MAPPING THE TECHNOLOGY LANDSCAPE OF NATIONAL TB PROGRAMS

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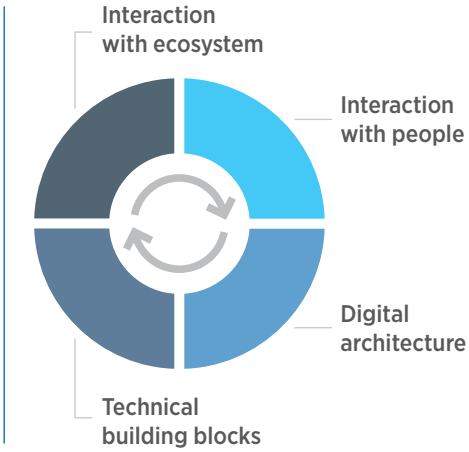
FOREWORD

THE GLOBAL FUND TO FIGHT AIDS, TUBERCULOSIS AND MALARIA & THE STOP TB PARTNERSHIP

Harnessing the power of digital health technologies and ensuring that all TB affected people can benefit from those innovations is essential to driving progress in the fight against TB. There is a necessity to understand the technology landscape across National TB Programs (NTPs), share best practices and identify existing gaps in TB affected countries to help accelerate progress. The COVID-19 pandemic has further underlined the importance of digital tools and international cooperation and collaboration for global health.

This report explores existing digital tools used in 13 TB affected countries for the management of TB, including documentation of best practices, outstanding gaps and priorities for the future. Four interconnected themes, depicted at right, emerged in this report. In order to strengthen the use of technology in National TB Programs, it will be important to simultaneously address each of these thematic areas. In addition, the report also contains a survey of specific tools used across the cascade of care, 24 case studies of digital systems and their deployment, and 13 country profiles that document the digital ecosystem in each of the countries studied.

High-level findings and recommendations across the thematic areas are summarized below.



Multiple existing platforms for TB case management can be leveraged by countries

Countries surveyed all seek to develop an integrated "backbone" that manages information on TB affected people as well as aggregate national reporting. While much progress has been made in digitizing the cascade of care, significant gaps remain. Aggregate reporting systems often leverage shared infrastructure and are relatively mature. However, the architectures for managing individual cases are under active development and can improve interoperability with external tools to ensure continuity of care across screening, diagnosis, and treatment. About half of countries surveyed utilize a customized, home-grown platform for case management, while the remainder use systems built on DHIS2 Tracker or e-TB Manager (both open source). We would invite countries to consider the relevant elements of systems used by peers that may offer added value in streamlining case management in order to learn from each other's systems and experiences. We support, encourage, and are keen to facilitate more detailed assessments of case management platforms to understand their relative strengths and weaknesses and collectively work towards improving their capabilities and connectedness across the cascade of care.

Clear country-level policies on data governance and management, including cloud storage, are needed to unlock progress towards improved systems

We found a lack of policy guidance in key technical areas, which unaddressed can stifle progress towards digital transformation. The question of whether, or under what conditions, a program can utilize public cloud offerings to host public-sector services is a key concern with a great deal of ambiguity. Such guidance will need to balance data sovereignty goals, including a desire to store data in-country, with security and reliability goals, where cloud services can provide modern standards, robust guarantees and economies of scale. Related practices of data privacy and sharing of data are often handled informally and are critical areas of importance for clearer policies. We would invite countries to develop and publish such policies to empower implementers in-country. The Global Fund, the Stop TB Partnership and partners are committed to facilitating progress on these topics and would invite countries to engage with us as they develop and finalize their plans.

Consultations can help address pricing or licensing concerns that prevent countries from leveraging desired tools

We found that countries often build certain tools from scratch rather than reusing available solutions. One example is diagnostic connectivity solutions, where robust versions are available on the market but are being rebuilt locally in four countries surveyed. We fully acknowledge that customizing tools to the local context and having the rights to modify and use them in perpetuity are critical for ensuring long-term uptake and sustainability. At the same time, creating new versions of mature tools that have been refined and proven elsewhere could also lead to wasteful spending or risk near-term compromises in quality and robustness. We would invite countries to discuss with global partners whenever concerns over pricing or licensing terms prevent reusing an existing tool in the local context. We support the use of platforms that have limited barriers to reuse as well as strategies and techniques that help achieve better pricing, such as volume pricing.

User-centered approaches are needed for countries to achieve desired outcomes with digital tools

Our results confirmed that successful implementation of digital health solutions requires consideration of the broader context of the population and the health system in which they operate. Just as good healthcare requires looking at persons holistically, introducing digital innovations with end-users in mind is required for appropriate adoption. Country respondents shared that needs of TB affected people and healthcare providers should be positioned at the center to support quality care. Training and education to use digital technologies by healthcare workers is critical, and so is ensuring those in health-policy leadership positions have the skills and knowledge to develop and manage in-country digital health initiatives. Countries would do well by strategically addressing ongoing skills gaps that often prevent utilization and benefit from digital technologies.

Awareness of local infrastructure gaps is critical for countries to realize the potential of digital tools

Finally, results showed that poor Information and Communication Technologies (ICT) infrastructure often limits the potential of digital health. Reliable access to connectivity and devices is often assumed by global organizations when espousing the benefits of digital health for TB. Where such technical building blocks are lacking, we invite countries to remain vigilant in prioritizing functionality or tools that are most appropriate for the local context. For example, investments in offline functionality in mobile tools may be the leading priority in low-resource contexts, even if it not needed in higher-resource contexts. In some country environments, broader investments in the technology infrastructure itself may be among the most important enablers of a digital health ecosystem and should be prioritized.

Path forward

The commendable investments made to digitize the management of TB programs deserve continued attention to ensure they are most effective and sustainable. While each country has a differing level of maturity in using digital tools for TB elimination, this report underscores that all countries are embarking on a similar journey of digital transformation, with considerable overlap in the challenges faced, the solutions developed, and the lessons learned. To date, however, the experiences of country programs have been siloed.

To catalyse progress, we invite further coordination to facilitate knowledge transfer, both between country programs and with international agencies, including the Global Fund and the Stop TB Partnership. We also invite further collaboration with the private sector, as appropriate, to advance technology support within and across countries to ensure that the best tools and resources are tackling this critical opportunity.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

API	Application Programming Interface
CAD	Computer-Aided Detection
CHW	Community Healthcare Worker
DHIS2	District Health Information System Version 2
DOT	Directly Observed Therapy
DR-TB	Drug-Resistant Tuberculosis
DS-TB	Drug-Susceptible Tuberculosis
e-TB Manager	Electronic TB Management Information System
HIV	Human Immunodeficiency Virus
HMIS	Health Management Information System
ICT	Information and Communications Technology
MoH	Ministry of Health
NTP	National Tuberculosis Program
SMS	Short Message Service (mobile phone texting)
TB	Tuberculosis
WHO	World Health Organization

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Special thanks goes to all of the country informants interviewed for this project (listed in the Appendix) who provided valuable insights and made significant contributions to this study.

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Competing interests: Bill Thies is also Co-Founder and Chairman of Everwell, a company that develops technologies to support the TB cascade of care.

INTRODUCTION

Digital health holds transformational potential for the fight against TB around the world. Information and communication technology (ICT) presents opportunities for innovative approaches to overcome some of the key challenges and barriers that limit TB efforts for prevention, detection, treatment, and management of TB. Given that many countries are affected by TB, there is a collective desire to understand the technology landscape across national TB programs, share best practices, and identify gaps that can be addressed through future investments.

Up until now, studies of technology infrastructure for TB have been generally limited to a single country or single digital tool and have not spanned the entire TB cascade of care. With national TB programs, in recent years, initiating several digital health applications that also span across individual stages of the cycle of care, an exploration of the existing state of the art of ICT tools for TB is warranted. This report describes a research study that seeks to provide a holistic understanding of the prevailing technologies used for national management of TB, including documentation of best practices and unmet needs. Data stems from semi-structured interviews conducted with representatives of 13 TB affected countries and explores the latest status of national tuberculosis infrastructures, as well as qualitative experiences, challenges, aspirations, and lessons learned as countries evolve their digital architecture.

This report, created as a partnership between Microsoft Research, the Global Fund, and the Stop TB Partnership, aims to draw on collective insights to understand how to adopt, implement, and sustainably support these technologies. As the evidence and experience on the use of digital health for TB increases, further investment in these technologies and bold action is needed for improved TB care and prevention.

This report complements several related initiatives. The Stop TB Partnership's Re-Imagining TB Care[1] provides an excellent resource to help innovators understand the landscape of country programs while also facilitating uptake of innovations by those countries. Other pieces of work that parallel some of the concepts examined include USAID's TB DIAH[2], WHO's IR4DTB[3] and the Stop TB's Digital Health Technology Initiatives[4]. Prior resources cover a limited number of countries and have limited engagement with qualitative narratives that can help to contextualize the nuanced history and ever-evolving aspirations of digital platforms in different locations. We hope that the current study, via its use of qualitative research methods, will complement the thoughtful and structured approaches employed by previous work.

As the COVID-19 pandemic now threatens to set back progress seen in TB, it is even more important that digital technologies and innovations be translated into substantial improvements for national TB programs worldwide. Digital technologies are showing their potential during the current crisis. Using the momentum created for digital tools, it will be crucial to mobilize appropriate tools, strategies, skills, and resources to help them realize their true potential for TB efforts. This report hopes to distill insights for innovators, funders, and individual country programs by using a comparative lens to understand the similarities, differences and trends seen across countries and generate the largest benefit for individuals affected by TB worldwide.

METHODOLOGY

SCOPE AND STUDY DESIGN

The overarching goal of this study was to understand the current landscape of digital technologies used by National TB Programs (NTP), associated best practices, and gaps to be addressed.

The study utilized semi-structured qualitative in-depth interviews and accompanying desk research of documentary materials. Qualitative methods were used to capture the richness of subjective understandings of technologies used, tensions that arise in adapting tools to local needs, supporting best practices witnessed by country informants and existing challenges.

1 https://www.reimaginingtbcare.org/
2 https://www.tbdiah.org/
3 https://ir4dtb.org/
4 http://www.stoptb.org/dhthub/

COUNTRY AND PARTICIPANT ENROLMENT

The proposed geographical scope was a spectrum of 10-15 countries with varying ICT capacity. The Global Fund's 20 TB high-burden priority countries were used as a starting point. Fifteen countries were selected by Global Fund technical teams for inclusion, in consultation with the Stop TB Partnership, and a final 13 countries accepted and were formally enrolled into the study. Final country inclusion consisted of Bangladesh, Democratic Republic of Congo, India, Indonesia, Kenya, Mozambique, Nigeria, Philippines, South Africa, Tanzania, Uganda, Ukraine, and Zambia (Figure 1).

Selection of country informants to participate in interviews were based on knowledge of technologies used for national management of TB. A purposive sampling technique and interviewee recruitment strategy was chosen based on discussion with Global Fund country Fund Portfolio Managers and the Stop TB Partnership technical team. Introductions to representatives of government TB programs and associated implementation partners were provided. Snowball sampling was then utilized to gain additional perspectives within countries. To ensure breadth of viewpoints and equal representation, three to four stakeholders were interviewed in each country. A list of participants' roles and affiliations appears in the Appendix.

FIGURE 1:
The 13 TB affected countries enrolled into the study

STUDY METHODS

Interview Topic Guide Development

The study team developed a semi-structured topic guide[5]. The topic guide was divided into 6 sections covering the following areas: digital tools used across the TB cascade of care, data harnessing for national TB programs, challenges and best practices associated with the existing digital architecture, ICT interoperability, a roadmap for the future and COVID-19 implications.

Data Collection

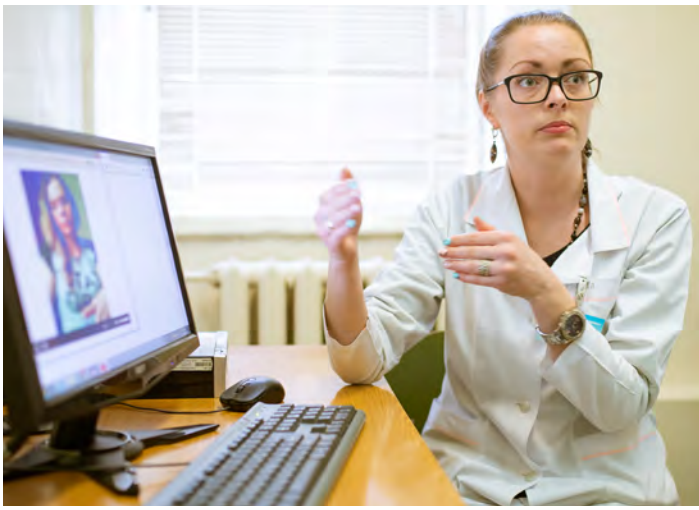
A series of in-depth semi-structured interviews and document review were completed between the months of September 2020 and February 2021. Forty-one interviews were conducted with forty-four stakeholder participants (3 interviews consisted of 2 stakeholders present) via video call with a duration of 45-90 minutes, using the topic guide to help steer the conversation. All interviews were conducted in English with the exception of four interviews with DRC stakeholders which were conducted in French with the assistance of translators.

TB Cascade of Care Tool

To identify and map existing digital tools (the first topic within the interview guide) used across countries for the management of TB, a simplified cascade of care was used to prompt and facilitate recall with country informants. The cascade focused on four stages – outreach and screening; diagnosis and drug-susceptibility testing; treatment initiation and patient management; and monitoring and reporting. Additional stages, such as prevention or post-treatment support, fell outside the study's scope. The interview began with an introduction of the country participants to the cascade by the study team and a discussion of various digital tools used.

ANALYSIS

Data analysis utilized qualitative methods of thematic content analysis. This method addressed themes embedded in the research questions while still allowing enough flexibility to incorporate new and hitherto unconsidered issues which arose during data collection. All interviews were audiotaped (with the exception of 1 interview), transcribed verbatim, and imported in N-Vivo11 for thematic analysis. Transcripts were individually coded based on thematic nodes. Triangulation with desk research materials informed the resulting recommendations and conclusions of the study.



5 https://1drv.ms/b/s!Ahmx2KRsbBvRgUvmVIkiHS8szkt-

SUMMARY OF RESULTS

The study findings are presented in two sections:

1. Digital tools for the TB cascade of care
2. How to strengthen the digital health ecosystem.

KEY FINDINGS

- Strengthening information and communications technologies used by national TB programs can improve the management of TB care
- Countries may benefit from a shared understanding of globally available tools and associated best practices for using technology in TB care beyond what may be evident from their own local geography
- There is a need to focus on both technical and non-technical components for maximum impact when of strengthening the digital health ecosystem
- Many digital health tools are already proven and available, but there is a need for countries, donors and procurers to use their purchasing power and influence to promote market shaping and address shortcomings of financing, policies and appropriate resources to make tools available in each country and realize the full potential of existing innovations
- Since different backbone infrastructures are used in different countries, it is difficult to disseminate new tools and subsystems globally. Fragmentation of systems may prevent leveraging innovative tools, therefore digital technologies and subsystems seeking scaled deployment need to be flexible to accommodate interoperability.
- Policy guidance is needed at national and global levels for shepherding appropriate multi-stakeholder partnerships on digital strategies, ICT infrastructure, cloud hosting, data privacy and security, interoperability, and governance. Setting expectations for investments and a predictable environment will be important.
- Digitization of all stages of the cascade of care can enable the use and benefit of real-time data and enable better informed and strategic decision making. To facilitate this, a backbone which we have defined as a fully integrated case management and aggregate reporting platform, will be needed

LIMITATIONS

In this qualitative study, we interviewed 44 stakeholders. Our sample size was relatively small, especially in considering the even smaller sample representing each country included in the study. We acknowledge this limitation and recognize that a different set of stakeholders might yield slightly varying results. In addition, self-reported data might have limitations, including imperfect recall of all digital tools used in a country. Thus, we do not draw any quantitative conclusions from this study. The digital tools represented in this report are not exhaustive but rather a subset of available tools as highlighted by interviewed stakeholders.

HOW TO READ THIS REPORT

This report is intended to guide country programs, innovators, implementers, funders, and other global stakeholders alike to strengthen the use of technology in National TB programs. We hope that readers will reflect on the technologies used and associated best practices shared across geographies and re-calibrate according to their own contexts and identify areas for improvement. Therefore, we ask readers across these specific designations, keep the following questions in mind as they read the report, to help facilitate local prioritization and identify opportunities to adopt, implement and support new and existing digital health technologies.

Country Programs:

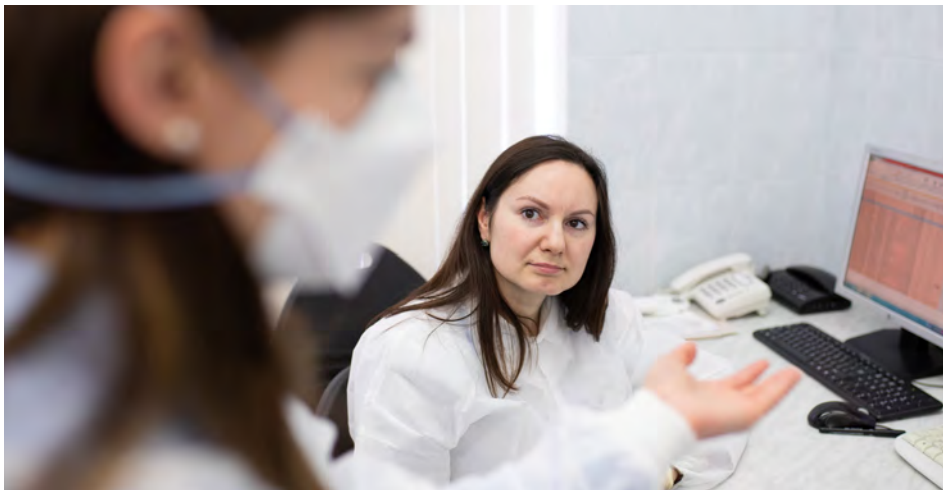
- What digital tools, best practices or strategies could be adopted to address existing challenges within own context?
- Could shared lessons be applied to re-calibrate local priorities to global practices?

Innovators and Implementers:

- Looking at existing gaps, is there an opportunity to innovate and/or implement digital tools to solve these challenges?
- Are there features lacking in existing digital tools that could be augmented or further developed to satisfy the needs seen across countries?

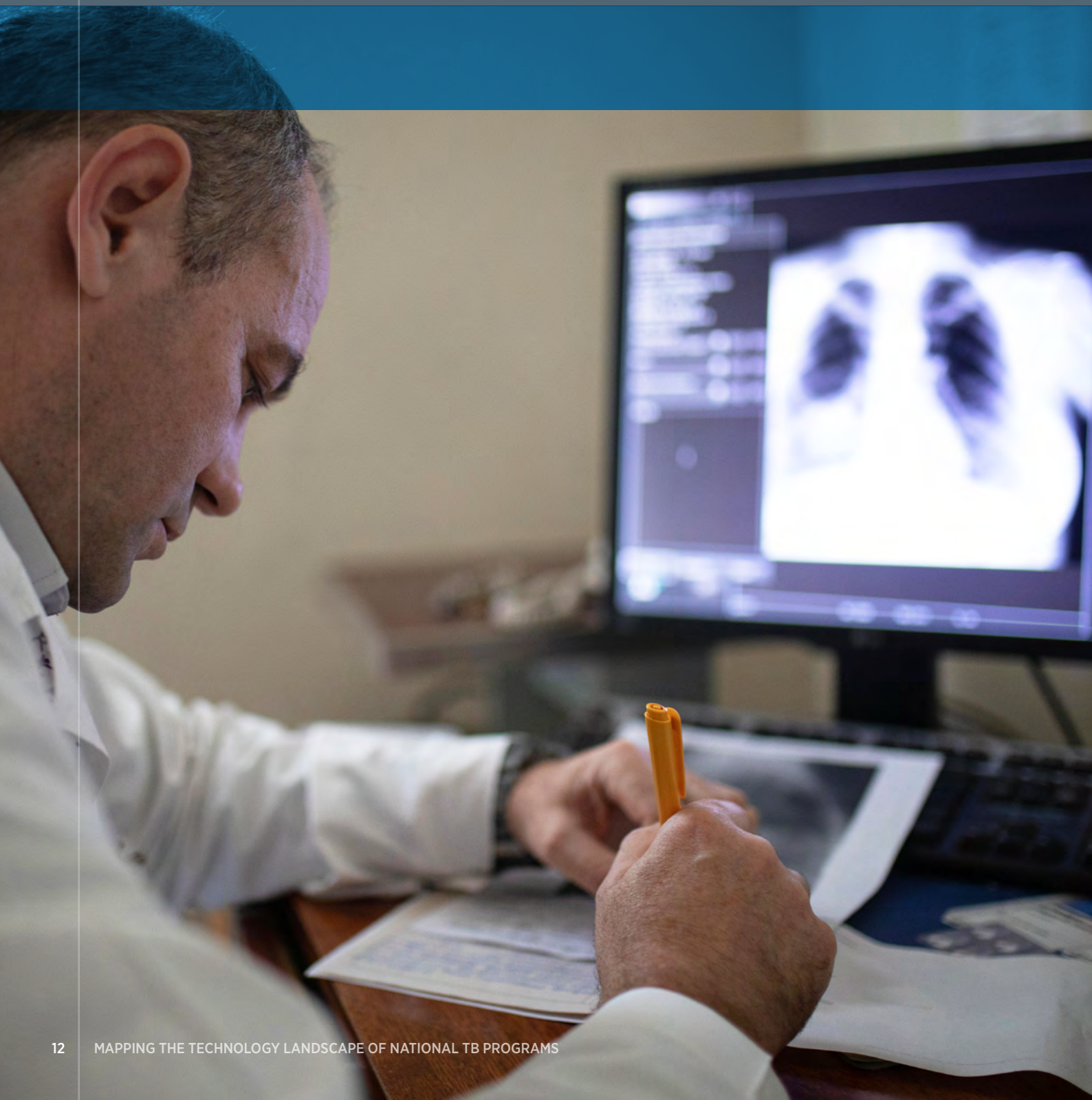
Funders and Conveners:

- What common problems seen across countries can be offered more support (country programs digital strategies, communication gaps, etc.)?
- Are there opportunities for stronger global coordination of digital transformation to be shared across countries?



SECTION 1

DIGITAL TOOLS FOR THE TB CASCADE OF CARE



In recent years, TB programs and technical partners worldwide have initiated several digital health projects to enhance TB care. The deployment of innovative digital health solutions aspires to improve the adoption, speed, efficacy, flexibility, and capacity of existing processes to deliver better TB care for populations across the globe. Improving the knowledge base of these experiences can enable learning from failures, and increase opportunities for more successes to be shaped and fed into future investments and digital improvements that benefit global and in-country coordination.

Elimination of TB requires vigilant coordination across each stage of the TB cascade of care, which in the case of this study has been simplified to consist of screening, diagnosis, treatment, and reporting. Other activities such as preventing TB infection and providing post-treatment care and support are also receiving growing attention but were not addressed within this study.

Technologies used by national TB programs can generally be considered in two categories. The first category, which we refer to as the "backbone", provides the core functionality of patient case management and aggregate reporting, interoperating across stages of the cascade. The second category consists of specific digital tools that are localized to a single stage of the cascade and plug into the backbone as needed. We describe each of these categories in turn in the sections that follow.

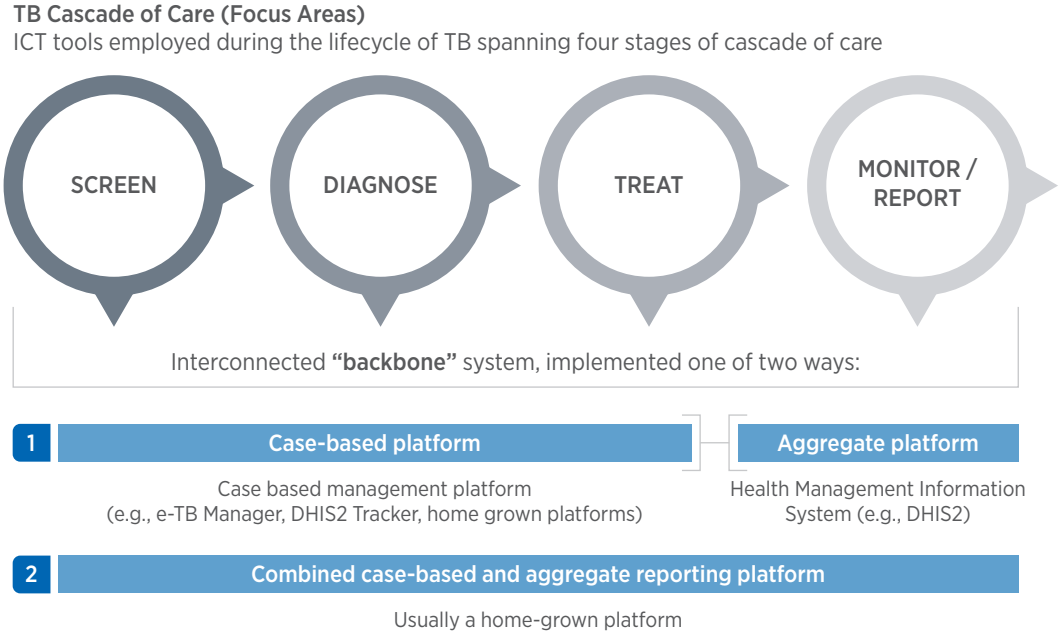
BACKBONE SYSTEM

Across the 13 countries interviewed, either a fully implemented or planned expansion of an interconnected system that spans the entire cascade of care has been adopted by NTPs. A respondent in Nigeria referred to such a system as *"the backbone of the entire TB digital health ecosystem."* In the countries under study, the backbone is typically constructed in one of two ways (see Figure 2):

1. A platform for case management (e.g., e-TB Manager, DHIS2 Tracker, or home-grown solution) is connected to a platform for aggregate reporting, sometimes called a Health Management Information System (e.g., DHIS2). In some countries this connection still requires manual steps.

2. A new solution (typically home-grown) provides a unified case management and aggregate reporting system.

FIGURE 2:
Simplified TB cascade of care and relationship to backbone system



This backbone may either be a web or desktop-based tool and manages all information needed by NTPs. It aims to integrate data across all aspects of TB control including information on presumptive TB, confirmed cases, medicines for TB, laboratory testing, treatment initiation, patient management and outcome.

Despite consistency of having a backbone system in each country, the landscape is fragmented with no single infrastructure dominating. As illustrated in Table 1, many countries have developed home-grown backbone systems, while others have extended other architectures – e-TB manager and DHIS2 Tracker – to derive a version that is tailored to country requirements.

TABLE 1:
Backbone architectures used across countries. Asterisks (*) indicate systems that link to DHIS2 for aggregate reporting; others have aggregate reporting built-in as part of the backbone.

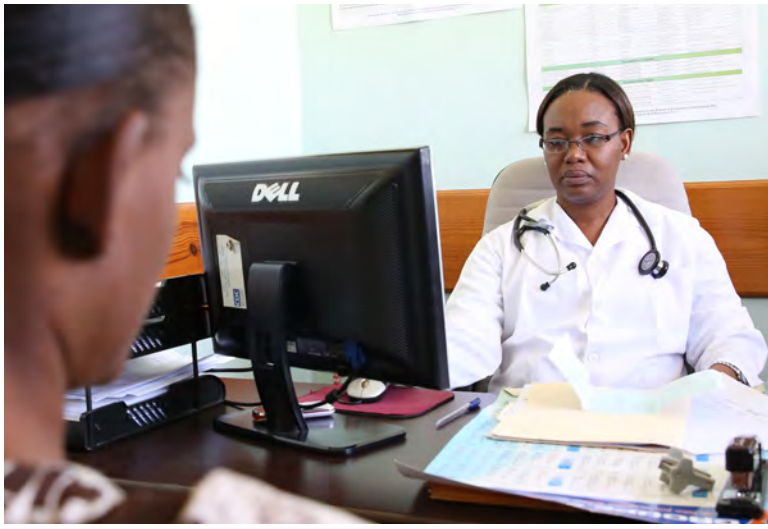
COUNTRY	HOME-GROWN SYSTEM	DHIS2 TRACKER DERIVED SYSTEM	E-TB MANAGER DERIVED SYSTEM
Bangladesh			e-TB Manager*
DRC		DHIS2 Tracker*	
India	Nikshay		
Indonesia	SITB		
Kenya	TIBU*		
Mozambique		SIS TB*	
Nigeria			e-TB Manager*
Philippines	ITIS		
South Africa	EDR.Web* & TIER.Net*		
Tanzania		DHIS2 ETL*	
Uganda		e-CBSS*	
Ukraine			e-TB Manager*
Zambia	Smart Care*		

A noteworthy observation seen across all countries is the natural evolution of the backbone systems. In most countries, the backbone was originally envisioned as a reporting tool for case-based information to connect to the aggregate reporting tool used at the national level. Over time, it evolved to incorporate increasing amounts of information – such as a laboratory module for diagnostic information and a screening module to capture presumptive TB cases. All backbones have been shown to have a consistent case management tool that captures basic demographic and treatment information, and a reporting module that helps to generate facility-level reports.

Despite some backbones not yet capturing all stages of the cascade of care, nearly all are planning to do so. The backbone system also acts as an 'interoperability layer' to collect incoming data from external supporting digital tools that capture data across individual stages of the cascade of care. As a stakeholder in Nigeria expressed, *"The desire to capitalize on the backbone's evolution and incorporate all stages of the cascade might be a direct result of existing investments made for scaling [the backbone] nationwide. The idea is to make sure that e-TB Manager which is the only electronic platform that has been rolled out in every state of the country should be the one that's used… we don't want to have silos…we want to have e-TB manager optimized to its full capacity to capture every part of the patient cascade from the screening all the way to the outcome and whatever tools we have currently - to find a way that they feed into the e-TB manager"*

The distinction between drug-resistant and drug-susceptible TB similarly followed an evolutionary trend. Countries were observed to first digitize DR-TB by developing a backbone specific to DR-TB before expanding to DS-TB. Once digitization was expanded to DS-TB, countries opted to develop separate digital tools, with the emergence of two parallel systems. Yet, the evolution has continued with the majority of countries choosing to merge DS-TB and DR-TB tools into one holistic system for increased efficiency.

In contrast to the unified configuration of the backbone which seamlessly incorporates data from all stages of the cascade including aggregate reporting as seen in India's Nikshay (see Case Study: "Nikshay, India's backbone IT system"), the other configuration requires transfer of data from the case-management tool to the aggregate reporting tool. For some countries, digital integrations using APIs have enabled interoperability between the two systems. Yet, many still rely on manual transcription to encode data for national reporting. This, alongside the reality that many remote facilities do not have the capability for data entry, has resulted in parallel digital and paper-based records in certain contexts. Digitization is largely dependent upon intrinsic infrastructure and capabilities present at facilities. Across the 13 countries in the study, the concurrent use of parallel paper-based and electronic record keeping is widespread and a significant challenge despite varying maturity of digital tools. The slow migration to a fully automated system has been expressed by country informants with one difficulty being the uneven propensity at clinic-level. Where data is digitized at the point of care, the ability to analyze facility-level information has been extremely advantageous.



CASE STUDY

NIKSHAY, INDIA'S BACKBONE IT ECOSYSTEM

India's Nikshay system is an example of a home-grown backbone spanning case-management and aggregate reporting. It functions as a comprehensive, integrated platform to digitize TB treatment workflows in real-time and has independent modules for stages of the cascade that all work seamlessly together. A clinician can register a person as a presumptive case when they approach a clinic with symptoms. They can request a diagnostic test and use connected diagnostics to log the test result within the respective module. Should the result come back as confirmed TB positive, the provider can initiate the person on treatment through Nikshay. Medications are dispensed and clients can be provided with treatment support using digital adherence technologies. Throughout the duration of treatment, providers can view their care population as individual cases or in aggregate to understand who has taken medication, where test results are pending, and reach out to persons affected by TB through various virtual care mechanisms, and finally declare treatment outcomes. A set of add-on modules deal with processes related to themes such as Direct Benefit Transfers, contact tracing and public health action, comorbidities, internal C&DST workflows and processes (Niskhay LIMS), and drugs and consumables supply chain management (Nikshay Aushadhi). Aggregated reports and dashboards inform program managers and policy makers where action or intervention is needed within their specified jurisdictions; data on notification is available in the public domain (reports.nikshay.in). The system holistically captures public and private sector patients and DS- and DR-TB and works as a single integrated system for the whole country. It currently holds data of over 15 million people serving over 400,000 users.

SCREENING AND CASE FINDING

The screening and case-finding stage of the cascade of care remains primarily paper-based across all 13 countries. It is still in the nascent stages of digitization as countries begin to develop applications to capture presumptive TB cases. Existing digital tools are being implemented by partners within small regions of countries, as pilots. These different applications are targeting different users and different modalities, with the most prominent being digitization of the usual workflow of community healthcare workers (CHWs). By supplying CHWs with a mobile application, they can capture their traditional paper-based screening data digitally, as seen in Nigeria with MATS (see Case Study "Nigeria's mobile screening application").

CASE STUDY

NIGERIA'S MOBILE SCREENING APPLICATION

The recent launch of the Mobile Application for Tuberculosis Screening (MATS) in Nigeria has been viewed as a great success. The mobile application enables screening and notification of TB cases by private health care providers. Appropriate referral of clients or samples for diagnosis and treatment can also be initiated and logged into the application. Since the launch, there has been an increase in TB screening and linkage between facility and community-based units. The application has increased real-time information on progress made by private-for-profit facilities, faith-based organization facilities, patient medicine vendors, community pharmacists, private laboratories and other TB referral entities. The release of the application shows the efforts directed towards finding tuberculosis cases and the desire to improve both public and private sector contribution to the national TB case notification.

Other tools are targeting patient-facing modalities where individuals can use a mobile application that guides them through a screening questionnaire and refers them to appropriate facilities should their answers deem them symptomatic. One application in Tanzania (see Case Study: "Tanzania's TAMBUA"), is using a toll-free number, which similarly empowers individuals to initiate their own care-seeking. Both mobile application and toll-free number modalities are able to capture identifying information to help link people with TB to the health system and ensure no loss to follow-up.

CASE STUDY

TANZANIA'S TAMBUA TB

In Tanzania, an m-Health application called TAMBUA TB, is being used to facilitate individuals to self-screen using a toll-free line that guides them through a set of self-screening questions. Upon completion, if the client is symptomatic, the system will direct them to go to health facility in the area of his/her domicile for diagnosis and links the individual to the existing backbone system. The NTP launched the "TAMBUA TB" mobile application in an effort to find TB missing cases and facilitate TB awareness. For confirmed TB patients, the mobile application can also be used for treatment monitoring by sending messages to promote adherence and ensure treatment success.

Lastly, the use of computer-aided detection (CAD) for tuberculosis (see Case Study "Computer aided X-ray detection of TB") and contact tracing applications are being piloted in some settings. By targeting households of TB confirmed cases, some countries are exploring the use of geotagging to map potential hotspots. As one stakeholder in Zambia explained, "*to aid in the contact tracing as well as mapping of hotspots in our community... before they present in the facility, they are in the community, right? So really if we can have an app and if it can be an interactive one, whereby this data can be entered and then if it can do some kind of impact and modelling, some kind of artificial intelligence to help us map our hotspot - that can really be a game changer.*"

The example of CAD for TB and another vendor's qXR, showcases the value of using AI algorithms to detect abnormalities and help facilitate TB screening and diagnosis. Other novel software being developed and implemented includes qTrack which utilizes AI powered chatbot to converse with people who may need to be tested, such as household contacts. These and other AI powered interactions, which are yet to be developed, may be applied to improve other stages of the TB cascade of care.

CASE STUDY

COMPUTER-AIDED X-RAY DETECTION OF TB

Implementing simple, effective, and inexpensive ways to detect new TB cases at an early stage is warranted. The use of low-cost, quick digital chest x-rays for systematic TB screening can be extended to remote settings with computer-aided detection. It is designed to help non-expert readers to detect TB more accurately and cost-effectively with deep learning and remote expertise with the speed of digital x-rays, as well as enable images to be interpreted by WhatsApp or email. It is also primarily used to help triage patients at the point of care to determine who should receive a GeneXpert test. This extends the reach to remote settings where local expertise for accurate reading may not be possible. In countries under study, including Nigeria, Bangladesh, Uganda and Tanzania, different types of projects are exploring the use of chest x-rays with AI functionality to facilitate systematic and active detection of TB. Some contexts are exploring the use of mobile vans that are equipped with x-ray machines and computer-aided detection software to enable mass screening in remote areas with a lack of health facilities or in facilities with high out-patient department (OPD) attendance

DIAGNOSIS AND LINKAGE TO CARE

The diagnosis stage of the cascade of care has received a lot of attention as a supporting digital tool primarily due to the diagnostic connectivity of GeneXpert machines. Cepheid's GeneXpert machine is a highly sensitive, rapid, and fully automated molecular test that was recommended by the World Health Organization in 2010 and widely deployed in LMICs[6]. The use of a fully automated rapid test improves diagnosis of tuberculosis and identifies TB drug resistance. All 13 countries in this study reported having either nationwide or piloted GeneXpert connectivity solutions. This enables faster reporting of GeneXpert results and has been shown to allow clinicians to act faster and initiate patients on treatment sooner. Digital connectivity solutions have been developed by private vendors, such as GxAlert (see Case Study: "GxAlert diagnostic connectivity in Mozambique") and Data to Care, and by countries themselves, in home-grown versions as seen in Indonesia (SKAT) and Kenya (Gx LIMS) (see country profile appendices).

CASE STUDY

GXALERT DIAGNOSTIC CONNECTIVITY IN MOZAMBIQUE

In Mozambique, GeneXpert machines were first piloted in 2011 and diagnostic connectivity solution, GxAlert, was introduced in 2014. The expansion of the GeneXpert network has been coupled with the expansion of GxAlert to full national scale, capturing 90% of all GeneXpert test results. The connections and support enable the regular and timely flow of diagnostic results to clinicians for faster treatment initiation and to program managers in the NTP for better decision-making. Following the rapid scale-up of GxAlert, linkage to care for RR-TB patients diagnosed by GeneXpert had significantly increased to above 85% by end of 2020.

Yet gaps remain within the stage of diagnosis as other significant steps remain largely paper-based. The transport of sputum specimens from facility to laboratory for GeneXpert testing or drug-susceptibility testing centers is yet to be digitized in many settings. Oftentimes, these samples are delayed, do not reach the laboratory, or become lost, and paper-based tracking is not feasible to facilitate the process. Countries which have taken steps to automate tracking have seen significant benefits such as faster diagnosis, initiation of treatment and follow-up. An example specimen transportation system is described in the Indonesian case study, SITRUST.

"There's nothing tracking specimen movement. Which is one of the biggest headaches... that's what causes a lot of extended turnaround times."

6 There is an emergence of GeneXpert alternatives such as Molbio's Truenat that did not come up in interviews but should be highlighted as options for countries to consider.

CASE STUDY

INDONESIA'S SITRUST FOR SPUTUM TRANSPORT

Indonesia has developed a systematic specimen referral mechanism, called SITRUST (Sistem Informasi Treking Untuk Spesimen Transport), for specimen transportation to GeneXpert sites. The user-friendly mobile and web-based application helps to monitor the transportation of sputum specimens from health facilities to both GeneXpert laboratories and/or drug susceptibility testing (DST) labs to be tested for TB. SITRUST enables all health facilities, couriers, GeneXpert and DST labs to monitor the delivery process. The application automatically tracks and reports the condition of the specimen and the release and arrival timepoints along the transportation process. To enable this transportation, a cooperation agreement was established for Provincial Health Offices to collaborate with the National Post Office. One of the key elements for the scale up and sustainability of this system is the involvement of Provincial and District Health Officers to implement and monitor the platform in their respective district areas.

For people that require drug-susceptibility testing (DST) to determine type of TB, this requires testing at a reference laboratory. There are limited numbers of these laboratories and therefore require longer travel for both specimen and result transmission to facility. Some countries have laboratory information systems that digitize these DST results, whereas others do not yet. Faster and automated transmission can similarly improve on turnaround times and facilitate faster initiation of treatment for drug resistive TB.

Even when automated systems for tracking diagnostic information exist, as the case of GeneXpert or DST connectivity, the information is not necessarily entered automatically into the case management platform. Recording of testing data into the backbone oftentimes requires manual transcription. Many country informants shared that being able to automatically transmit data from supporting tools into the backbone through an API would reduce the need for the timely and onerous manual transcription required by laboratory personnel or health care workers.

TREATMENT INITIATION AND PATIENT MANAGEMENT

The backbone, or more specifically the case-management platform, has the central role of managing information on people with TB as they progress through treatment. Notable supporting tools for this stage include digital adherence technologies (DATs) that help to monitor and track real-time dosing history to inform counseling and remote support. These tools have received increasing attention and emerged as promising aids to support treatment. In a differentiated care model, contrasting to the traditional Directly Observed Therapy (DOT), there is prioritization on patient autonomy. The most prominent digital adherence technologies include:

- Video Observed Therapy (VOT)
- Electronic pillboxes
- Medication sleeves coupled with two-way messaging

These DATs exist jointly in the integrated in India's backbone system, Nikshay (see Case Study: "Integrated Digital Adherence Technologies in Nikshay").

CASE STUDY

INTEGRATED DIGITAL ADHERENCE TECHNOLOGIES IN NIKSHAY

Digital adherence technologies (DATs) leverage the growing prevalence of inexpensive mobile and communications technologies to promote self-reported dose administration and adherence monitoring and empower people to take their medications independently while maintaining a connection with their healthcare providers. India's backbone system, Nikshay, integrates three leading DATs: 99DOTS, VOT and evriMED/MERM devices, along with provider reported adherence. 99DOTS is a low-cost solution that uses inexpensive packaging (envelopes or stickers) so that when someone dispenses a dose, the packaging reveals a hidden toll-free number that can be called to register daily adherence. VOT allows for virtual directly observed therapy through video recordings, whereas MERM (Medication Event Reminder Monitor) is a digital pillbox that provides daily visual and audible reminders for both daily dosing and refills. All solutions transmit data to a server that a healthcare provider can remotely view and use to support enhanced adherence counseling. The system also allows switching between technologies based on patient/provider preference in a seamless manner. The integrated model of DATs are available to other countries through an open-source system called Everwell Hub which is being used to pilot DATs in six of the other study countries.

Other DATs being explored use biometric tracking of patient visits and offering adherence support via stimulus payments or self-reporting on a mobile application.

Nearly all digital adherence technologies across the 13 countries under study are in pilot phase, with several pilots running in parallel in a single context. In India, medication sleeves have been scaled across the country. Countries that have yet to implement DATs have expressed interest, and others have shared the need to integrate seamlessly into the case-management platform to demonstrate biggest impact. As one country informant in Kenya noted, *"providing an adherence module as a standalone may not add much value if it's not linked up with the other modules that are key in the quality of care."*

> "[Having an] adherence electronic tool.. that's a gap that we need to really really fill, especially COVID has shown that it is needed. That is one gap in the program...we need to invest."

Country informants also shared the critical role of digital tools to capture treatment adverse events. Still captured primarily in paper-based forms, there is opportunity to strengthen drug safety monitoring and management activities. In the Philippines, the roll-out of a new medicine called bedaquiline in 2015 was coupled with the development of a digital pharmacovigilance monitoring system, as described in "Philippines PViMS application."

CASE STUDY

PHILIPPINES PVIMS APPLICATION

To address MDR-TB in the Philippines, a shorter regimen was introduced in 2015 and bedaquiline in 2016. But with any new treatment, active pharmacovigilance is needed to help ensure both patient safety and drug effectiveness. This allows monitoring people with TB to identify and evaluate adverse events, such as unexpected or serious side effects. In response, a web-based application called Pharmacovigilance Monitoring System (PViMS) was developed to help clinicians, regulatory bodies and implementing partners monitor medicine safety. The PViMS system is currently implemented in DR-TB/PMDT facilities only, while the roll-out plan for DS-TB facilities has not yet been finalized. The introduction of PViMS, initially for operational research, has improved the availability and quality of information for decision making through the use of electronic tools. The routine use of PViMS by the National Tuberculosis Program is expected to start this year.

MONITORING AND REPORTING

National aggregate reporting systems, which house TB data alongside other programmatic data (e.g., HIV, Malaria, etc.) have been shown to be the first digital tools to reach widespread maturity. Out of the 13 countries under study, 10 use the free, flexible, and open-source solution developed by the University of Oslo called District Health Information System-2 (DHIS2) for aggregate reporting of TB data. The successful adoption of DHIS2 in multiple countries can be attributed, among other things, to its extra functionality which can meet country-specific requirements. In most countries, data becomes digitized at the district-level and then becomes aggregated and recorded within DHIS2. As described above, the aggregate reporting tool together with the case-management platform makes up the first configuration of the backbone. Some countries have developed linkages that seamlessly facilitate flow of information, as described in the case study on Bangladesh's interoperability between e-TB Manager and DHIS2. Others still require manual transcription by country personnel.

CASE STUDY

E-TB MANAGER AND DHIS2 INTEROPERABILITY IN BANGLADESH

In 2015, Bangladesh undertook a comprehensive mapping exercise to review opportunities to link tools for improved efficiency. More specifically, the consideration to integrate e-TB Manager (case management platform for TB) and DHIS2 (national aggregate reporting tool) so that patient summary data could become available through DHIS2 for indicator reporting and better decision-making. The assessment concluded with a link established through a standard API interface to ensure data flow from one to another. This enables the NTP to push summary data from e-TB Manager to DHIS2 and generate World Health Organization quarterly reports, among others, and avert onerous manual transcription.

Another notable digital tool to be mentioned as a national monitoring solution used by many countries is the tool for national-level forecasting and procurement of TB drugs. A large majority of countries use QuanTB to ensure that people with TB have continuous access to TB drugs. This requires complex projections and calculations by program staff and therefore, having a digitized tool to track and quantify stock management at national-level combined with facility-level tools (largely paper-based) has been shown to reduce stockouts. Some countries have chosen to develop a home-grown solution for medicine procurement as seen in Uganda's TWOS system (see Case Study: "Uganda's TWOS system for medicine procurement).

CASE STUDY

UGANDA'S TWOS SYSTEM FOR MEDICINE PROCUREMENT

Uganda's tuberculosis medicines web-based ordering and reporting System (TWOS) is hosted by the Ministry of Health in the official national health management information system, called DHIS2. TWOS has the ability to facilitate timeliness of TB medicine orders, ease monitoring of facility reporting rates (percentage of facilities that order medicines from the warehouse), gives access to facility stock status, and reduces central warehouse workload in compiling paper-based orders before distributing TB medicines to health facilities. Facilities with computer, internet and DHIS2 access can place orders directly into TWOS system. Other facilities without computers and internet connectivity submit paper-based copy orders to district officers who enter the orders into the web-based system at district level. The TWOs report can provide recommendations and actions to be taken by stakeholders to mitigate supply issues.

ELEARNING

Despite not being directly attributable to a stage of the cascade, all countries have expressed interest in investing more in e-learning digital tools. Still in early stages of development, these applications target different users and different functionalities. For patient-facing tools, countries have focused on mobile applications that can provide easy access to verified information on TB screening, testing, treatment, and prevention as well as information pertaining to nearby testing facilities. Some applications are also incorporating the ability to report side effects, treatment adherence and issues with clinical services. These digital tools are targeting individuals affected by TB but are also applicable to close contacts of TB patients, and general members of the community. A prominent community-based digital tool, called OneImpact, deployed in 4 of the 13 countries under study is highlighted in the context of DRC (see Case Study: "OneImpact in the DRC").

CASE STUDY

ONEIMPACT IN THE DRC

In the Democratic Republic of Congo, the Stop TB Partnership's mobile application called OneImpact supported through the Global Fund Strategic Initiative 'Finding Missing People with TB', is being deployed to support meaningful community-led advocacy and monitoring. OneImpact, among other things, is intended to give people affected by TB access to information on their rights, and TB care and support services. It provides a virtual space for individuals to engage with each other in TB support groups and gives a provision to people affected by TB to report challenges they face throughout their TB journey which prompts a response at the local level. In the DRC, the application is specifically targeting key objectives of a human rights-based TB response and strengthening the meaningful participation of people affected by TB in all aspects of the TB response.

Provider-focused digital tools are similarly focused on providing easy access to pertinent information for clinical care and management. To help healthcare workers stay on top of the most recent policies and procedures, countries are exploring the use of digital tools to house a library of up-to-date manuals, strategic plans, and other key documents. This can enable easy dissemination of information and support better clinical care. The COVID-19 pandemic has also highlighted the need for remote training capabilities, with digital applications as a potential solution. To enhance the utility of digital tools, an example from the Philippines (see Case Study: "Philippines End TB app suite") highlights the value of an interconnected suite of applications covering distinct areas that provides a strong foundation to support the NTP.

CASE STUDY

PHILIPPINES END TB APP SUITE[7]

The Department of Health in the Philippines, in association with the WHO, has recently rolled out a comprehensive End TB app suite that captures the entire cascade of care for TB communities and their families. The app suite encompasses four mobile applications covering distinct areas. The Care TB app focuses on patient care with modules for people with TB, providers, and civil society organization. It contains the OneImpact app functionality and customizes it to the Philippines context, enabling TB patients to retrieve their electronic health records, chat with their doctors, and more. The Race TB app supports surveillance and monitoring activities with real-time dashboards. The Lead TB app is used for programmatic management and supervision, including remote supervision. Lastly, the Guide TB app which is specifically focused on e-learning for healthcare workers, acts as an important reference with all major documents (e.g., manual of procedures, strategic plan, latest program review, etc.) easily accessible and all in one place. The EndTB app suite aims to provide a complete digital solution for people with TB, care providers and program staff in the Philippines.

7 ntp.doh.gov.ph/apps

DISCUSSION

The summary of insights from country informants across 13 national TB programs suggests that a key enabler in the fight against tuberculosis will be to devise a shared understanding of globally available tools and associated best practices for using technology in TB care. By using a comparative lens to understand the similarities, differences, and trends across countries, we hope to glean existing gaps and potential opportunities for innovators, funders, and individual country programs to aspire towards.

Findings show that while the uptake of digital infrastructures is fragmented, countries share a desire for developing a "backbone" system for the management of TB. This, alongside similar supporting tools used in multiple geographies, confirms that many of the challenges faced by national TB programs are shared. As such, lessons learned and best practices across countries can benefit multiple geographies. The emergent pattern of technical advancements following similar trajectories can provide a framework for countries to follow. And only by understanding the full scope of local country requirements and matching to existing global technologies that may or may not apply, can we hope to make noticeable strides towards the global fight against tuberculosis.

Yet gaps remain that can inform opportunity areas for future action in the development of the digital architecture for the management of TB. Outlined below are illustrative steps along the described pathway to digital maturity that can guide both countries and global partners to strengthen their usage of technology in service of eliminating TB.

GAPS IN DIGITAL TOOLS FOR THE TB CASCADE OF CARE

- Most backbone systems do not yet incorporate all stages of the cascade - some data is not captured digitally, while some digital tools are not interoperable with the backbone
- A diversity of backbone architectures are used; there is a gap of knowledge on how such systems compare and in which contexts countries should switch to a different platform
- Digitization of DS-TB needs to catch up with DR-TB and integrate into a single system
- Interoperability between case-management and aggregate reporting systems is often missing
- While many innovative systems have been piloted (digital adherence technologies, new approaches for screening), few have been integrated into a coordinated standard of care or taken to nationwide scale
- Lack of digitization across some steps in the diagnostic stage of cascade, including sputum transport
- Need for automated transmission of diagnostic results into the backbone
- Paucity of digital tools for pharmacovigilance monitoring across countries
- Largely paper-based facility-level ordering of medicines; should link with digital tools for national supply chain
- Nascent stages of development of e-learning applications
- Lack of mechanisms to ensure appropriate linkage to care from community-based digital tools to ensure no loss to follow-up
- Massive time lag in data reporting with nearly no systems offering real-time data largely due to parallel paper- and digital- records and time required for data cleaning

OPPORTUNITIES FOR DIGITAL TOOLS FOR THE TB CASCADE OF CARE

- To encourage countries to appraise their existing digital architecture, challenges, and ambitions and to recalibrate goals and priorities relative to the global practices described herein. The sharing of experiences and best practices can lead to collective digital transformation and result in significant benefits across localities.

- To formally evaluate available tools (such as alternate open-source backbone architectures) and assist governments in choosing the most appropriate solution, in terms of technology, cost, integration and vendor support, etc., pertaining to their own specific contexts. This will help the decision-making process and ensure long term sustainability and scalability.

- To create an open, community-maintained resource (Wiki or similar) to document the ongoing usage of tools surveyed in this report. Opportunity to leverage and partner with existing resources (e.g., Digital Atlas) to reduce documentation burden on countries. Such a resource could facilitate lateral transfer of tools between TB affected countries.

- To encourage countries to plan ahead for a single integrated system for drug-susceptible and drug-resistant TB rather than developing parallel systems and merging thereafter.

- To ensure all stages of the cascade of care are digitized and eliminate bottlenecks that prevent 'real-time data' from being achieved to full potential.

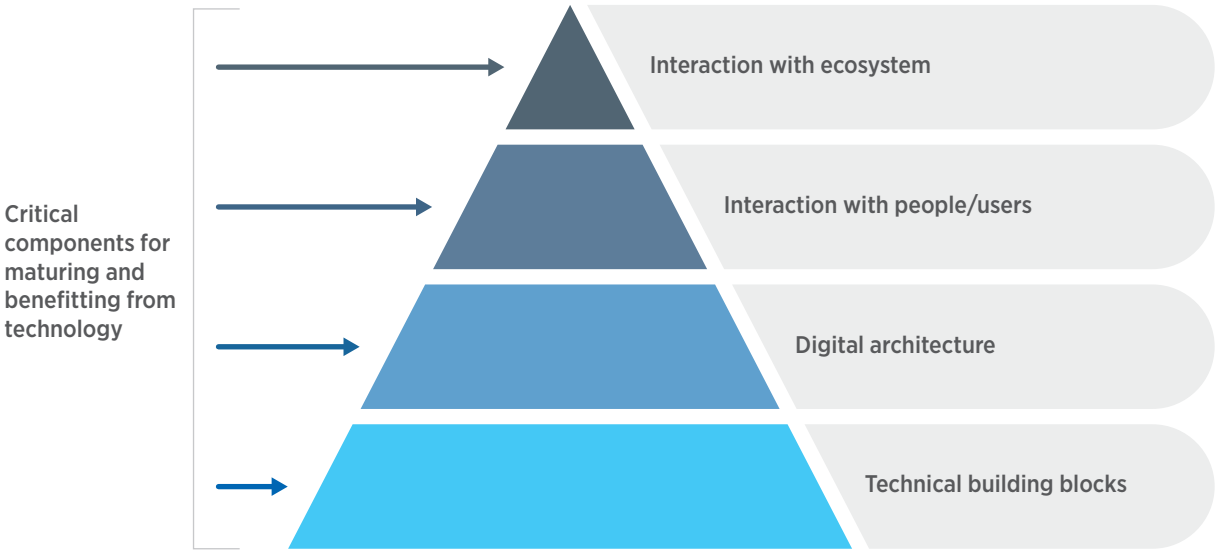
- To prioritize interoperability by investing in modular architectures and reusable APIs, making it easier to integrate new technologies in the future. Retrofitting mature architectures for interoperability can be more challenging and costly. The benefits of digital health systems are not gained when data flows are inhibited.

SECTION 2

HOW TO STRENGTHEN THE DIGITAL HEALTH ECOSYSTEM

Mapping available technologies, across the cascade of care, reveals best practices and highlights opportunities for lateral transfer of technologies across TB affected countries. Study findings also reveal cross-cutting dimensions in which those technologies could be further nurtured and evolved. It is anticipated that countries will be able to draw on the lessons shared and cultivate opportunities for digital improvements that benefit global coordination. This section describes these dimensions along four major themes (Figure 3) – technical building blocks, digital architecture, interaction with people and interaction with the ecosystem.

FIGURE 3:
Emergent themes needed to nurture and evolve to an ideal system



TECHNICAL BUILDING BLOCKS

Implementing digital health systems is limited to areas where satisfactory levels of infrastructure, such as electricity, connectivity, and access to devices, is available. Poor infrastructure severely limits the potential of digital health systems and therefore, investments to strengthen these foundational components should remain a high priority across countries. In this study, a large variability in access to mobile devices and internet usage was reported, with countries employing different practical approaches to help respond and alleviate constraints posed by infrastructural limitations.

For example, some countries have responded by developing offline functionalities and mobile-based versions of existing web-based platforms that enable the recording of data when connectivity is unavailable, as seen in Indonesia (see Case Study: "Indonesia's SITB offline and mobile"). Other countries, with limited access to hardware resources, have deployed programs whereby district-level officers are equipped with tablets and record data from each facility through monthly visits (see Case Study: "TIBU tablet data entry by sub-county TB coordinator"). Yet despite these significant advancements, limitations are still experienced as noted by a country informant in Nigeria, *"offline mode is restricted to just basically registering the patients and starting them on treatments. You can't do drug management...you cannot do logistics management on offline mode. So that's a bit restrictive. So while the platform might be a bit effective - but we have challenges operationalizing to its full capacity"*

CASE STUDY

INDONESIA'S SITB OFFLINE AND MOBILE

Indonesia's backbone system, called SITB, is a comprehensive and interconnected system that recently replaced two parallel systems for DS-TB and DR-TB, namely e-TB Manager and SITT. The platform is intended to capture all stages of the cascade of care and be used by different individuals depending on access levels within facilities, laboratories, and ministry-level. Yet, Indonesia being an archipelago, suffers from inadequate internet connectivity in certain remote areas. To address this, an offline mode has been developed for remote facilities to upload to computers. City-level TB officers then travel to make a backup of TB data captured offline. Similarly, SITB mobile is currently in development to enable users at health facilities use their phones or tablets to access SITB when only mobile connection is accessible.

CASE STUDY

TIBU TABLET DATA ENTRY BY SUB-COUNTY TB COORDINATOR

In Kenya, where access to hardware at all facilities is a challenge, the TB program has chosen to equip sub-county TB coordinators with tablets bundled with airtime and internet data. These TB coordinators are then tasked with visiting all facilities within their jurisdiction and digitizing the TB registers. They are responsible for visiting each facility on a monthly basis, but oftentimes visit several times a month for data entry and to provide support to the facility staff under their supervision. This enables the utilization of a digital platform, despite infrastructure and physical resource challenges.

Unique Identifiers

Lack of unique patient identifiers is a well-known health system challenge experienced across most TB affected countries, which hinders the ability to track individual data over the course of their lifetime and to link individual patient records across the health system. A major impediment to scaling up of TB services is the relative weakness and fragmented nature of healthcare and social services. Many people living with TB receive health services in multiple settings, such as TB clinics, DOT (Directly Observed Therapy) centers, and HIV clinics. The absence of a unique identifier can lead to loss to follow-up, patient duplication, ineffective management of recurring TB, etc.

Nearly all countries have adopted disease-specific or platform-specific unique identifiers which enable continuity of care through the TB cascade of care. While mitigating loss to follow-up within the program, they still do not enable linkages across the healthcare system to address comorbidities or facilitate universal health care. One example of a unique identifier modality being explored in Zambia showcases a platform-specific identifier that is hoped to scale across programs (see Case Study: "SmartCare in Zambia").

CASE STUDY

SMARTCARE IN ZAMBIA

Zambia's SmartCare electronic health record system, introduced in 2010 and implemented in anti-retroviral (ART) clinics has been adopted as the e-care solution for the country, with plans to scale and incorporate a TB module. SmartCare was developed to improve continuity of care and provide timely data. Patients are issued smart-cards at their initial consultation which contains all their clinical information and treatment details and can be accessed from any SmartCare facility. Rather than keeping individuals accountable for paper records documenting their medical histories, details can be stored on a smart-card they hold in their wallets. As a proxy unique identifier, the card maintains continuity of care between visits, disease programs, and across health facilities, with a backup in the SmartCare health management information system.

National-level identifiers can be highly beneficial if well-institutionalized laws and rights can support a sound health information system. Yet, difficulties remain in equitable access to national ID's and individuals not providing ID numbers when seeking care for reasons including fear of breaches in confidentiality. Other programs have endeavored to use heuristic-based identifiers, using a combination of identifying bits of personal information such as name, birthday, sex, etc., to help match individual data to existing records in the system. This can assist with automated linkage of records, but can still suffer from inconsistent spelling, recall of information and data entry.

> "HIV has their own unique identification system. TB has got a different one – so sometimes very difficult to link the patients between the two programs."

Hosting Data Centers

An area that has received increasing attention and concern in digital health is hosting and maintenance of data centers. Government policy is generally understood to require storing data in-country, and may prescribe the use of on-premise infrastructure as opposed to cloud servers from third-party companies. Yet, an ambiguity exists between official legal policy and informally conveyed preferences surrounding data centers. Concerns over privacy and security are also top of mind and may influence the preference for in-country data hosting, though there are mixed views as to whether this is a valid concern.

Currently, most countries abide by either in-country physical or in-country cloud servers. Yet, participants have raised several challenges including the maintenance of a physical server that is robust to variations in peak load at a nationwide scale, and cloud hosting capabilities within country borders. To overcome these challenges, a few countries are employing hybrid approaches, as seen in the case study highlighting Kenya and Indonesia. It is anticipated that with growing usage of ICT systems, different approaches will be needed to confront the limitations posed by country policies and capabilities surrounding hosting.

CASE STUDY

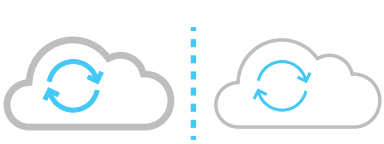
HYBRID HOSTING IN KENYA AND INDONESIA

Challenges associated with in-country physical and in-country cloud servers have been addressed through hybrid approaches in Kenya and Indonesia. In Kenya, data is hosted on an in-country cloud server with a mirrored cloud server in South Africa to mitigate any potential failure. Whereas, in Indonesia, an in-country physical server is used for the persistent data store while a linked in-country cloud server is used for serving users.

FIGURE 4:
Data hosting approaches to manage country specifications and capabilities

Most common models:
in-country physical server **OR** in-country cloud

Hybrid approaches:
backup of data mirrored outside country, or two servers in country (physical server for data store, cloud server for serving users)



(Kenya)

(Indonesia)

DIGITAL ARCHITECTURE

The digital transformation across national TB programs has revealed a spectrum of technical advancements that have notably followed a similar trajectory across the 13 countries in the study. Many of the challenges experienced have been shared across multiple geographies, and as such, defined best practices and lessons learned can be used to inform other localities.

An emergent pattern is that, while there is great diversity in the context and constraints of national level programs, there is often a shared pathway of digital evolution, including steps that each country can take to strengthen its usage of technology in service of eliminating TB. For example, stakeholders shared the challenge of parallel systems which can exacerbate the weakening of national health systems by diverting resources and leading to difficulties and inefficiencies. One example of parallel systems is the development of two different systems for drug-susceptible (DS-TB) and drug-resistant (DR-TB) tuberculosis. A best practice or digital evolution observed has been the merging of parallel systems into one holistic backbone platform, which has been completed or planned by several countries to improve service delivery.

Another challenge has been counting notifications twice due to patient duplication in the system as expressed by many countries. This is primarily due to patient mobility, whereby individuals move from one part of the country to the other. One approach to mitigate this, seen in South Africa, has been to embed tracking of transfers in the system, however access to previous case record data in the old facility are yet to be transferred and accessible in the new facility. Another level of digital evolution, in India, showcases an effective management mechanism, detailed in the case study "India's patient transfers between facilities."

CASE STUDY

INDIA'S PATIENT TRANSFERS BETWEEN FACILITIES

In India, patient mobility is a significant challenge to manage in terms of accountability and continuity of health care. If a person is diagnosed with TB in one part of the country and then moves to another part of the country, the earlier protocol would necessitate the record existing in the original location where it was notified and a new record would be created in the newest location, potentially counting the individual twice or the patient being missed altogether. In 2018, a new effective management mechanism of transferring patients was developed. The new process maintains separate fields for the location where the patient was diagnosed and the current location of the patient, ensuring that each notification is counted only once while also enabling continuity of care with accessible medical history.

Interoperability

With increasing digitization across the cascade of care and the development of supporting tools to capture data in each respective stage, country informants have shared difficulties of required manual transcription steps to transmit data across tools. In response, countries have initiated activities to develop interoperability between existing digital tools in their TB digital architecture. The resulting linkages can enable data to flow and results in faster and informed decision-making. Automated interoperability between the case-management platform and aggregate reporting tool in countries is a priority development, if not already complete. Interoperability between supporting tools and the backbone is also consistently highlighted as a critical next step in the maturity of the overarching system.

An additional critical dimension is the integration of data from the private sector for many countries. Countries have expressed that it is a big challenge to ensure all private notifications are captured, and approaches vary across the 13 countries under study. Some private sector facilities send paper-based reports to the district level where it is manually entered into the electronic system, other countries enable direct transcription into the backbone at private point of care, and a few have developed specific supporting tools geared for capturing private sector data (as seen in Case Study: "Indonesia's WifiTB for private sector reporting"). Overall the coverage of private sector reporting is largely suboptimal in most countries and requires strengthening.

CASE STUDY

INDONESIA'S WIFITB FOR PRIVATE SECTOR REPORTING

In Indonesia, tuberculosis notification is mandatory, and all health facilities must record and report identified TB cases using standardized formats. Doctors in private health facilities have found it burdensome to fill TB reporting forms and do not directly record into the backbone system, SITB. To facilitate the reporting of people with TB, and to address the low TB notifications from the private sector, a mobile application called WiFiTB (Wajib Notifikasi TB) was created. The application is interoperable with the backbone platform, SITB, and helps automatically integrate private and public sector data for more accurate reporting.

Quality assurance

The transition from paper-based to electronic-based data transcription has been largely beneficial and effective. However, countries have reported difficulties with incomplete data where data entered is inconsistent with facility paper-based records. Data quality being of critical importance, countries have utilized various approaches to ensure accurate records. One effective way to address incomplete or bad data is incorporating mandatory validation features at point of entry. In Kenya, incorporating validation checks for creation of a new record or managing an existing case has addressed issues of incomplete, incorrect, or inconsistent data (see Case Study: "Kenya's TIBU auto-validation features").

Nearly every country has shared the necessity of a parallel process of data cleaning through ad-hoc exporting into a spreadsheet such as Microsoft Excel. This intermediary step, in some contexts, is used as secondary validation to ensure accurate data reporting. Yet, in other contexts, Excel sheets are used as part of the required protocol for monitoring and evaluation, with each jurisdiction transferring data into a spreadsheet for cleaning and aggregation before sending it further upstream. According to most country informants, this is an area for improvement due to inefficiency and susceptibility to errors. In India and the Philippines, for example, automation has enabled cleaning steps to be embedded within the main platform tool to streamline usual workflow and with little need to validate information using Excel.

"Technologies help us automate the validation checks, so we are assured of quality of data, instead of having to do that manually at different levels."

CASE STUDY

KENYA'S TIBU AUTO-VALIDATION FEATURES

Kenya's TIBU system was developed with a priority placed on ensuring ease of data quality checks. The system focuses on validation at point of entry with maximum and minimum values indicated, flagging required entries, and will not allow a record to be created if a duplicate already exists. Notably, the automatic detection will also flag that a record exists if a client seen the previous year, was treated, cured, and comes back with a recurring episode of tuberculosis. The system will provide a warning and the existing client record. Similarly, automated z-score and BMI checkers are embedded in the platform to ensure accurate and consistent values of height, weight, sex, and age. Outcome data is also verified based on diagnosis tests entered to satisfy relevant thresholds. Data quality assessments are also conducted annually to ensure appropriate oversight. All these validation checks mitigate human errors and preemptively remove more burdensome data cleaning at later stages of reporting.

INTERACTION WITH PEOPLE

Technological advancements have drastically advanced national TB programs, however, technology alone is insufficient to reap the associated benefits. Interactions and appropriate use by people are just as critical for proper uptake of digital tools. Despite a myriad of existing tools, insufficient utilization is prevalent and expressed by informants across all 13 countries under study. In many TB affected countries, a lack of digital literacy prevents users from changing behaviors from well-established paper-based workflows to digital platforms that are perceived as difficult to use and cumbersome. This impedes on motivations to use applications as they are perceived as an extra burden rather than a modality to ease day-to-day tasks. Another critical element lacking is appropriate implementation training to guide healthcare workers to use existing tools effectively.

Using data and digital technologies is contingent on having a digitally competent workforce at all levels of the health system. Inadequate staffing to support monitoring and reporting at national and sub-national levels requires special attention. Skills shortages directly undermine the use of digital health interventions. There is a need to ensure people in health-policy leadership positions have the skills and knowledge to both develop and manage digital health initiatives and strategies.

User-centered approach

To address challenges associated with appropriate adoption and utilization of existing tools, some country informants stressed the importance of user-centered design, where tools are developed to suit the needs of users and aligned with usual workflows. An example of how user-centered design can be best incorporated into the development of digital architecture is demonstrated in the case study from Philippines which highlights best practices employed (see "User-centered design in the Philippines").

CASE STUDY

USER-CENTERED BACKBONE DESIGN IN THE PHILIPPINES

In the Philippines, elements of human-centered design were pivotal in the development of the revised ITIS backbone system. From the beginning, a series of workshops were conducted which involved selected stakeholders from every level in the health system, including region, province, city, and health facility. This enabled end-users of all roles in the TB program to share ideas and be involved in the design of the system. Per these requests, adaptations were integrated into ITIS that reflected appropriate workflows. To enable ongoing refinements to the system, a help desk is available that considers any suggestions and upgrades the digital platform regularly.

Other best practices have focused on the need for strong capacity-building and implementation training to ensure end-users feel well equipped to use available tools. Providing supportive resources can allow individuals to acquire appropriate skills and knowledge to perform at greater capacity. Facilitating existing workflows and embedding training components into the system can strengthen motivations to use technology.

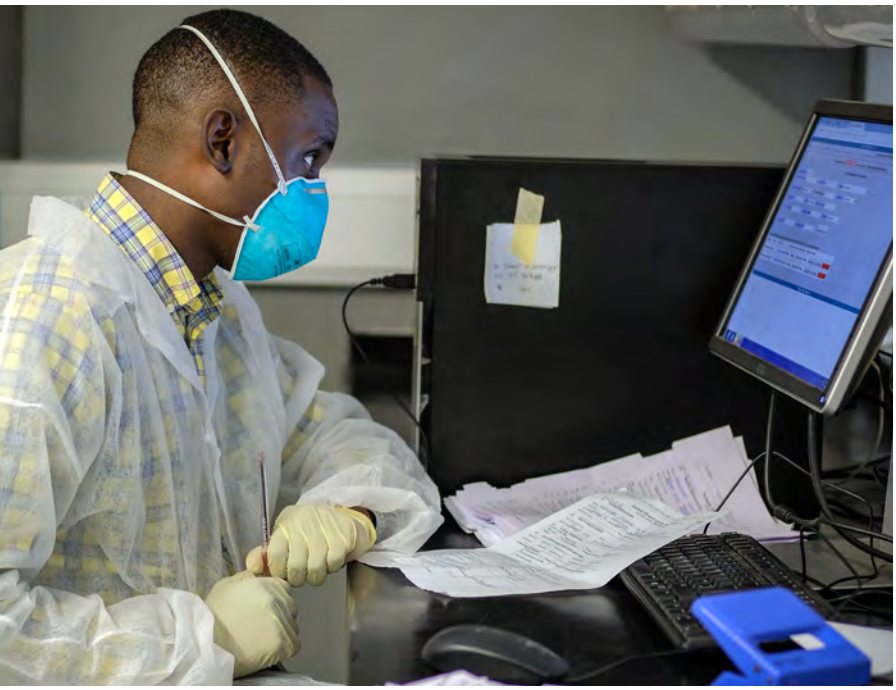
Human components are required to fill gaps of the digital architecture, as exemplified in the case study "Timeliness of reporting dependent on human elements." A strong interdependency exists between human and technical elements.

> "[ITIS] also serves as a work management tool. If I am a new staff and I don't know what to do, the technology will guide us what to do next."

Data privacy

Data privacy and security are priority elements reported by all 13 countries in this study. Most programs ensure access to data is restricted to the appropriate roles of individuals at different levels including facility, district and national. Built-in permissions within the electronic systems certifies only certain individuals to access patient-level information. Given the sensitive nature of TB data, all countries have stated that privacy of patient-level data is of paramount importance and data is oftentimes de-identified when shared beyond the caregiving team and aggregated for programmatic or decision-making purposes at national-level. Even more stringent policies are in place for sharing data outside of the country, with implementing or funding partners, or research groups. Yet, the maturity of established data policies across the 13 countries varies, with some having strictly enforced rules regarding data privacy and security, and others still in development.

For data that is necessary for research or other reasons, the development of data governance frameworks and data sharing policies is critical to balance data privacy and protection with appropriate innovation.



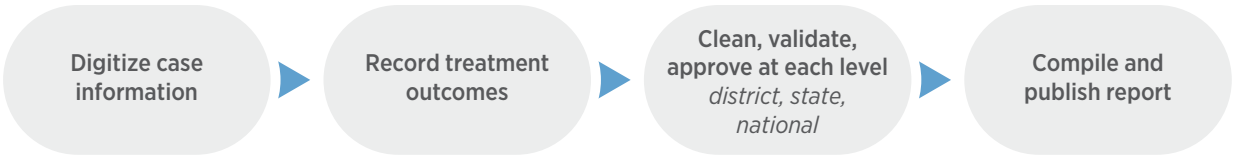
> "There isn't finalized documents, but the policymakers insist that data privacy is paramount... in terms of the law and other dimensions, I think that this is still the beginning. I know that we're working on it... we are aware that personal data must be protected."

CASE STUDY

TIMELINESS OF REPORTING DEPENDENT ON HUMAN ELEMENTS

National-level reporting of TB surveillance data is performed on an annual basis to inform TB prevention and control efforts across countries, with some indicators being reported quarterly. Real-time data would enable even more immediate insights that could significantly improve decision making. Technical advancements can help facilitate timeliness of reporting, including automation, interoperability, and incorporating validation features. However, there is a limit to what technology can achieve by itself. Frequent bottlenecks are human processes, such as digitizing patient records, reporting on treatment outcomes, and approving reports at each level of the hierarchy. Figure 5 illustrates this interdependence graphically. Without human and technical elements, timeliness of reporting cannot significantly improve.

FIGURE 5:
Timeliness of national reporting is dependent upon both technical and human factors



COORDINATION WITH PARTNERS

A critical yet oftentimes overlooked component of implementing a strong digital architecture, is the consideration and interaction with the wider ecosystem. This includes elements of policy, partner coordination, funding, and collaboration with other disease programs, including implications of the ongoing COVID-19 pandemic. As mentioned in the data privacy section, stronger policy guidance and creation of digital strategies for the use of digital tools is needed (see Case Study: "Digital Health Strategy in South Africa" for an example digital strategy). Deficient coordination can lead to fragmentation and inefficiencies for digital tool implementation. Without clear and definite guidance, insufficient partner coordination can transpire and result in multiple parallel systems and duplication of efforts. One participant shared, *"So you end up with a multitude of systems... every partner that comes with the system, wants to be the one that works for the whole country."*

CASE STUDY

DIGITAL HEALTH STRATEGY IN SOUTH AFRICA

With the proliferation of digital health technologies, it is opportune for countries to develop guiding digital health frameworks to further strengthen health systems. South Africa's National Digital Health Strategy, 2019-2024 has proposed nine strategic interventions to be achieved by 2024. As digital technologies transform the way services are provided and the way individuals engage with those services, South Africa has indicated there is a need to strengthen governance structures, create robust integrated platforms for development of information systems, and establish requisite broadband network infrastructure. The strategy outlines five principles including person-centered emphasis, expanded access, innovation for sustainable impact, digital health workforce for economic development and whole-of government approach.

Collaboration across programs

Participants reported that treatment of TB and HIV, which show high comorbidity across the 13 countries, would benefit from more coordination. Many HIV programs have developed their own digital platforms that act in a similar fashion as the backbone systems described for management of TB. Interoperability between the two digital systems would help to support patients and prevent loss-to-follow up. Some countries are opting to use the same platform for both diseases, as seen in the case study from Ukraine (see Case Study: "Integration of TB and HIV in Ukraine"). A range of levels of collaboration exist, despite a consensus that more interoperability and collaboration would be beneficial.

CASE STUDY

INTEGRATION OF TB AND HIV IN UKRAINE

Ukraine, where MDR-TB (multi-drug resistant TB) prevalence is high, is also experiencing one of the world's fastest growing HIV infection rates. The combined epidemic presents an enormous public health challenge as people living with HIV/AIDS are many times more susceptible to developing all forms of TB. In response, a scale up of TB/HIV collaborative activities to provide synergies is being planned. To increase efficiency of routine surveillance systems, the country plans to integrate TB surveillance in the HIV MIS (Management Information System).

Sustainability

Pilots are a longstanding norm to test and evaluate the feasibility and performance of digital tools, or to facilitate a short-term project. However, stakeholders shared concerns regarding pilot implementations without sustainability or scalability in mind. Without a long-term view during implementation, a piloted tool may provide fleeting programmatic benefits but not offer any enduring gains in establishing a mature digital architecture. In a similar fashion, once the pilot phase is complete, and has shown favorable outcomes, ongoing management of digital tools is a concern to the sustainability of a solution. Country informants expressed *"There are so many systems that could be functional but the problem is making sure these systems are being owned by the government and the government has those resources to manage it."*

> "Right now we still [match people with TB and HIV] in a manual way. We export SIHA to Excel and then export SITB to Excel and then we use a manual way to match based on a single identity number."

Planning for long-term affordability and customizability of digital tools is also critical for adoption. Proprietary solutions may be passed over even if they offer desired functionality. Diagnostic connectivity (see Case Study: "Repeated Implementation of Diagnostic Connectivity Solutions") is an example of where replication of work across countries is leading to inefficiencies. Finding ways for sustained financing of digital tools is necessary to enhance the digital architecture for management of TB.

CASE STUDY

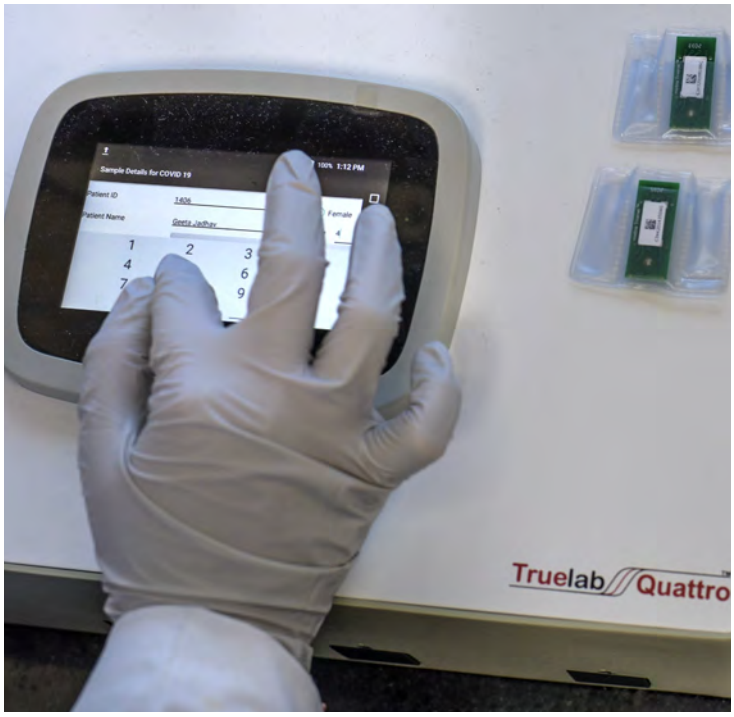
REPEATED IMPLEMENTATION OF DIAGNOSTIC CONNECTIVITY SOLUTIONS

Diagnostic connectivity solutions such as GxAlert and Data to Care have demonstrated benefits and have been piloted in most countries surveyed (and taken to nationwide scale in two countries surveyed). However, in four countries, these commercial solutions were evaluated and liked but eventually set aside in favor of developing a home-grown version with equivalent functionality. The associated recurring costs and not being open-source solutions were reported to be reasons for abandonment. Sustainability of digital tools is critical to long-term health impact and maturation of digital architecture, and replication of work seen in developing home-grown solutions emphasizes the importance of finding ways to incentivize private sector innovation whilst facilitating market dynamics for their sustained use.

COVID-19 implications

The COVID-19 pandemic has had a devastating impact on the fight against tuberculosis. Yet, some positive lessons learned from the pandemic were voiced by participants which shed light on the value of digital technologies. With travel restrictions upending normal treatment support services at DOTS centers across the globe, the need for remote patient monitoring and support was stressed by country informants. Likewise, the urgency placed on COVID-19 testing resulted in innovative developments to swiftly match diagnostic information with individuals, which could similarly be adapted for TB. Other digital adaptations for contact tracing for COVID-19 using geo-mapping could be replicated for TB efforts. As expressed by a participant in South Africa, *"we need something around contact screening that would help link people to a person with TB in a way. And we thought that COVID did it quite well."*

With the momentum created for digital tools, as result of COVID-19, many interviewees shared sentiments that it would be beneficial for funders, partners and other interested parties to band together in the same way for tuberculosis.



DISCUSSION

Analysis of insights shared by country informants demonstrates the need for both technical and non-technical elements to strengthen the digital health ecosystem. To establish the necessary infrastructure with appropriate levels of internet connectivity and access to devices, policies established by higher factions of government, separate from the national TB programs, are necessary. Similarly, establishing unique health identifiers that can track individual data across diseases requires collaboration between programs. Only by breaking existing program silos can there be continuity of care across the healthcare system as a whole. Interactions with users is just as critical for national TB programs to gain positive programmatic benefits from digital investments. Digital tools need to be appropriately utilized by healthcare workers, laboratory technicians and ministry of health staff to assist with clinical workflow, diagnostic laboratory procedures, and programmatic decision-making.

The global TB community is increasingly recognizing the value of digital systems for the fight against TB. There is a need to acknowledge the interconnected components that are necessary to nurture and evolve to an improved system. The gaps and opportunities outlined below demonstrate the foundational building blocks, technical components, human interactions and interlinkages with the broader ecosystem.

GAPS IN THE DIGITAL HEALTH ECOSYSTEM

- Infrastructure challenges still keep technologies out of reach for many
- Large variability in access to mobile devices and internet usage across countries
- Inability to track individual patients across contexts (locations, recurrent episodes, comorbidities, etc.) without unique identifiers
- Lack of clarity and guidance on cloud hosting of data
- Laborious manual entry for paper-based records, need for innovation
- Inefficient data cleaning processes leading to prolonged reporting timelines
- Paucity of analysis functionality embedded within aggregate platforms for generation of reports
- Necessity for better application of user-centered design into digital tools for appropriate uptake to follow
- Inadequate digital literacy and appropriate training of end-users which inhibits use of technologies
- Inadequate staffing for monitoring and reporting to drive the use of digital tools at all levels of the health system
- Data governance policies (e.g., data sharing, etc.) are still in their infancy in many countries
- Replication of work in developing similar tools in multiple countries leads to marketplace inefficiencies and duplicate tools with similar functionalities
- Pilots oftentimes not designed with scalability and sustainability in mind
- Inadequate policy guidance that results in difficult partner coordination and parallel systems
- Disjointed collaboration between disease programs limiting continuity of care for patients

OPPORTUNITIES FOR THE DIGITAL HEALTH ECOSYSTEM

- To revitalize attention and resources to closing gaps in ICT infrastructure in LMICs specifically in areas where the benefits of digital health technologies remain out of reach. Funders, implementing partners, governments, development agencies and interested parties need to continue to advocate, prioritize, and increase investment for infrastructure development that will support the use of technology (e.g., internet connectivity, access to devices, etc.).

- To create appropriate data governance policies at national and global levels that balance the data privacy and security with appropriate use and sharing for effective digital health programs.

- To develop holistic national and global health strategies that can support and inform whole-of-government participation and multi-stakeholder engagement. Opportunity for international organization to continue developing strategies, templates and applicable guidelines that can be adopted by LMICs.

- To promote market shaping and avoid repeated implementations of similar digital tools. Global health is inextricably linked to the health of the marketplace that delivers life-saving products and services. There is an opportunity to transform existing market structures to adopt new and more efficient approaches.

- To integrate digital health solutions horizontally across programs and lessen disease-specific siloed approaches. Through better-coordinated and aligned investments in scalable, sustainable and interoperable digital systems, data can be exchanged in real-time.

- To bolster training and education in digital technologies and address skill gaps (at all levels) that prevent tools from being adopted, maintained, and benefited from.

CONCLUSION

Study findings indicate that while each country exhibits differing maturity in current infrastructure and tools, there is a shared journey of digital transformation that has meaningful similarities between contexts. As such, the ability to share lessons learned and best practices across countries can be greatly advantageous, especially in areas where local solutions are still maturing. The pattern of technical advancements in the digital architecture of national TB programs has been shown to follow similar trajectories that can provide a framework for countries to follow. These illustrative steps along the described pathway to digital maturity can guide countries as they strengthen their usage of technology in service of eliminating TB. With TB affecting many countries, this collective knowledge is especially crucial.

FIGURE 6:
Emergent themes discussed are interdependent and need to be addressed with a holistic approach

Gaining perspectives on the four major themes identified by the study (technical building blocks, digital architecture, interaction with people and interaction with ecosystem), underscores the premise that digital maturity relies on more than just the technical components. These technical and non-technical elements are interconnected and mutually dependent. Rather than functioning as separate components, study findings have shown they are reliant and must co-exist together (as depicted in Figure 6). For example, to establish the necessary infrastructure with appropriate levels of internet connectivity and access to devices, policies established by higher factions of government, separate from the national TB programs, are necessary. Similarly, tracking individuals across their life course and across disease programs requires breaking program silos to enable continuity of care across the healthcare system as a whole.

Digital technologies are being applied in diverse and innovative ways to help overcome key challenges and barriers that constrain efforts for prevention, detection, treatment, and management of TB. Notably, the disruptive innovations that emerged during the COVID-19 pandemic hold key lessons and examples for improvements in TB prevention and control. There is a rare opportunity to seize the momentum garnered by the novel virus pandemic to ensure new investments contribute not only to the control of COVID-19, but also to strengthening technology platforms used by national TB programs. Digital technologies will be a key enabler in the global fight against TB. Acknowledging the interconnected components underlying such platforms will be an important part of strengthening the digital health ecosystem.

APPENDICES

LIST OF STUDY PARTICIPANTS

Bangladesh

- Monitoring and Evaluation Expert, National Tuberculosis Control Programme
- MIS Officer, National Tuberculosis Control Programme
- Senior TB Strategic Planning Technical Advisor, USAID STAR Fellowship Project
- TB REACH Technical Officer, Stop TB Partnership

Democratic Republic of Congo

- Database Manager, Monitoring and Evaluation Division of National Program for Leprosy and Tuberculosis (PNLT)
- Director, National Program for Leprosy and Tuberculosis (PNLT)
- DHIS2 Focal Point, National Program for Leprosy and Tuberculosis (PNLT)
- National Secretary, Club des Amis Damien

India

- National Consultant (TB Epidemiology and Digital Health), WHO-NTEP Technical Support Network - Central TB Division Ministry of Health and Family Welfare
- Senior Program Officer, Bill and Melinda Gates Foundation
- Deputy Director, Bill and Melinda Gates Foundation

Indonesia

- Head of Section Drug Resistant TB, National Tuberculosis Program
- IT Coordinator, National Tuberculosis Program
- Executive Director, Yayasan KNCV Indonesia

Kenya

- ICT & Data Specialist, National Tuberculosis Program
- Sub County TB Coordinator, National Tuberculosis Program
- Director TB and Lung Health, Center for Health Solutions – Kenya

Mozambique

- Specialist Public Health, Monitoring and Evaluation, The Global Fund to Fight AIDS, Tuberculosis and Malaria
- Health Information Systems Team Lead, Centers for Disease Control and Prevention
- Head of Health Information Systems Department, National Tuberculosis Program

Nigeria

- Program Management Unit Team Lead, Global Fund TB Grant in National Tuberculosis and Leprosy Control Programme
- Monitoring and Evaluation Manager, Programme Management Unit, National Tuberculosis and Leprosy Control Programme
- National Professional Officer TB/HIV, WHO Nigeria

Philippines

- Monitoring and Evaluation Coordinator, Department of Health-National TB Control Program (DOH-NTP) Philippines
- Technical Officer, Tuberculosis, WHO Philippines
- Medical Officer, WHO Philippines
- Senior Systems Analyst for ITIS, Department of Health-Knowledge Management and Information Technology Service

South Africa

- Data Management and Provincial Support, TB Cluster
- Director - Drug Resistant TB, TB & HIV, National Department of Health
- Director - TB Control and Management, National Department of Health

Tanzania

- Data Manager, National TB and Leprosy Programme
- TB Care and Prevention Coordinator, National TB and Leprosy Programme
- Deputy Program Manager, National TB and Leprosy Programme
- Data Analyst - Central TB Reference Laboratory, National TB and Leprosy Programme

Uganda

- Epidemiologist, Uganda National TB and Leprosy Program and USAID DEFEAT TB Project
- Assistant Commissioner, Tuberculosis Leprosy Control Program
- Senior Monitoring, Evaluation and Learning Advisor, USAID Defeat TB Project – National TB and Leprosy Programme

Ukraine

- Senior TB Monitoring and Evaluation Advisor, STAR project of USAID, Public Health Institute USA and Public Health Center of Ukraine
- Program Management Specialist (TB and Infectious Disease), USAID Regional Mission to Ukraine
- Public Health Expert, Local Agent of Global Fund in Ukraine

Zambia

- Director TB Programs, Centre for Infectious Disease Research in Zambia
- Epidemiologist, National TB/Leprosy Programme in Zambia
- Technical Assistant, National Tuberculosis Program
- M&E Advisor, National Tuberculosis Program

BANGLADESH

COUNTRY PROFILE

CONTEXT

In Bangladesh, **e-TB Manager,** a web- and desktop-based TB reporting system, was first introduced in 2010. At the time, the National Tuberculosis Control Program (NTP) sought online TB data recording and reporting systems to improve data quality and efficiency due to the challenge of a lack of timely and incomplete reporting in the paper- and Excel-based systems. e-TB Manager underwent a pilot phase followed by several rounds of expansions, whereby through an official WHO joint monitoring mission in 2014, international TB experts recommended nationwide scale up of e-TB Manager due to the systemwide benefits seen in real-time data access and gradual improvement in quality of reporting. e-TB Manager is a flexible, comprehensive, and robust information system developed with open-source tools and is now being used across all districts following an extensive scale-up process.

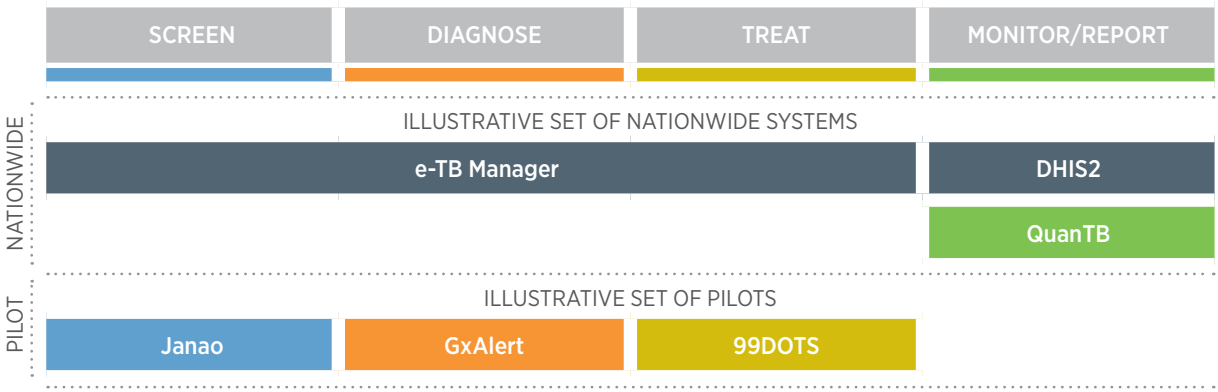
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

In Bangladesh, e-TB manager is used for the recording and reporting of drug-resistant TB (DR-TB) and assists in identifying high-risk population groups and their geographic coverage, identifying previous treatment history to select the right regimen for patients, generating reports, evaluating data quality and conducting epidemiological surveillance. E-TB Manager is currently being expanded to also include drug-susceptible TB (DS-TB) patients in Bangladesh. The patient is entered into the system when first 'suspected' of having TB, and follows the protocols, from lab results to the different stages of treatment. A reporting module allows access to all reports and a data analysis module allows for analysis on request. As e-TB Manager has been implemented in all MDR sites, the system provides real-time complete patient data for forecasting second line medicine needs and used for procurement orders to the Global Drug facility through the **QuanTB** drug forecasting tool.

DHIS2 is an open-source platform that collects and stores aggregated summary data monthly from a wide range of health systems across the nation and generates reports, including for TB. In Bangladesh, DHIS2 was introduced in 2009 and has been in use for reporting since 2011. It is the national platform for country reporting and is supported by government funding. The inclusion of TB data into DHIS2 has been supported by the Global Fund. Interoperability of DHIS2 with e-TB Manager was initiated in 2017 and has since been completed, which has enabled the full integration of Bangladesh's backbone system, so that patient summary data can be easily available in the DHIS2 platform for key indicators.

Bangladesh ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

For laboratory data, a diagnostic connectivity solution called GxAlert is being piloted for automatic reporting of GeneXpert results to enable real-time encoding. GxAlert is not currently linked but planned to be interoperable with e-TB manager once further rolled out. For culture and drug-susceptibility testing, results are currently shared through paper-based forms, however a laboratory information system (LIS) is being proposed that will capture all diagnostic data from laboratories and not just specific to the TB program. An adherence monitoring digital application called 99DOTS is being piloted in a few facilities. The solution uses custom pill sleeves that reveal toll-free numbers, so that once a patient is confirmed TB positive and initiated on treatment, their adherence progress may be tracked. The 99DOTS system is planned to be linked with e-TB Manager following the pilot phase. Two community-based mobile applications are being piloted. One, named Janao, has been developed in close collaboration with Ministry of Health and Family Welfare with support from USAID to enable physicians to enroll a suspected patient under the NTP's DOTS facilities as well as provide patients support through their care journey. The other, Childhood Tuberculosis Screening, developed by Interactive Research and Development (IRD) Bangladesh, is designed to meet the needs of children with TB. The customized communication mobile application targets both children and adults to increase awareness and generate more demand for childhood TB services. Furthermore, to ensure adequate human resources for the management of TB in Bangladesh, a Training Management Information System (TMIS) is planned to be developed which would track human resources and training modules within the TB program. Similarly, a logistics management information system (LMIS) is planned to be developed which will further assist with inventory tracking and tracing drugs supplied. The central warehouse in Dhaka currently uses a warehouse inventory management system (WIMS) and will become interoperable with the planned LMIS.

DEMOCRATIC REPUBLIC OF CONGO

COUNTRY PROFILE

CONTEXT

The Ministry of Health of the Democratic Republic of the Congo (DRC) adopted the District Health Information Software 2 **(DHIS2)** as the country's national health information system. The government began to pilot and roll out the system sub-nationally in 2014, scaling it up countrywide over three years. The introduction of DHIS2, as an aggregate reporting system, has contributed to improvements in data quality, the availability and accessibility of health statistics, and the generation of data visualizations to facilitate data interpretation. The DHIS2 transition has been successful in incorporating private sector facilities as part of the public health reporting system. Like public facilities, private facilities that register receive the same training and tools.

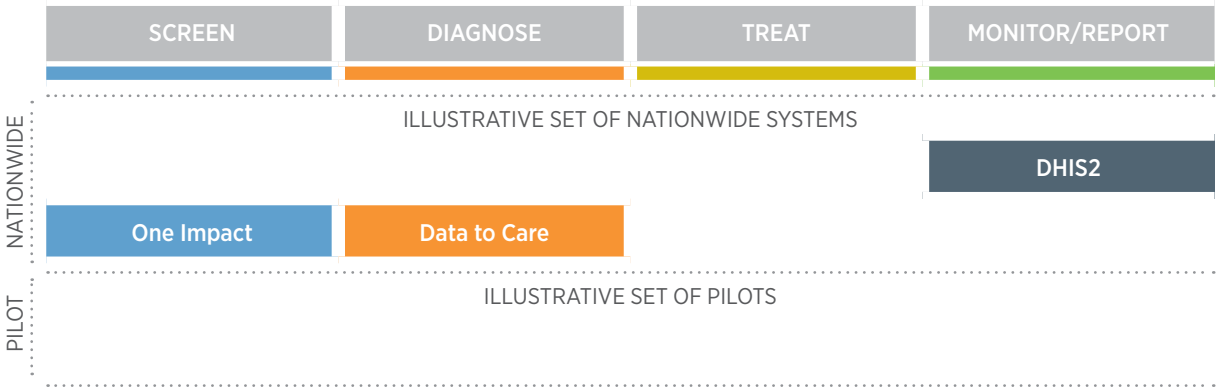
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

A case-based information system is not currently implemented for the management of TB. However, proposals are underway to scale the existing HIV system called TIER.Net to collect and track clinical patient TB data and transition from paper-based to digital systems at the point of care. Integration of facility-based electronic patient management systems will allow for improved sub-national TB surveillance and facility-level monitoring.

Currently, the DHIS2 national reporting system collects aggregate TB data including the proportion of referral TB presumptive cases, proportion of new TB case notifications through community and treatment success rates.

DRC ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

One Impact is a community-based patient-facing mobile application that is used for the purpose of supplying information on TB, guidance on nearby TB centers, access to support groups and report barriers to health services, human right violations and TB stigma. Furthermore, the One Impact platform can serve as a monitoring alert system for when services are not available, not accessible or of poor quality; people affected by TB can notify community and formal health systems using the application in real-time. Once reported, the integrated feedback system automatically informs multi-sectoral community responders and national TB programs of current gaps in service provision via a dashboard so that they can subsequently mobilize to address and overcome these challenges at local and programmatic levels, enabling monitoring and analysis of trends to close the gap in number of people who fail to receive TB care.

A number of piloted GeneXpert machines in the DRC are connected to the **Data2Care** software system, with further expansion planned, allowing the program to have real-time results transmission. The advantages of diagnostic connectivity include transmitting results via email or SMS and monitoring the functionality of the machine network to intervene proactively for maintenance. The use of this system has facilitated electronic transmission of TB test results to MoH, clinicians, and notification alerts to patients.

INDIA

COUNTRY PROFILE

CONTEXT

In India, the National TB Elimination Program (NTEP) provides comprehensive strategy and support for the prevention, detection, and treatment of tuberculosis. Starting in 2012, the program sought out digital case-based management for all patients initiated on treatment. The resulting system, called **Nikshay,** reached nationwide scale in 2016. The initial version of Nikshay had certain limitations, including lack of integration between public and private sectors and DS-TB and DR-TB cases. In September 2018, a new and significantly enhanced platform known as Nikshay v2 was deployed nationwide. Nikshay now provides a unifying system that spans across the entire journey of patient care and provides the backbone for other ICT initiatives in the TB program.

CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

Nikshay is the backbone ICT system that manages the end-to-end cascade of care for tuberculosis in India. In 2020, it tracked 2.4M patient notifications and had >60,000 monthly active users. The core elements of Nikshay include a web application (http://nikshay.in/), an Android application for health workers, an Android application for citizens (TB Aarogya Sathi), and additional linked applications/systems such as LIMS, Aushadhi, DBT, DAT, diagnostics module and so on, that are described below. Nikshay is built on top of an open-source platform and was developed in-country by collaboration of many stakeholders as partners to the government. The platform traces cases from identification of presumptive TB cases, referral for testing, diagnosis and drug susceptibility testing, initiation of treatment, treatment adherence, follow-up (on treatment and post treatment) outcomes and many more events during the care cascade. It provides unified support for both private-sector and public-sector patients, as well as DS-TB and DR-TB patients. Nikshay strives for continuity of care, allowing multiple treatment episodes to be linked to the same case file, supporting both transfer-in and transfer-out capabilities to seamlessly track migrating patients across the country. It also offers web-services (APIs) that can be utilized by external private hospitals and laboratory systems to notify cases electronically to Nikshay. Patient identification is done through systems provided by the National Digital Health Mission (NDHM) as well as the Nikshay patient ID, and de-duplication is facilitated using a combination of information provided by patient.

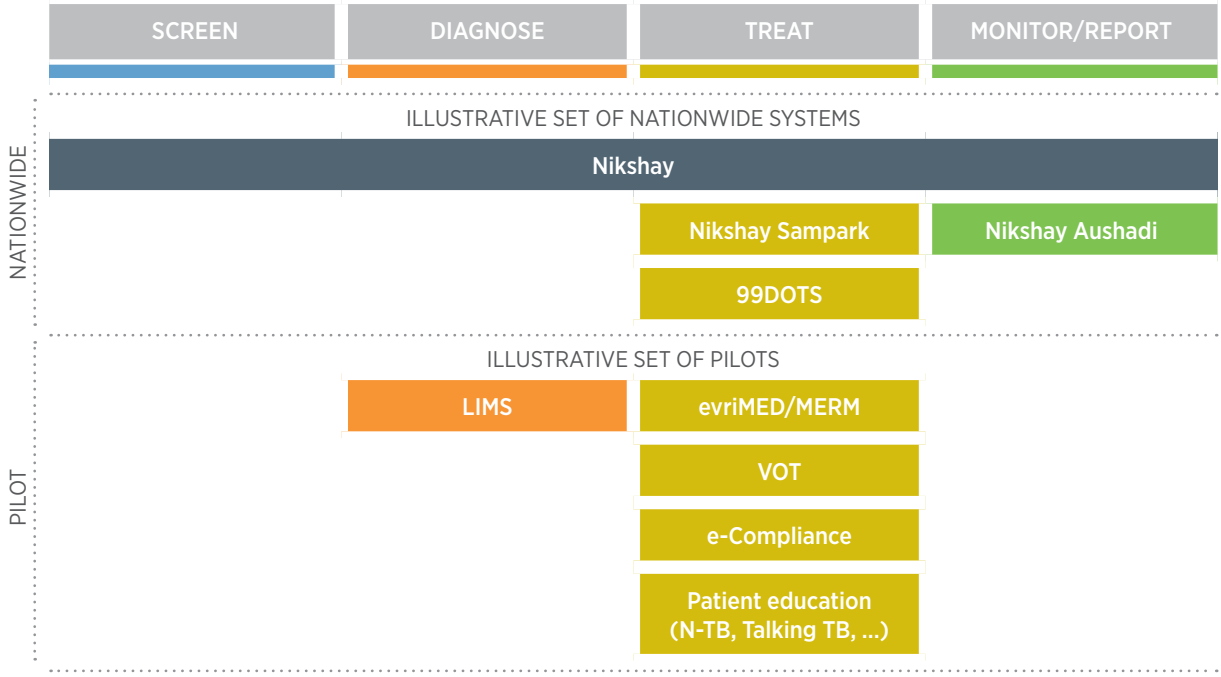
Nikshay is built as a modular set of services, an ecosystem of applications enabling extensibility and interoperability. The Direct Benefit Transfer (DBT) service enables electronic payment of financial incentives to notified TB patients, treatment supporters, and providers and volunteers who notify new cases. To date, Nikshay, linked to the Public Financial Management System (PFMS) has disbursed over $72M in DBT payments to almost 4 million beneficiaries. The diagnostics module offers API integration with diagnostic machines and also allows importing files that are exported from GeneXpert (automated linkage from GeneXpert is currently being built in-country). The Digital Adherence Technology (DAT) module enables integration of various adherence technologies, described below. The dispensation module tracks differing regimens, prescriptions, and refills. Apart from providing the platform on which patient service delivery and records are managed, Nikshay also maintains the latest structure of the reporting hierarchy, a national register of health facilities (public/ private, including labs and chemists), a register of staff and community volunteers, and a database of users and their permissions.

Finally, the dashboards and reporting application enables real-time (updated daily) reporting and visualization of all processes and data handled by the above modules and applications in the Nikshay ecosystem, throughout the entire administrative and reporting hierarchy, from peripheral health institutions, sub-district, district, state level, all the way up to regional and national level dashboards. These dashboards and reports allow reviews, supervision, monitoring, quality control and evaluation, and overall enables the TB surveillance functions of the National TB Elimination program.

While Nikshay is already a mature platform, further enhancements are underway, if not already available. Virtual care capabilities can augment existing SMS/IVR communications with engaging interfaces such as WhatsApp and video calls. Email functions have already been added as a communications module.

India ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

A suite of supporting tools augment and interoperate with Nikshay for specific purposes. **Nikshay Aushadhi** provides management of the medication supply chain and logistics, while **Nikshay Sampark** is used to manage a call center for structured outreach to patients; both are used nationwide. A Laboratory Information Management System (LIMS) has been piloted to manage and automate laboratory workflows across 55 culture and drug susceptibility testing (C-DST) sites and will soon be expanded. Several Digital Adherence Technologies (DATs) provide real-time electronic dosing records, bolstering patient autonomy and differentiated care while maintaining a close connection to care providers. Four DATs are integrated with Nikshay. **99DOTS,** in which patients call numbers printed on the medication packaging, has been used by over 300,000 patients, including TB-HIV patients nationwide and TB patients across six states. Smaller DAT deployments include a low-cost electronic pillbox called evriMED/MERM; video observed therapy (VOT); and a biometric tracker for patient visits called e-Compliance. A number of mobile phone applications, predominantly in the pilot stages, seek to guide and support patients, including the N-TB app for providing nutrition information and the Talking TB app (from Survivors Against TB) in providing general treatment support. New pilots for LTBI & vulnerability mapping and digitally enabled sample collection transportation & tracking system, and digital signature based payments have been initiated.

INDONESIA

COUNTRY PROFILE

CONTEXT

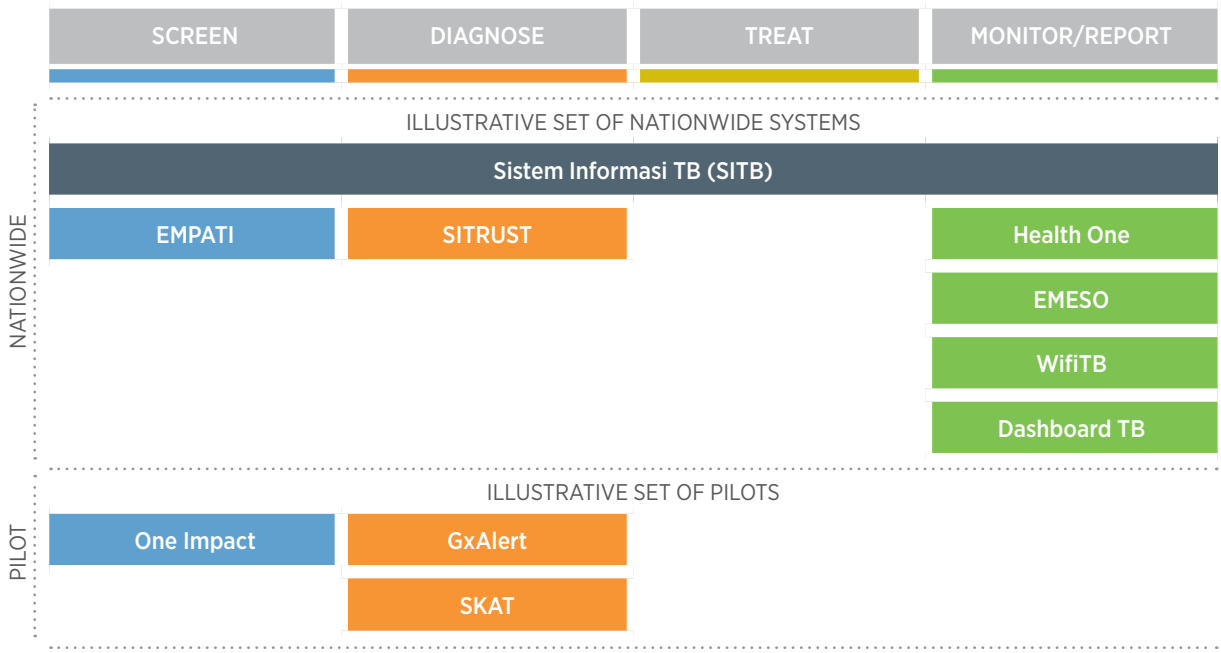
The National Tuberculosis Program (NTP) has had two electronic recording and reporting systems in Indonesia since 2014. The TB electronic surveillance system for case-based reporting of drug-susceptible TB (DS-TB), called eTB-Manager, was first implemented in 2009 at 93 sites nationally. A web and case-based TB information system, called SITT, started capturing drug-resistant TB (DR-TB) cases in 2014, covering all public health centers and some government hospitals. A new system, the **Sistem Informasi Tuberkulosis Terintegrasi (SITB)** (Integrated Tuberculosis Information System) currently being rolled out and scaled, is an integrated software which will be used for recording and reporting case-based data for DS- and DR-TB. The application, created by the Sub Directorate of Tuberculosis, Ministry of Health with KNCV through the TB Challenge project, is planned to similarly integrate laboratories and logistics into one integrated platform.

CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

As of January 2020, SITB replaced SITT and e-TB Manager with an integrated platform. SITB is used to record and report data on DS-TB and DR-TB, logistics management, and laboratories and is integrated with other health information systems (SIHA, EMESO, Health One, etc,). **Health One** is the national reporting tool used across health programs. The combined SITB system will provide the NTP with a single software architecture for recording and reporting TB data, which is expected to play a role in achieving the targets of the NTP, namely TB elimination by 2030.

Indonesia ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

For laboratory data, the diagnostic connectivity solution GxAlert is being piloted for automatic real-time reporting of GeneXpert results. A locally developed solution called SKAT is also being piloted with the same capabilities in parallel. Once both are scaled, it is planned that they will feed data and be interoperable with SITB. **SITRUST** is an information system that supports delivery of TB test specimens for laboratory examinations. SITRUST monitors the movement of test sample shipments, pickup and delivery by couriers, as well as confirmation of acceptance and feedback by the receiving health facility. SITRUST is not currently interoperable but there are discussions for integration. The mobile application named **EMPATI** was developed to strengthen the patient assistance system for drug-resistant tuberculosis by the community in accordance with the guidelines for case finding and assistance for DR-TB patients as agreed between the MoH, community-based organizations and TB patient organizations. Among many functions, EMPATI helps to monitor treatment for DR-TB patients to prevent loss-to-follow-up, assist with home visits and monitor the performance and contribution of civil-society organizations in the TB program. EMPATI was integrated with e-TB Manager and is planned to be interoperable with the new SITB. The electronic system used to strengthen pharmacovigilance data management, called **EMESO,** captures adverse drug reaction reports and is interoperable with SITB. A financial management information system, FMIS, is in development to facilitate payments and is similarly planned to be interoperable with SITB.

The Minister of Health Regulation no. 67 of 2016 on TB control established mandatory notification for both public and private sectors. Every health facility must record and report identified TB cases using standardized recording and reporting formats. As such, **WiFi TB** was developed as a mobile app that allows private practice doctors to notify TB patients. The WiFi TB application is planned to have linkage to the national TB surveillance system, SITB. A TB dashboard for Indonesia is also available for public viewing of TB data and acts like a global TB report but specific to Indonesia TB data. TB data from SITB informs what is reflected in **Dashboard TB** Indonesia. Lastly, to enable better linkages across disease programs, there is planned integration between SITB and the new case-based HIV information system with marked enhancements, SIHA 2.0. This will ensure accurate capturing of patients with comorbid conditions.

KENYA

COUNTRY PROFILE

CONTEXT

In 2012, the Division of Leprosy, Tuberculosis and Lung Disease at the Ministry of Health in Kenya underwent the transition from a paper-based recording and reporting system to an electronic system called **TIBU.** The flow of information in the surveillance system is based on a hierarchical reporting structure, where at facility level, healthcare workers record key data on TB patient cards which are then transcribed into TB facility registers. During monthly visits, TB coordinators electronically transcribe data from TB registers using tablet computers provided by the national TB program.

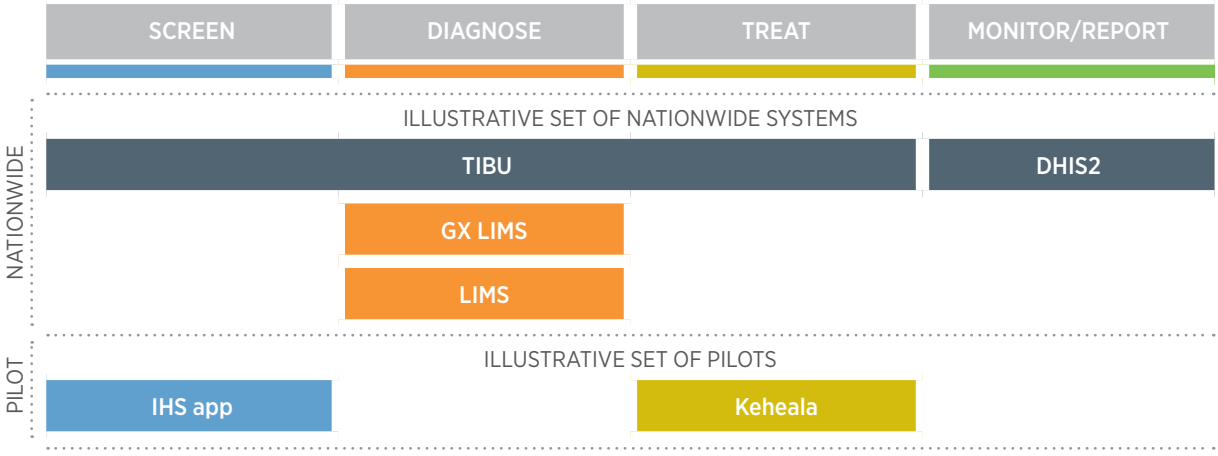
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

TIBU is a national case-based surveillance system that stores details on individual patient episodes of TB reported to the national TB program. This includes patient locating information, demographic characteristics, clinical details, laboratory results and treatment outcome data. Data is collected electronically with mobile computer tablets and uploaded into the central database at the Ministry of Health. The data is available immediately for analysis and TIBU can generate cohort reports on case finding, treatment success, MDR incidence and mapping of specific TB issues. TIBU can also be used for logistics planning of commodities and MDR-TB patient support. TIBU has had nationwide coverage since 2012. To enable integration, TIBU is also linked with the national District Health Information System (DHIS2).

Kenya deployed a totally online health information system (HIS) powered by **DHIS2,** completed in September 2011, that captures both public and private sector individuals. The TIBU system has been linked to DHIS2 so as to inform policy makers through dashboards and summary reports on program performance at any time.

Kenya ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

A diagnostic connectivity solution called **GX LIMS,** developed locally, enables GeneXpert machines to be connected and remotely posts diagnostic and logistical data onto a cloud server for consumption by the NTP. The system is important for monitoring equipment usage and for reducing the turnaround time for clinicians to receive results. An integration of GX LIMS with TIBU is currently underway. Kenya has a laboratory management information system **(LIMS)** which is not specific to TB testing but captures DST testing and culture in labs. These results are sent back to referring clinicians through emails and short message services (SMS) to reduce delays in initiation of treatment. A pilot has begun that is testing interoperability of the LIMS system with TIBU. A pilot mobile application, named **Keheala,** improves healthcare access and treatment outcomes for patients by empowering patients with information, motivation and support.

A pilot of a community-based mobile application developed by Interactive Health Solutions (IHS) is being proposed to strengthen patient screening, enrolment, sputum submissions, follow-up and treatment. Similarly, a mobile phone screening application has been introduced in 2019 and is being implemented as a pilot.

MOZAMBIQUE

COUNTRY PROFILE

CONTEXT

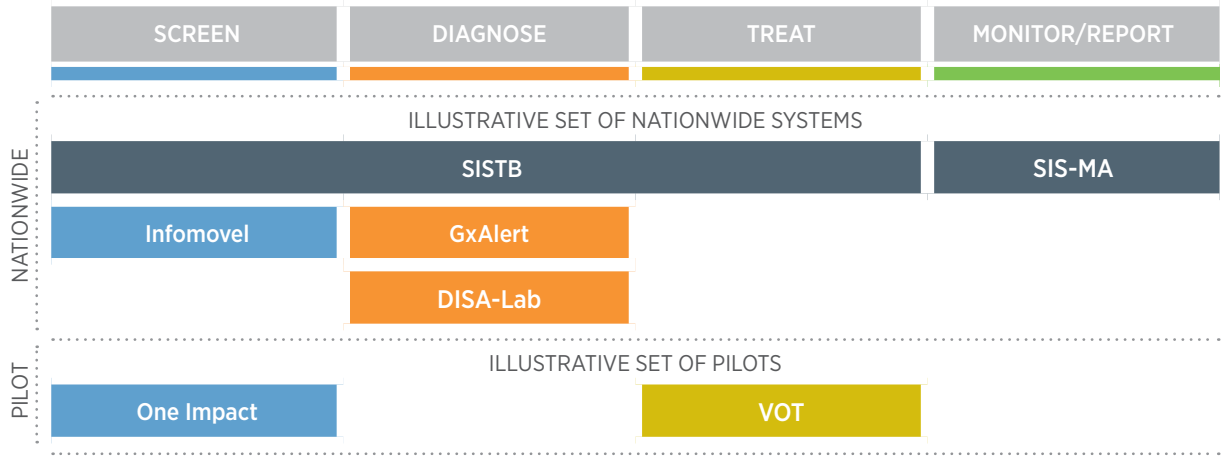
The National Tuberculosis Program transitioned from Excel spreadsheet reporting of facility-level data to integrated electronic reporting with the introduction of **SIS-MA.** SIS-MA is a District Health Information Software 2 (DHIS2) platform, and the official aggregate data management solution for the Ministry of Health. The new official aggregate SIS-MA national reporting system, implemented in 2018, provides better analytics and real-time feedback to each level of the healthcare system for both TB and HIV program management. The expansion to digital patient-level "point of care" information is currently being rolled out following a pilot in 2019. This system, called **SISTB,** is based on DHIS2 Tracker, with widespread scale up expected in the coming year.

CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

The development and scale up of innovative mobile-based SISTB will improve surveillance at all levels of care and incorporate individual-level data as opposed to only aggregate data in existing systems. The SISTB system will track an individual from identification as a presumptive TB case to treatment completion and will interoperate with SIS-MA, based on DHIS2, for national-level reporting. Currently SIS-MA captures aggregate TB data within the national reporting system.

Mozambique ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

The roll-out of GeneXpert machines and associated electronic data management system **GxAlert** is helping to address logistical hurdles related to platform maintenance, cartridge deployment and long result turnaround times. With intended expansion of GeneXpert machines, the connectivity solution GxAlert will strengthen and expand connectivity to all additional GeneXpert point of care devices and second-line LPA and MGIT devices in central labs. Connecting all three central laboratories to a single integrated platform where health workers can view results and track the patient to treatment will reduce loss to follow-up. Additionally, the GxAlert system will integrate with **DISA-LAB,** the national laboratory information system (LIS) in Mozambique. DISA-LAB has similarly drastically reduced average turn-around times of results and improved workflows in testing laboratories as well as clinics.

A community-based mobile application called **Infomovel** has been developed as a tool to support community health workers in administering services and supporting patient registration, follow-up, and household screening. The tool was originally piloted in 2015 and has since been expanded to national scale. Infomovel supports linkages between community workers and health facility focal points for TB as well as HIV. OneImpact is also being piloted as a community-based application to give voice to TB affected communities. The system is leveraging the opinions and experiences of people affected by TB to pinpoint systemic and social challenges.

NIGERIA

COUNTRY PROFILE

CONTEXT

In 2011, the Nigerian National TB and Leprosy Control Program (NTBLCP) sought to migrate from paper-based to electronic reporting. Initially an electronic tuberculosis management system, **e-TB manager,** was introduced in Nigeria for drug-resistant TB case management. By 2016, e-TB manager was in use in all 16 treatment centers where DR-TB patients are managed. Following its successful implementation for DR-TB reporting, the process to harmonize and implement the system for both DS-TB and DR-TB patients was launched in 2015 by the federal government of Nigeria.

CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

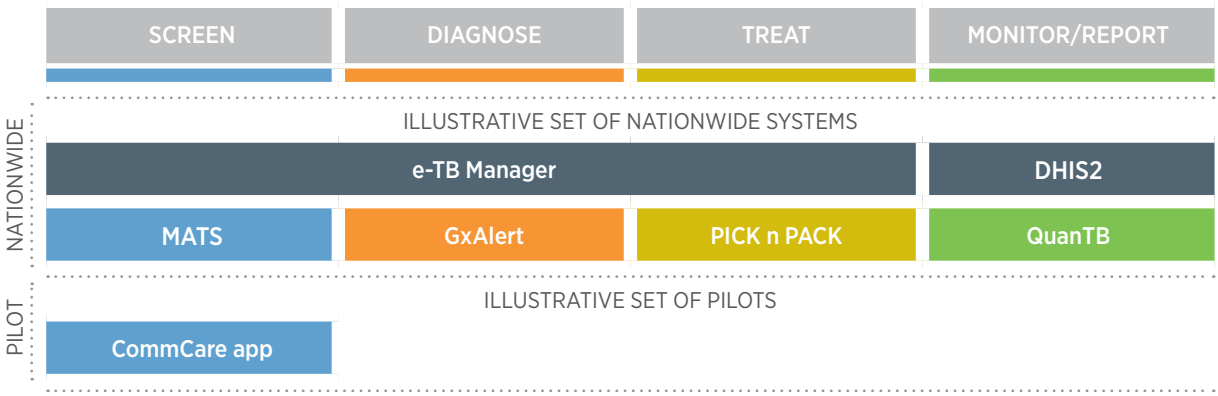
e-TB manager, developed by Management Sciences for Health (MSH), is a web-based case-by-case real time reporting system for TB patient data in Nigeria. It includes five operating units called modules that support the notification of DS-TB and DR-TB presumptive clients and cases; provides first- and second-line TB medicine management; and has a new laboratory module designed to help reference laboratory staff report completed tests for TB patients across the country. The generic version of e-TB manager was transformed (and is still evolving) with customizations to reflect Nigeria's paper-based reporting system, address gaps reported during pilots, and meet the needs of the NTP and end users. Along with the basic features of e-TB manager for DS-TB and DR-TB presumptive clients and cases, the tool was remodeled to reflect the NTP's paper-based quarterly reporting templates to simplify report generation by primary users.

Because e-TB manager is a web-only portal application (which requires internet connection), its use was a major challenge for high-burden facilities in areas with no or low internet connectivity across Nigeria. In coordination with the NTP and other implementing partners, a more agile offline-mode mobile application version of e-TB manager was designed and deployed in 2017. This Android application allows for users in network-restricted areas to upload case data, which are stored in a phone's local data storage and then synchronized with the application server when the user has adequate internet connectivity.

The reporting of TB data in Nigeria follows a quarterly schedule whereby data collection and collation are carried out using both paper-based and electronic-based systems. Also, direct interoperability between the country's DHIS2 and the TB program's e-TB manager was established to ensure that aggregate TB data from e-TB manager is shared with DHIS2 for real-time national dissemination. The electronic system of the NTP is referred to as the National Electronic TB Information Management System **(NETIMS),** and presently, NETIMS comprises of the GxAlert, e-TB manager and DHIS2 systems.

Nigeria ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

To find and treat more tuberculosis cases in Nigeria, the Institute of Human Virology Nigeria (IHVN) and the National Tuberculosis and Leprosy Control Program (NTBLCP) introduced a new mobile application for screening and notifying TB cases by private healthcare providers. The application, **Mobile Application for Tuberculosis Screening (MATS),** launched in June 2020 and is already being used across 20 states, enabling private health providers in the community to be screened using the standard TB symptom checklist on the app. Presumptive cases are then referred for diagnosis and treatment. Computer-aided detection for tuberculosis using digital X-ray has been successfully implemented in Lagos State and is in routine use. The connectivity solution **GxAlert,** first designed and launched in 2012 in Nigeria, has enabled real-time transmission of relevant data from GeneXpert machines to a real-time central online database that can be accessed anywhere. Reporting time has been reduced allowing faster enrollment into care.

A locally developed tool called **PICKnPACK** enables managers at the central level to monitor performance of every segment of the supply chain, from national to facility level. Since this tool's implementation in January 2011, the country has not seen any widespread stock outs for main anti-TB drugs. A community-based mobile application built on CommCare is utilized to carry out active TB finding within private sector providers of health services in Nigeria. The program uses this mobile application to complete the registration of probable cases, screening for TB and follow-up care.

PHILIPPINES

COUNTRY PROFILE

CONTEXT

The **Integrated Tuberculosis Information System (ITIS)** is the official system of the Philippines Department of Health (DOH) for the recording and reporting of TB information. The system is used by all providing facilities and laboratories associated with the National TB Program (NTP) as well as private providers reporting under the mandatory notification law. This electronic, internet-based TB surveillance system was developed and is maintained by the Knowledge Management and Information Technology Service (KMITS) of DOH. The system includes standardized forms for recording person-based information, processing, reporting and the use of the information necessary for improving tuberculosis control efforts in the Philippines. ITIS has replaced paper-based reporting and is used by all NTP facilities nationwide since 2010.

The NTP network consists of public facilities (e.g., health centers, laboratories, prisons/jails) and some community-based facilities and integrates all TB initiatives including drug-susceptible TB, drug resistant TB, TB/HIV, laboratory and stock inventory. Currently, a limited number of private practitioners participate in mandatory TB notification, as dictated by Republic Act No. 10767. As such, a version of ITIS called ITIS Lite was developed to specifically capture TB notifications at private facilities. A mobile application, SwipeRX, is also being piloted to capture people with TB who go directly to pharmacies, to enable connecting them with appropriate care facilities.

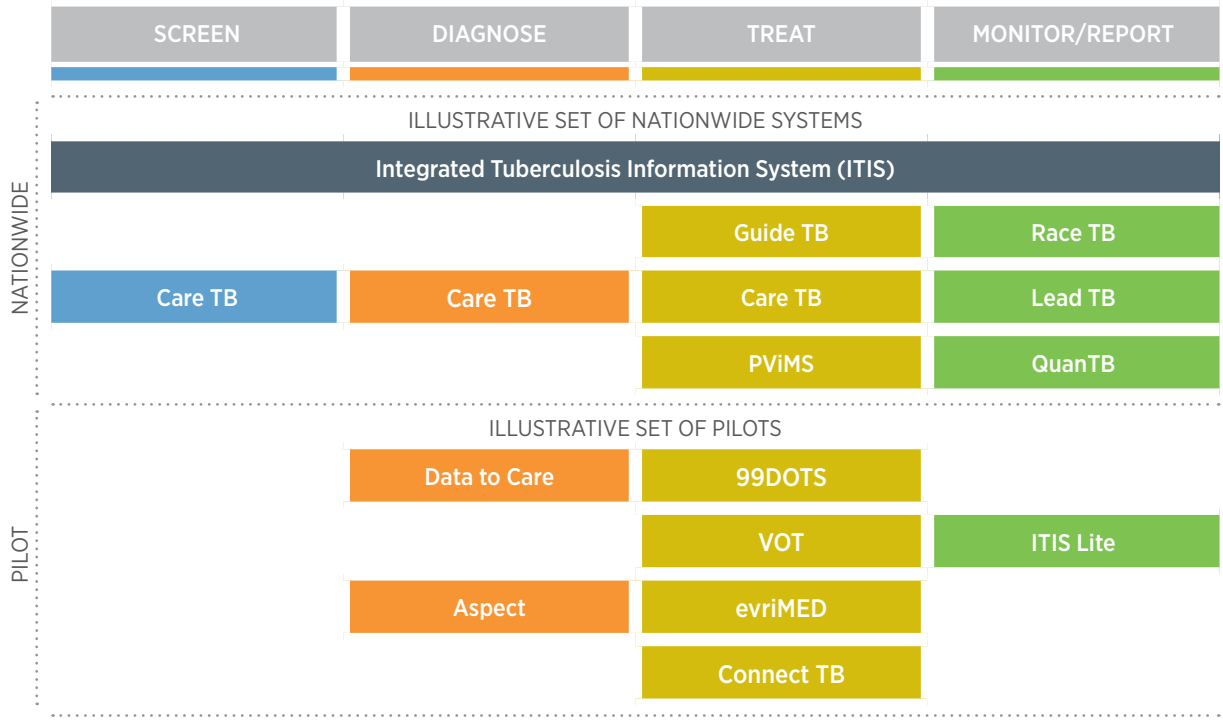
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

ITIS records person-based information noting each encounter of screening, testing, treatment, or prevention. Patients are identified using unique registration codes. Test results and treatment status are recorded as patients move through the continuum of TB care, along with sociodemographic characteristics and TB disease type (anatomical site, treatment history). ITIS captures surveillance information in real-time, such that data entered at local levels are immediately available for viewing by higher-level offices. Indicators based on these data are publicly disseminated through an online and mobile app dashboard called Race TB. ITIS captures and syncs data across the cascade of care, using system modules. The case management module captures the patient's data which includes a demographic profile, TB encounter(s), examinations and treatment information.

The reports module features the generation of all NTP reports as per the NTP Manual of Procedures, suitable to each level of reporting facility. Generated documents are printable and convertible to Excel (for data analysis) and PDF. All data received is stored at the KMITS data center where servers are protected with enterprise-level security. The information is then validated at the facility-level through a set of data cleaning processes. ITIS also has quality assurance procedures built into the system to validate data entry, to prevent potential duplication and require users to enter key fields. For analysis, Race TB is expected to be continually upgraded to include various data analysis tools to ensure that the focus is on the use of data for decisions, rather than organizing data. Similarly, a transition to user-friendly formats for recording and reporting such as ITIS mobile and Care TB (both Android and iOS) are currently underway to expand use by both public and private providers.

Philippines ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

New patient-centered approaches for supporting adherence are currently under pilot, including the 99DOTS pill sleeve, Video Observed Therapy (VOT), evriMED pill boxes and a locally developed solution called ConnectTB. If successful and implemented post-pilot, they are planned to be interoperable with the ITIS case management module. A web-based application, pharmacovigilance monitoring system **(PViMS),** is being used to help clinicians, regulatory bodies and implementing partners monitor drug safety and effectiveness and evaluate adverse events. The PViMS system is available nationally and interoperable with ITIS. **QuanTB** is used as an automated tool for forecasting and supply planning of TB drugs. The laboratory module within ITIS is intended to facilitate the receipt of incoming requests and the real-time encoding of examination results once available. Automatic reporting of GeneXpert results is being piloted to enable real-time diagnostic data to flow into ITIS through two piloted applications, Data to Care and ASPECT.

Following a midterm status of TB elimination in the country, the DOH introduced the updated *Philippine Strategic TB Elimination Plan, Phase 1: 2020-2023 (PhilSTEP1)* to dramatically scale-up the response under the renewed and strengthened global End TB strategy. The Race to End TB campaign was launched to support this effort and the Race TB online and mobile apps were developed to help local implementers to track their progress. Three more accompanying applications were developed to assist with reaching the End TB goals and facilitate the Race to End TB. These apps, with ITIS Lite and ITIS Mobile are collectively called the End TB App Suite. The applications are all integrated within the ITIS digital architecture.

- The **Care TB** application is a patient-facing mobile application that aligns with the stages of the cascade of care: screen, test, treat, prevent. It enables TB clients to retrieve their electronic health record, chat with their doctor, get relevant information on TB and report side effects, treatment adherence and issues with clinical services.
- For healthcare workers, the **Guide TB** application can be used to view the latest departmental memoranda and administrative orders related to TB, to view and consult the full TB Manual of Procedures and TB strategic plan, and to follow updated algorithms for better clinical care.
- The **Lead TB** application is used by individuals with a guiding role within the DOH, partner organizations or local government units. It enables retrieval of electronic versions of standard monitoring tools, completion of forms digitally offline and measurement of progress.

I SOUTH AFRICA

COUNTRY PROFILE

CONTEXT

In South Africa, the National TB Program has been supported by a central standardized recording system to monitor TB cases and treatment outcomes using paper-based registers at facility-level since 1995. An Electronic TB Register (ETR.Net) has routinely been used for reporting of drug-susceptible TB at sub-district, district, provincial and national levels since 2005, with a separate **Electronic Register for Drug-Resistant TB (EDR.Web)** since 2009. In 2014, the National Department of Health of South Africa took a decision to integrate the TB and HIV information systems at facility level into a single non-networked **Three Interlinked Electronic Register for TB & HIV (TIER.Net).** The three tiered approach involves paper registers (TIER 1 – for facilities with <500 patients), an offline electronic register (TIER 2- for facilities with 500-2,000 patients) and networked electronic medical records (TIER 3 – for facilities with more than 2,000 patients). With the integration of TB and HIV program data, a specially developed TB module for TIER.Net supplants the paper-based TB register at facility level. This patient-level data in TIER.Net for both HIV and TB information at facility level is integrated with the **District Health Information Software 2 (DHIS2)** for reporting various program data from sub-district to national levels.

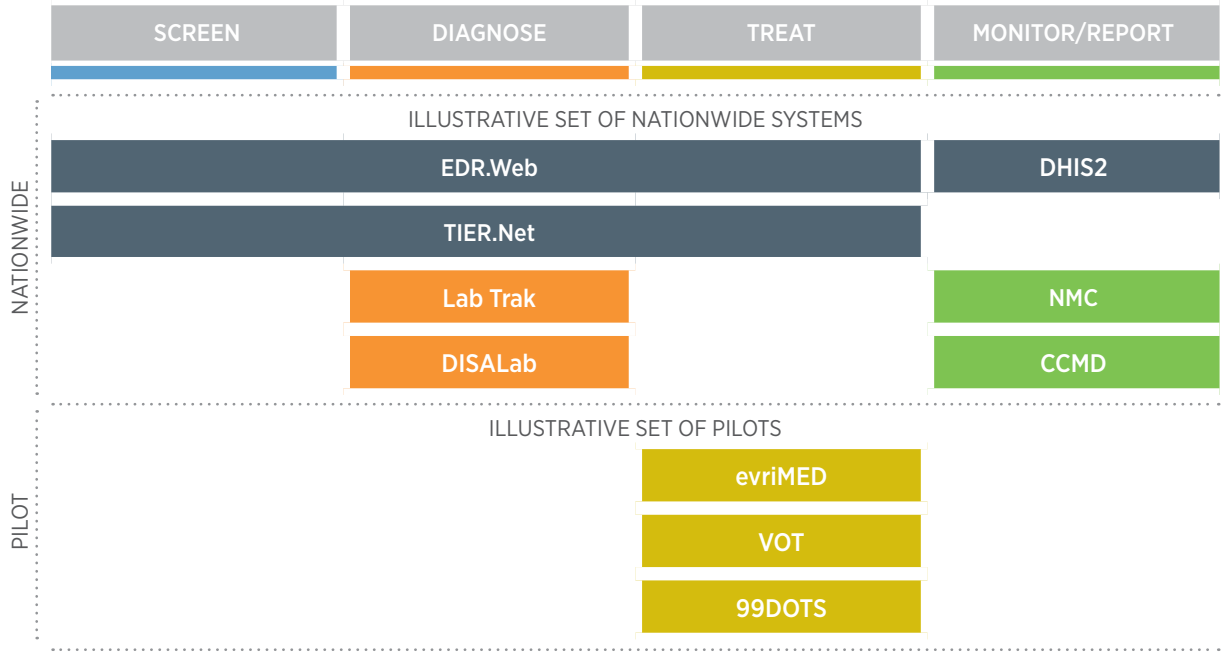
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

The Electronic Drug Resistant Software (EDR.Web) is a web-based software that allows authorized users to access a central database and enter data for drug-resistant (DR) TB units. EDR.Web is used for surveillance and management of DR-TB. Key information is readily displayed to allow rapid decision making and to determine where interventions are needed. The software is implemented in 85 DR-TB units throughout the 9 provinces of South Africa and is interoperable with District Health Information System 2 (DHIS2). TIER.Net has been serving as the primary monitoring platform for the national antiretroviral treatment (ART) program and was incrementally expanded to include HIV testing and pre-ART data modules. In contrast, TB program data remained separate from other health programs, where TB nurses capture patient information into facility level paper-based TB registers. With the integration of TB and HIV program data, a specially developed TB module

for TIER.Net has been developed which allows TB program staff at facility level to immediately access individual and aggregated TB data. The TB module of TIER.Net provides real-time data for patient management and is integrated with DHIS2 for overall health program reporting, yet real-time reporting to DHIS2 is still a challenge. TIER.Net and EDR-Web, which house DS-TB and DR-TB respectively, are separate unlinked government-mandated systems, and implementation and management is through the South African National Department of Health (NDOH).

South Africa ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

Diagnostic testing is the mandate of The National Health Laboratory Service (NHLS) in South Africa. Infrastructure supporting the NHLS program includes the NHLS laboratory information system using **TrakCare** (also known as **LabTrak**) or **DisaLab,** to which all analyzers within the NHLS are interfaced, and mobile alerts of GeneXpert results to sub-districts called NICD alerts. All national tests are collected centrally and archived within a single central data warehouse, where a large sever is able to store, manage and analyze all laboratory information system data from all tests generated. DisaLab and LabTrak are currently not interoperable with either TIER.Net and EDR.Web. Two digital adherence technologies being piloted for adherence support include evriMED pillbox and VOT (video-observed therapy). A community-based application used for screening is being similarly piloted for screening of diseases including tuberculosis. A recently introduced computer-aided screening for X-ray and mobile phone self-screening is also being implemented as of November 2020 and January 2021, respectively. **The Chronic Medicine Dispensing and Distribution (CCMD)** system improves access to chronic medicines by enabling patients to collect repeat medicines from a convenient collection point through an electronic prescribing and parcel management program. It is currently utilized for HIV but is being piloted for TB drugs. Every doctor and nurse in both the public and private health sector who diagnoses a tuberculosis patient must report as a category 2 **Notifiable Medical Condition (NMC)** through NMC mobile application.

TANZANIA

COUNTRY PROFILE

CONTEXT

The Tanzania Government has been supporting electronic systems as reflected by the introduction of ICT policy in 2003. A DHIS2 (District Health Information System 2) system was first introduced in 2002 under an action research project. The Ministry of Health later fully adopted the system, a web-based integrated and interoperable electronic system, as the preferred software for the health management information system. The Tanzania National TB and Leprosy Program (NTLP), having experienced challenges with the historic electronic TB surveillance system (ETR.Net), decided to leverage the existing DHIS2 platform used by the Ministry of Health to build an electronic platform for TB.

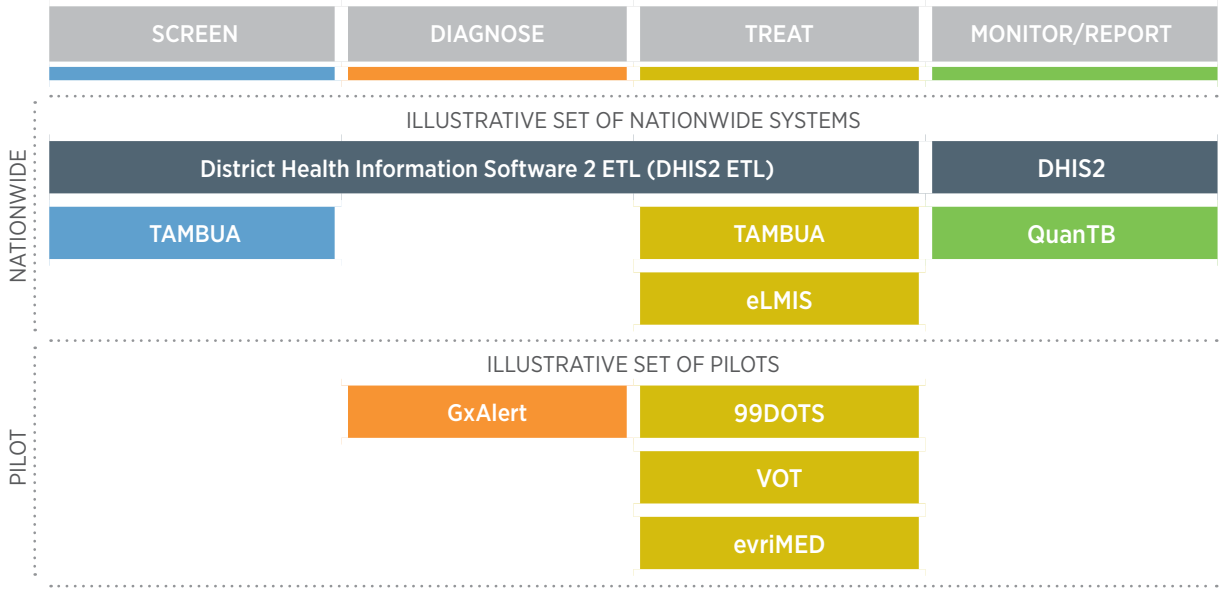
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

The development of the **DHIS2 Tracker** case-based electronic TB and Leprosy Register (DHIS2 ETL) started in 2017. The system has four main functionalities arranged as registers of DS-TB, DR-TB, Leprosy and TB laboratory results. DHIS2 ETL offers real-time recording of case data and therefore real-time visibility at all appropriate levels for effective monitoring, reviews and decision making.

The TB case surveillance tracker enables registration and longitudinal tracking of TB cases from the point of notification to final case outcome, inclusive of laboratory results. The generic version of DHIS2 was used, but the system underwent critical and ongoing customizations to reflect Tanzania's specific needs and current workflow. This captures TB notifications from both public and private facilities.

Tanzania ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

In 2013, a pilot **GxAlert platform** was installed connecting GeneXpert diagnostic devices with the aim of monitoring GeneXpert results and improving linkage of TB patients to care as facilitated by real-time reporting of diagnosis results hence timely decision-making. The GxAlert diagnostic connectivity is not yet scaled country-wide. The Logistics Management Information System (eLMIS) for TB has been redesigned and all facilities are now able to report their stock on hand. This is interoperable with the **QuanTB** system which enables forecasting, supply planning and procurement at the national level.

In effort to find missing TB cases in Tanzania, the NTP launched the **TAMBUA TB mobile applications** – one for self-screening and general TB knowledge to the general public and the other for treatment adherence. The NTP officially launched the TAMBUA TB application in September 2018. The self-screening application allows consenting clients to take a self-assessment using the mHealth diagnostic service. If the system classifies a client as presumptive, SMS messages will automatically be sent to the client recommending TB testing and providing educational information. The treatment application is designed for healthcare workers to register TB patients for treatment adherence messaging as carefully timed and tailored reminders. DHIS2 ETL is currently linked with TAMBUA TB for adherence. A pilot using 99DOTS is currently underway to explore using the medication sleeves as real-time remote monitoring of daily intake of treatment. Similarly, VOT (video-observed therapy) and evriMED pill boxes are similarly being piloted for adherence support. Lastly, Zoom is being used to facilitate video communication to live stream programme/partner virtual meetings, specifically for DR-TB case management along decentralized mode and for periodic monitoring issues.

UGANDA

COUNTRY PROFILE

CONTEXT

The District Health Information System 2 (DHIS2) was adopted in Uganda in 2011 which facilitated the transition from paper-based reporting and storage to an electronic web-based system. The government of Uganda through its Ministry of Health recognized e-health in the Health Sector Development Plan 2015/2016 – 2019/2020 as a key enabler for supporting the health system to deliver good healthcare to the population. Although health facilities are reporting some TB indicators through DHIS2, the DHIS2 aggregate system does not track individual data for cohort analysis. As such, the recently developed **electronic case-based surveillance system (e-CBSS)** will begin rollout to better report and integrate TB data collection.

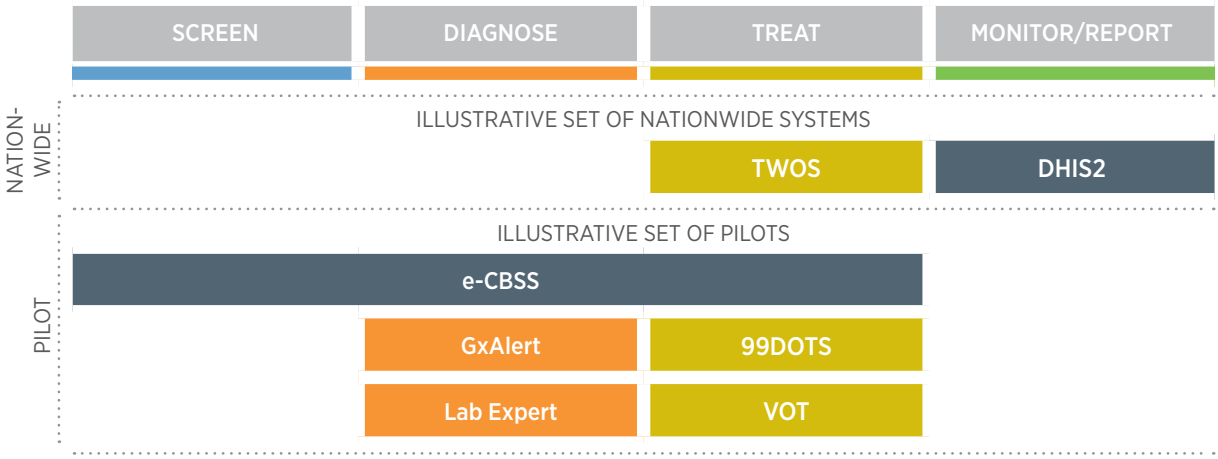
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

The development of e-CBSS, based on DHIS2 Tracker, is planned to be pilot-tested and rolled out nationally over the next few months. The process of transitioning from a mixed paper/electronic service reporting system to a purely electronic case-based surveillance system is a necessity for the end TB strategy in Uganda. The case-based system will focus on contact tracing as well as following a patient through diagnosis, treatment, and outcome reporting.

The existing DHIS2-based DR-MIS (drug resistant management information system) that is meant to provide real-time patient level data on enrollment and follow-up of DR-TB patients plus their contacts will be migrated and merged with the newly developed e-CBSS, alongside DS-TB cases (drug-susceptible-TB cases).

Uganda ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

GeneXpert connectivity in Uganda is being piloted with GxAlert and a locally developed platform called Lab Expert. To enable timely reporting of laboratory information, it is proposed that these systems or future laboratory information systems for TB will feed into e-CBSS.

The **Tuberculosis Medicines Web-Based Order and Reporting System (TWOS)** increases timeliness of orders/reports for TB medicines, eases monitoring of facility reporting rates, gives access to facility stock status and reduces central warehouse workload in compiling paper-based orders before resupplying health facilities with TB medicines. Facilities with computer, internet and DHIS2 access rights place their orders directly into TWOS. Facilities without computers and internet connectivity submit hard copy orders to the district office, which enters orders into the web-based DHIS2 system.

A pilot to evaluate effectiveness, implementation and cost-effectiveness of a culturally and contextually adapted version of 99DOTS adherence monitoring and VOT (video-observed therapy) is being conducted in Uganda. The self-reporting through toll-free phone numbers hidden in pill blister packs and VOT through video submission into a secure server is intended to assist clinicians with patient management.

UKRAINE

COUNTRY PROFILE

CONTEXT

According to the legislation of Ukraine, the detection of patients with presumptive TB is to be carried out at all healthcare levels, including primary care institutions. The diagnosis of TB is only confirmed at specialized TB institutions of secondary/tertiary medical care. The recording and reporting system is both on paper as well as electronic. The paper-based system comprises of a set of medical cards, forms and registers which are approved by the orders of the Ministry of Health. For electronic records, **e-TB Manager** is the comprehensive web-based tool used in the Ukraine and was implemented countrywide in 2009.

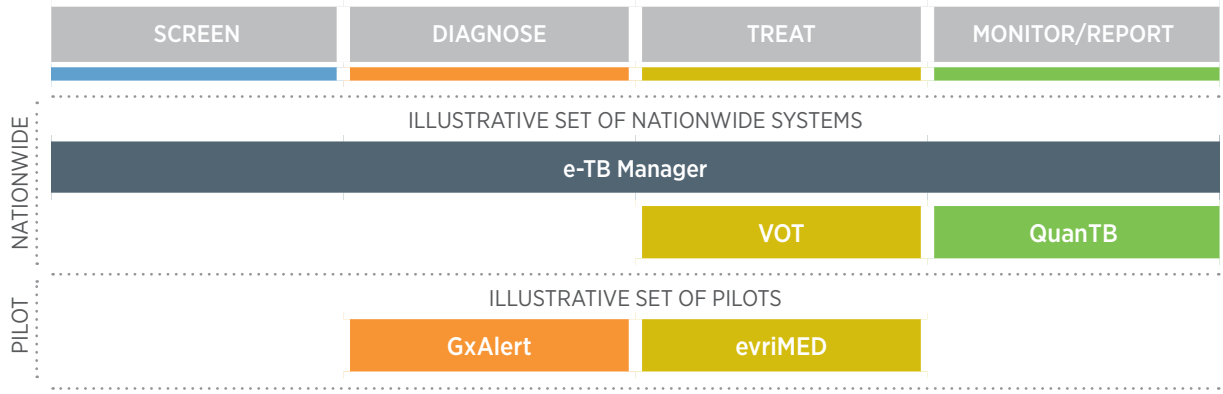
CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

e-TB Manager strengthens the TB program by integrating case management, consumption of medicines and surveillance information into a single platform. The platform comprises four modules: TB patients; laboratory; TB medication; and TB management and administration. The module for TB patients has been implemented since 2014 whereas the laboratory module has been active since 2009. The module for TB medicines is not yet operational. Data is entered via a web-based interface, coming from paper-based TB recording cards, forms and registers at the district, hospital, regional and national levels.

Quality assurance of data entered in e-TB Manager includes measures preventing errors during data entry through validation checks; cross-checking between electronic and paper-based systems during M&E visits performed at national and regional levels; and validation of statistical data carried out at all levels of care.

Ukraine ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

Diagnostic information is inputted into e-TB Manager manually by the managing physician, however some sites are being piloted to include automatic reporting of GeneXpert results through GxAlert. When GxAlert is scaled up, there will be the opportunity to link with e-TB Manager. For adherence monitoring, a pilot of evriMed pillboxes and **VOT (video-observed therapy)** are underway. VOT was significantly scaled up in 2020 country-wide with implementation in 22 out of 25 regions including some regions covering more than 70% of patients, as a result of adaptation to the COVID-19 pandemic-related challenges in TB service provision. For stock management of TB drugs and forecasting, **QuanTB** is used to ensure patients have continuous access to treatment. The One Impact mobile application is used in pilot areas to support community-based monitoring of the TB response, with scale up planned starting in the second half of 2021. To assist with the high-burden of comorbid TB and HIV, there are plans to integrate the TB surveillance e-TB Manager with the HIV Management Information System (MIS). The annual TB statistical directory is available on the internet on the website of the Centre of Public Health. This directory contains statistical information that includes indicators from the two reporting processes: paper-based and e-TB Manager.

ZAMBIA

COUNTRY PROFILE

CONTEXT

The importance of electronic information systems in the Government of the Zambia was demonstrated by the launch of the National ICT Policy in 2007, with the inclusion of ICT as a priority sector in the development plan. The **SmartCare** Electronic Health Record system (EHR) is a fully integrated electronic health record system designed to provide continuity of care and clinical management information at the facility and district level. The SmartCare database is a derivative of the PTS (patient tracking system), which was developed in 2004, based on a health facility-centered EHR system. In November 2007, it became the nationally recognized EHR system for HIV/AIDS patient management and was then rolled out throughout the country.

CASE MANAGEMENT AND AGGREGATE REPORTING BACKBONE

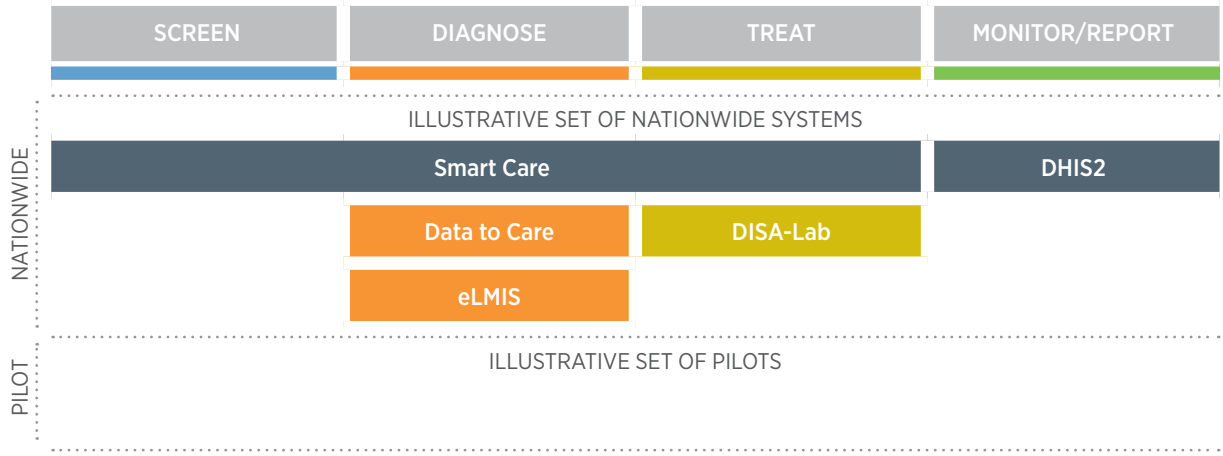
SmartCare is an electronic health record (EHR) system used for management of client health records, generation of reports and in auxiliary services such as pharmacy, labs, logistics, and user and provider management. SmartCare is organized into comprehensive modules and submodules: Voluntary Counselling & Testing (VCT), Antenatal Care (ANC), Delivery, Pharmacy, Antiretroviral Therapy (ART), Labs and Tuberculosis (TB). The ART module is the most highly developed, however the newly developed and refined TB module is currently underway.

Patients are issued smart cards at their initial consultation which contains all their clinical information and treatment details and can be accessed from any SmartCare facility. The SmartCare data are collected either directly onto a computer or using a paper-based method.

As the TB module in SmartCare is still being rolled out, TB data has continued to use the paper-based system of being entered into DHIS2 from district level in aggregate form rather than in the form of individual patients. The **District Health Management Information System 2 (DHIS2)** was introduced in Zambia in 1996 and its name has since changed from DHIS2 to HMIS. The key priority going forward is to ensure inter-linkages between SmartCare and DHIS2. Currently, DHIS2 data collection is conducted at health facility level using a paper-based system and is aggregated and computerized into DHIS2 from district to national level.

Zambia ICT Sampler

Based on stakeholder conversations; not exhaustive



OTHER DIGITAL TOOLS

The introduction of **Data to Care,** a software system that connects GeneXpert machines, has allowed the program to have real-time result transmission. The program has also seen enhanced transmission of laboratory data for microscopy, line probe assay (LPA), culture and drug susceptibility testing (DST) by introducing the Data to Care diagnostic connectivity platform. Based on the data generated by the Data to Care system, a targeted supervision of poorly performing GeneXpert sites has been conducted. Data to Care was introduced by the USAID-funded Challenge TB project and is facing challenges to sustain connectivity since the project ended.

eLMIS, an OpenMRS variant, is used nationally at the district level and deployed for direct use. It handles stock management and monthly reporting for medical commodities for all programs. Similarly, **DISA-Lab** laboratory information system facilitates electronic reporting of results from the main reference laboratories.