the participants to attend the training program.
- **Field visits conducted**: Local-level managers undertook visits on a regular basis. Visits were also organized for the senior-level personnel from headquarters.
- **Monthly review meeting agendas:** eMIS performance was discussed based on data in the monthly performance review meetings held at the upazila level.
- **Focal person appointed:** A focal person was identified by the departments to solve coordination issues between the departments.

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[43] The eMIS initiative is supported by USAID and includes a number of implementing partners (MEASURE Evaluation/icddr,b, MaMoni MNCSP/SCI). The SIAPS program also contributed before it phased out. MEASURE Evaluation/icddr,b contributed to the development of community systems and MaMoni HSS (later MaMoni MNCSP/SCI) to the facility systems.

Field Support and Management

icddr,b had a dedicated team at their headquarters which provided support to the field team. The field team consisted of one field support assistant (FSA) and later a field supervisor (FS) in each upazila where the eMIS was being implemented. The FSA and FS were responsible for maintaining communication with the local-level officials, supervisors, and managers. They participated in the TOTs, took part in the local training programs, and supported the field staff in eMIS implementation. In Tangail district, on-site support was provided by the FS in each upazila. On-site support for using the apps was essential for CHWs during the training session and later when they moved into the field. The on-site support was limited to building the capacity of the CHWs. Through training and group practice, the CHWs acquired knowledge about the system quickly and prepared the field staff for real-time data collection at the household to community levels.

A large number of CHWs and service providers lacked experience with smartphones, tablets, and laptops and required time to become accustomed to using the electronic systems. Initial on-site support helped them gain the skills to use the systems. In the demonstration districts where the eMIS was first implemented (Tangail and Habiganj), field-level project staff provided initial on-site support. The FS in Tangail accompanied each CHW and service provider during service delivery in the community or facility and helped the users as needed. The FS also provided limited troubleshooting support in consultation with the central IT team.

Frequent Version Updates

Updates to apk at the field level were frequent, which led to "update phobia" and tension between the developers and the implementers. These updates were complicated because of download issues. Due to network problems, the process was not smooth or required intervention or support from the field staff, who had to approach the CHWs or supervisors in person to assist with getting the updated version of the apk. Staff responsible for implementation in the field expressed the sentiment that the apk should go through rigorous quality testing, with a minimum interval of at least one month between versions and updates released in the middle of the month. Releases to fix bugs were recommended to be made after approval from the field team was obtained. The newest version should be automatic updated from the server, which was later introduced, and the changes in the new version should be properly documented.

Tablets Provided by the DGHS

Initially, the project was only slated to provide tablets to the staff of the DGFP, as they had no access to tablets, while the DGHS provided tablets to their HAs. However, after a quick survey to understand the performance of the two brands of tablets being used by the HAs in Basail and Tangail, most were found not to be functional and had to be replaced. Therefore, the project also provided tablets to the HAs in Tangail and Habiganj districts.

Defining Catchment Areas

During national rollout of the eMIS, the catchment area should be thoroughly checked with HAs/FWAs, supervisors, and managers, and the BBS should be notified if any discrepancies are found in the geo code.

The FWAs and HAs work in wards, which are a unit of the union, and have distinct catchment areas within the ward. There was a discrepancy between the details of the catchment area of FWAs and HAs as collected from the supervisors and those collected from the CHWs. For example, the following issues were identified:

- *Unit-ward mismatch*: In Bhuapur upazila of Tangail district, according to one FWA, *Sthal Kashi* village was in unit 1kha and village *Bokshir chor* in unit 3ka. Accordingly, the 1kha unit village was assigned to ward 1, and the 3ka unit village was assigned to ward 3 using monitoring tools. However, the HA mentioned that this ward unit information was incorrect for those villages.

According to the BBS geo code, those villages were in ward 2, but the local UPFO office allocated those villages to units 1kha and 3ka, respectively.

- *Village name mismatch*: In some cases, the name mentioned by the FWA or HA was not the same as the BBS code. In Delduar, one village name is *Bhurboria bokoltola* according to the BBS, but according to the HA and FWA that village name is just *Bokoltola*.

- *Villages not listed/absent in the BBS geo code*: Some villages were not found in the geo code list, probably because the list had not been updated. However, in some cases, it was found that the village had been allocated a code by the BBS later. It turned out that the local land or upazila office had the updated geo code database. To resolve the issue, all stakeholders, including HAs and FWAs at the union level (union parishad) met to identify the correct administrative area. The union parishad secretary also helped to identify the villages.

- *Wards under municipalities*: A pourashava (a municipality) is a peri-urban area divided into nine wards and usually established in an upazila headquarters. Parts of an upazila that had become a pourashava posed problems during finalization of the catchment areas of FWAs. The local upazila DGFP office treated them as wards of a union (as in the rural areas) for their work planning, while local government boundaries are not always followed during distribution of work to CHWs. For example, in some instances either the DGHS or the DGFP was following new demarcation of wards, but the other was not.

- *Catchment area Identification*: Due to river erosion or other disasters, it is possible for areas to disappear, as was found in Tangail sadar upazila, Bhuapur, and Gopalpur. In such situations, CHWs or local offices were consulted, as well as the supervisors and upazila managers (UH&FPO & UFPO). When consultations were not sufficient to sort out the issues, the local-level land office was contacted.

The demarcation of municipality areas presented a major implementation problem at the field level. At the upazila level, most municipalities lack their own health service delivery structure. The DGFP and DGHS seek to cover household-level activities through outreach workers from nongovernmental organizations (in place of HAs and FWAs), if possible. The DGFP and DGHS local authorities simply merge the municipality areas with the adjacent union's ward/unit. However, the problem was that in this situation, a particular provider has to work in two different administrative areas (union and municipality). This was a major challenge for eMIS implementation, as the catchment area was bigger and beyond the capacity of the CHWs to serve properly.

Managing Conflicting Catchment Areas

Some catchment areas are composed of multiple units or wards, which presented some challenges. Designating these areas properly was important for downloading PRS data and sharing the service data among providers. Field staff collected information about the catchment areas from the CHWs assigned to them. The developers then came up with the following schema for allocating a unit or ward (Figure 4).

Figure 4. Scenarios for allocation of single or multiple units or wards to HAs and FWAs

Provider (CHW)	Village	FWA catchment area		HA catchment area		Assignment	
		Single Unit (Y/N)	Multiple Unit (Y/N)	Single ward (Y/N)	Multiple ward (Y/N)	Unit	Ward
FWA	Village 1	✅	❌	✅	❌	✅	✅
	Village 2	✅	❌	❌	✅	✅	❌
	Village 3	❌	✅	❌	✅	✅	❌
	Village 4	❌	✅	✅	❌	✅	✅
HA	Village 1	✅	❌	✅	❌	✅	✅
	Village 2	❌	✅	✅	❌	❌	✅
	Village 3	❌	✅	❌	✅	❌	✅
	Village 4	✅	❌	❌	✅	✅	✅

In some villages, unit and ward data were identical for both FWA and HA, whereas in others, units and wards did not match. The area assignment was managed through the monitoring website.

FWA Units Served by Nongovernmental Organizations (NGOs)

Training could be provided to the NGOs whose CHWs work in the vacant areas, and an overall mapping of NGO providers could be conducted so as to enter them into a database and track them separately.

In some areas, NGOs were providing services in place of FWAs, using the same registers for collection of community-level data. In Basail upazila, Swanirbhar, a local NGO, was providing the services typically performed by FWAs, and their CHWs were also submitting the MIS-1 form to the upazila for compilation at the national level. In the absence of directives from headquarters or an agreement on assets, it was not possible to give them tablets, despite obtaining clearance at the local level. It may be appropriate for the program heads of the DGFP and NGOs to establish a formal agreement so that tablets may be provided to them. This would enable them to collect data at the community level and report to the national system. Technical assistance or training could also be provided to those NGOs. It is recommended that an overall mapping of NGO providers be conducted so that the NGO providers are entered into a database and tracked separately.

Organizing Trainings

Because the eMIS tools use digital technologies, training for the users was required. During the transition from a manual system to an automated one, elaborate training programs were planned for all users.

Format and Contents

eMIS training activities related to formatting and the contents of tablets under eMIS are discussed below:

- **Contents:** The participants were given a basic introduction to tablet use, and they were familiarized with the apps and their features. Hands-on practice played a key role in understanding the system. During training sessions, the participants practiced collecting data in real-time by entering data from their paper registers in the presence of their supervisors. Synchronization with the central server was an important part of the training.

- **Duration of training:** The first training was for the PRS before the community modules were rolled out. Three-day trainings were organized. The first two days were for demonstrating the system, and the last day consisted of hands-on practice. Initially, training on the community module was also for three days and included hands-on training. When the PRS was integrated with the community modules, the training duration was extended to five days.

- **Pool of trainers**: A pool of master trainers was created that included developers and implementing team members. The developers were responsible for providing support on any issues related to development of applications for devices. They tried to familiarize participants with the applications and resolve any issues related to them. They also provided support for installation of the applications on the device. Departmental master trainers trained in how to operate the modules delivered the training.

- **Number in each training:** The suggested size is 20 to 25 trainees per training.

- **Refresher training:** Refresher training was also necessary after the passage of time and when app versions changed substantially.

- **Equipment:** A multimedia projector was used in the classroom. For eRegister training, the software was installed on trainer's laptops to facilitate projection. It is not easy to display the whole page on the tablet. A portable wireless device with a cast feature could be considered in the future.

Preparing Tablet with Final Database and apk

Internet connectivity should be checked prior to conducting the training in the field.

On the final day of training, tablets with apk and the database downloaded from the server were distributed to the providers. Tablet preparation included tab primary settings (with catchment area), app lock, and system apps installation. If the Internet connection is poor, it takes time to get the apk, and it is difficult to download the provider database at the local level. The experience was negative at the initial stages, as after downloading, the database was found to be incomplete and required multiple downloads. Ideally, a better location with good Internet connectivity would be chosen beforehand for seamless downloads. At times, apk was supplied through micro SD cards, but that system was not sustainable for regular use, and emphasis was placed on improving the download even when Internet connectivity was poor.

Managing Challenging Participants and Motivating Participants

Identifying the challenging participants and focusing on them differently is more effective for training, while older participants may need special attention.

The demographics of CHWs varied to a great extent by age, experience, and education. This created some difficulties in conducting the training. Some participants lacked the motivation to use new digital tools, as they considered it an additional activity leading to increased workload. Many were apprehensive about having to do both paper and electronic work. Conducting the training with both HAs and FWAs revealed the mismatch between the two groups with regard to knowledge and skills related to use of tablets. Other participants seemed to have connections with the local power structure, and politically influential providers tried to hamper the training program and then did not want to do their work on the tablets following the training.

Another challenging type of participant was people approaching retirement age. Some were unable to operate the tablets even after extensive training. Others brought relatives such as a daughter, daughter-in-law, or grandson for the data collection or to learn how to use the system on the device. During data collection they stood beside their relatives, provided instructions, and helped them to complete data entry. Special attention was given to these participants during training to motivate them and help them practice. Some participants complained of visual problems, information that was shared with upazila managers. The presence of district- and upazila-level managers or high officials during the trainings was also helpful. Field staff from icddr,b also provided on-site support to familiarize participants with the system so that they could work independently in the future.

HID Card Generation, Printing, and Distribution

The printing of the HID card required careful planning, including the distribution of the card by the CHWs, the status of which is shown in the app.

To track individuals in order to address their health needs, identification of the individuals using the HID was required. After registration in the PRS, each individual is entitled to receive a printed HID card. Upon the completion of registration in any village, HID cards are printed for distribution. The HID card printing system, which is a desktop application, generates HID cards in ready-to-print or pdf formats. The method of printing, type and size of card, and distribution challenges had to be addressed during implementation.

Content of card: The names of the father and husband were not included initially. The CHWs suggested including them to help find the household member during card distribution. The husband's name was helpful for identifying the ELCO.

Card material: Two methods were tested for printing the HID:

- Icddr,b: An A4 sheet of plain paper was used to print eight cards using a standard laser printer. The cards were laminated before cutting. This was the least costly option.
- MaMoni HSS: Initially, PVC cards were printed at the upazila level using a special purpose printer, which was more expensive than using plain paper. Therefore, plain paper with lamination was introduced in the MaMoni areas.

File Generation: Pdf files were used to print the cards. Printing all cards for this sizable population required careful planning. The CHWs who registered the households are responsible for distribution of the cards during routine visits to the households in their catchment areas. Sorting was useful to find the cards easily from a big stack. However, sorting could not be done by HID number, as they are not contiguous. Household numbers also varied due to the absence of any established practices. However, sorting by village and household was practicable.

Printing and packaging of the cards: The printing of the HID cards was outsourced to a vendor. The pdf file was supplied to the vendor. Initially, the vendor sorted all the cards by union and then packaged them. However, the field workers and field staff requested packaging of the cards by village, as this would be more helpful for both the provider and the field staff to distribute HID cards to the registered individuals.

Storage: After printing, the cards had to be sent to the field for distribution. Printed HID cards are sent to the upazila level first, where the upazila manager stores them securely. Sometimes, union-level facilities are also used to keep cards of a particular union. The HID distribution plan was fixed after discussion with the providers.

Distribution of cards: Distribution of the HID cards presented some challenges. The CHWs are responsible for card distribution to individual members. A CHW typically has to distribute over 2,000 or more cards. The HID distribution plan was prepared in consultation with the CHW. A bag was needed to transport the HID cards. The CHWs requested that the cards be distributed by village. To keep track of distribution, a printed list was given to the field workers, but it was difficult to track the number of cards distributed, as well as distribution to registered individuals from the list. To resolve this, a tracking mechanism was developed. Card distribution status was included on the FWA and HA eRegisters to obtain real-time card distribution data. If the row for any household is shown in white, it means that no card has been distributed to any member of that household. When some, but not all, cards have been distributed, the color is yellow. Households with the status of fully distributed cards are marked in green.

During implementation of the eMIS, bulk numbers were collected from SHR. This system will need to be fully automated so that SHR can provide the HID in real-time through an online request.

Power Supply and Internet Connection

It was necessary to exercise caution when using the generator (due to power failure), as it caused damage to some of the equipment.

Frequent disruptions in electricity, a common feature in rural areas, interrupted training, particularly when the multimedia projector was being used. As a result, generators were hired, but the use of a generator also caused concern, as it could damage electronic devices like adaptors, the projector, and laptop chargers. For instance, the multimedia projector provided by Upazila Health Complex of Kalihati was damaged when the generator started after load shedding, and it damaged a laptop charger on the same day. It was, therefore, necessary to make sure that the venue had an electric line that supported the generator.

Data Quota

Although telecom operators rolled out high-speed Internet service nationally, this was not available in the rural areas, and there were issues with the quality of the services provided.

The eMIS implementing partners supported the Internet connection in the implementation areas. Packages were purchased from telecom operators. In the case of DGHS staff, the existing SIM provided

by the department was used. However, some of the HAs used both the SIMs provided by icddr,b and GOB. The icddr,b wanted to retrieve the SIM it had provided, but they were not ready to surrender the SIMs even though the DGHS had also provided SIMs. In addition, some of the DGHS staff needed Internet connectivity from the project on a temporary basis, as they had been recently transferred. Support was also provided to some HAs whose SIMs and Internet connection were not working. The DGFP did not supply their CHWs with SIMS, and these were thus supported by the eMIS project.

Internet data packages were obtained from a telecom operator for 3GB of data. The monthly charge was Taka (Tk.) 365, which was later reduced to Tk. 265. The package also included a credit limit of Tk. 1,200 per month (about US$15). However, the Internet connection was poor in the implementation areas and frequently fluctuated. When the 3G network was rolled out nationally, it was found that in some parts of the upazila 3G was good, but other areas had very poor or no connections at all. The slow Internet connection made data synchronization difficult. Technical team members communicated with the mobile service provider to minimize the issue by providing bandwidth support in the affected subdistrict.

There were also problems with data usage. Some CHWs were using up the full quota by watching movies or making large downloads. Some of the SIMs may have also been given to family members when the CHWs were not working. At one point, CHWs informed the project that that they were unable to synchronize data, even though they had a sufficient Internet balance. The mobile operator was contacted, and it was found that the internal chips of the SIM cards had been damaged. Due to this technical problem, the service provider was unable to synchronize data for over two weeks. In addition, sometimes the Internet package was not properly charged by the mobile provider, and the CHWs were unable to sync the data.

App Protector

An Internet data use policy was issued by the government to address issues with CHWs' personal use of the tablets that exhausted the data quota.

The app protector controls what apps can be installed or used on the tablet. Initially, the app lock was not used, but some CHWs were using their Internet data for watching online movies, YouTube, etc., which exceeded fair use. Due to heavy or inappropriate use, the data quota of the providers was exhausted quickly. Therefore, to minimize data use, the app protector was added to lock certain apps. However, the users got offended when apps were protected, and some were also able to disable the apps protector. To mitigate the issue, the technical team communicated with local-level supervisors and highlighted the proper use of the monthly data quota. Involving senior management was useful to ease the tension. The main concern was that if the data quota were exhausted, the Internet connection would stop after a certain amount of use, and there was no option for recharge by the user. Options for self-recharge were considered, and the mobile operator was consulted. It turned out that an Internet data use policy could be issued by the government for connections provided by the department.

Safety and Care of Devices

Quick Troubleshooting and Feedback Mechanism

A local-level technician could be helpful for resolving device-related problems.

During pilot implementation of the PRS in Basail upazila, the CHWs reported issues related to the performance of the tablets. For example, some were slowing down after registering 400 households. They also noticed that the charge was drained after a short period of data collection in the communities. Further, the touch screen would sometimes would not work or the app failed to respond, and the tablet would reset automatically. At times, the database was getting deleted, and there was a need to clean the cache. To get the system back into operation, a factory reset was often necessary. Some issues were related to hardware or software, while others were administrative.

Field-level supervisors were trained to provide immediate solutions and quick troubleshooting. They were able to handle software-related issues, for example, lost apk or uninstallation, missing file explorer, checking the Internet availability, and device settings in case of database deletion, which they then communicated the problem to the icddr,b developers. For hardware-related problem, the tablets were collected from the field and sent to the vendor for repair. In such cases, additional tablets were required.

There were some device-related problems which were reported to the central office directly by the CHWs. Central monitoring members then solved the problems with the support of the development team from icddr,b.

Some issues required changes in software, and the development team addressed these issues in the new version. The tablets were also checked physically by the development team and, in some cases, handed over to the vendor for replacement. The troubleshooting was triaged into the field and central levels depending upon the type of problem. Device-related problems required the services of a local-level technician/vendor.

Accessories (Screen Protector, Tab Cover, Waterproof Bag)

The tablet screens are susceptible to breaking or scratches. The tablets are not waterproof and require care while handling. During the first stage of deployment, tablet covers and waterproof bags were not provided; this created problems during the monsoon season or occasional rains. Each CHW was later given a screen protector, tablet cover, and waterproof bag.

Equipment Maintenance and Care

Appropriate care of the tablet is essential. A circular was issued by the MIS, DGFP, under the signature of the MIS director, assigning responsibility for the care of equipment to the users. Device handling led to some issues, as damage occurred due to water and dropping the equipment. Safety and care of the devices were emphasized during training sessions. A written undertaking was also collected fixing responsibility of proper use (user declaration form and acknowledgement slip) before handover of tablet. On the last day of training, special instructions were provided on how to maintain the safety of the tablet and take care of the devices. Users were advised to avoid water, fire, dropping the device, and sitting on it.

All reported thefts were thoroughly reviewed with the providers and other relevant entities. The upazila manager was also informed about the incident and requested to investigate the issue. For lost devices, the user was asked to file a general diary about the incident with the local police station. The supervisor had to be notified within 12 hours, and the supervisor would in turn notify the implementers and block the SIM. For stolen tablets, it was necessary to block the SIM through the mobile operator. In addition, access to the database could be blocked from the central server. An asset maintenance database was also maintained by the implementers.

Device Repair and Maintenance

A buffer stock of tablets should be maintained at the district level, and an extended replacement warranty could be included in the bidding document.

Some of the tablets became nonfunctional and required repairs. For repairs, the tablet was collected from the field site and sent to the vendor. It also required providing a replacement to the CHW so as not to hamper the ongoing activities. It is essential to maintain a rolling stock in the field which could be used for replacement purposes. Provisions for maintenance support from the bidder could be included in the bidding document. The status of devices is later monitored through an asset management database.

Coordination among Implementing Partners

To accelerate the work and promote team building, weekly meetings were established.

The first app under the eMIS (i.e., the PRS) was completed in February 2015 and first deployed in Habiganj on March 14, 2015 and in Tangail on April 4, 2015. At one point, things were not moving very quickly in terms of developing software tools for use by CHWs or facilities, and some conflicts required better interdepartmental collaboration. The issues were discussed in subsequent meetings, but few improvements were visible. For example, one issue was that there was segregation of data, and the monitoring tools had two web addresses with no linkages. To accelerate the work and promote team building, weekly meetings were established and have been held regularly thereafter.

Changes in the project design were identified with the change in work plan. It was decided that a technical document on system design would be prepared, and the team would be made bigger with the addition of positions for programmers, a database expert, networking, social media, content and design, etc. A retreat was arranged to finalize the structure and content of the technical document. These steps improved the coordination among implementing partners to a great extent. The identification of all requirements for the system also provided better guidance to the developers.

Use of Social Media

The eMIS team created a Facebook page,[44] whose membership continued to grow and stood at over 2,000 in August 2018. Members are mostly community workers, supervisors, and district- and subdistrict-level managers from implementing areas, as well as other relevant personnel throughout the country and abroad. Implementation training, field visits by high-level GOB officials, and actual data collection scenarios are described on the Facebook posts, which are commented on by community and facility workers and their supervisors. On the Facebook page of the eMIS initiative, communication materials are also posted. It is also used to disseminate contents (such as links to blogs or downloadable files) that had been added to the routine health information system website (www.rhis.net.bd). In Habiganj district, a few union-related pages have also been created.

A YouTube page was also established where videos related to eMIS implementation were uploaded.

Transition to Paperless

In the project areas, the CHWs keep records in the paper register and use the tablet to record the same transactions. Working with both paper and tablet registers simultaneously demotivates the users, because it involves additional work. The CHWs resent such duplication and prefer to use only one system for their convenience. However, it is also a fact that management needs to be convinced of the robustness of the system before discontinuing the paper records. While it is essential to move quickly to the new system in order to increase its adoption by the CHWs, the implementers need to ensure that the system is robust and that no loss of data will occur. The project also developed a tool on the website that replicates the paper register (in report format) and is available on demand, which was used in negotiations to pilot paperless data recording in two upazilas.

Conclusions

The wide variation in the demographics of the health workforce in the rural areas created challenges during implementation. Not all CHWs had been exposed to modern technologies. Therefore, there were apprehension and concerns about the adoption of technology by the range of CHWs. The results have varied, with some CHWs showing extraordinary aptitude and others not as proficient. However, the managers and supervisors helped to overcome any negative impact and made the implementation smooth, from assignment of catchment areas to training on care and use of tablets. The implementation experience was rich and helped to scale up eMIS tools in new areas.

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[44] Source: https://www.facebook.com/eMISRHIS/

CHAPTER 9. LOOKING FORWARD

The work of eMIS began in 2015 in two upazilas in Tangail and Habiganj districts. Tools were expanded gradually to other upazilas in those districts during 2016 and 2017. The DGFP took steps to scale up the eMIS tools to five more districts, and the eMIS tools were expanded to seven more districts in 2018 in the first phase. Later the tools were scaled up in two upazilas each of another 11 districts. An additional six districts will be covered by MaMoni MNCSP in 2019. The MIS of the DGFP has made provisions for introducing eMIS in two divisions covering 15 districts under the MOHFW's 4th HPNSP (January 2017–June 2022). Altogether, 2,500 UHFWCs will be covered, of which 500 will be supported by USAID. Thus, more than one-third of the country will likely be covered with eMIS apps and applications by the end of the current sector program.

The digital tools developed for the CHWs have helped to bring changes in the way the CHWs work in rural areas. These tools have benefited the field supervisors and their managers. There is now emphasis on data quality and visualization of data for performance management. There is also the potential to establish an accountability framework, as was evident from the upazila managers' monitoring the CHWs' work. The progress of work was reviewed by managers and CHWs during monthly meetings at the upazila level. Lower-performing CHWs could easily be identified in these forums, which encouraged them to improve (so as not to be called out at these meetings).

While technical assistance played an important role in designing the tools and also in implementation for the better part of the program, it should be noted that the government has begun taking responsibility for implementation, and in the future this will become mostly a government activity. However, there is a greater need for support and maintenance of the system, and in the longer term, some form of technical assistance will still be necessary. Although this document did not address sustainability issues in detail, a sustainability plan is under preparation and will address such issues.