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About SIAPS

The goal of the Systems for Improved Access to Pharmaceuticals and Services (SIAPS) Program is to assure the availability of quality pharmaceutical products and effective pharmaceutical services to achieve desired health outcomes. Toward this end, the SIAPS result areas include improving governance, building capacity for pharmaceutical management and services, addressing information needed for decision-making in the pharmaceutical sector, strengthening financing strategies and mechanisms to improve access to medicines, and increasing quality pharmaceutical services.

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ACKNOWLEDGEMENTS

INTRODUCTION

Good recording and reporting systems are vital for individual and group case management of tuberculosis (TB) and for ensuring continuity of care as patients are referred between health care facilities, assessing epidemiological trends in a country, and evaluating a TB program's performance in meeting its goals and those of the World Health Organization's (WHO) End TB Strategy.[1,2] Recording and reporting systems are either paper-based or electronic, and their accuracy and effectiveness is essential in ensuring the high-quality care of TB patients and the sharing of case and epidemiological information at the subnational, national, and global levels. WHO promotes electronic health information systems to generate better data on TB and on eHealth interventions to control TB.[3] WHO's digital health for the End TB Strategy calls for applying digital health solutions to help advance patient care and improve surveillance and program management.[4]

The Global Plan to Stop TB makes the case for investing in electronic patient information systems in various country and regional settings.[5] Donors such as the Global Fund to Fight AIDS, Tuberculosis and Malaria (Global Fund) and the US Agency for International Development (USAID) recognize the benefits of national health information systems at all levels, including patient-based electronic recording and reporting systems.[6,7,8] The current Global TB Strategy supports the introduction and scale up of case-based and/or patient-based electronic recording and reporting systems to improve TB control, national and global surveys, and other data gathering to inform programs and policies. The White House National Action Plan also calls for continued US Government investment in strong electronic health information systems as an essential tool for multidrug-resistant TB (MDR-TB) control, specifically aiming to work with up to 10 countries to introduce and scale up patient-based electronic recording and reporting systems within the next five years.[9]

The use of electronic health applications to manage MDR-TB is considered to be particularly helpful in improving the completeness of reporting on treatment outcomes. An electronic information system permitted clinicians to access real-time, laboratory results for MDR-TB patients that were not available on paper.[10] Other electronic systems, such as open medical record systems, have been implemented in a handful of countries for MDR-TB and other health conditions.[11] While scaling up diagnosis and treatment for MDR-TB remains a challenge that is being addressed, reliable implementation of and access to electronic information systems is crucial. One such web-based electronic system, e-TB Manager, has been implemented in various resource-constrained settings. e-TB Manager integrates data across all aspects of TB control, including information on presumptive TB cases, patients, medicines, laboratory testing, diagnosis, treatment, and outcomes.[12] First developed and implemented in Brazil in 2004, e-TB Manager was rapidly implemented in more than a dozen countries. Over the last eight years, e-TB Manager has been continuously improved with additional functionalities and general fixes for enhanced use. Updated versions have been regularly released and shared with selected countries that use the system. e-TB Manager is operating at more than 1,600 sites in 10 countries. Globally, as of September 2016, there were 2,876 active users managing 571,613 TB cases, MDR-TB cases, and presumptive TB individuals.

Over the years, the Systems for Improved Access to Pharmaceuticals and Services (SIAPS) Program, its predecessor programs, and other USAID global programs, gradually handed over e-TB Manager in all 10 countries to national authorities. In resource-constrained settings in low- and middle-income countries, functionality, organizational issues, and technical infrastructure often influence the success of implementing electronic systems.[13] A multicountry user experience analysis of e-TB Manager[14] and an in-depth study in Ukraine[15] were published. However, the procedural aspects of e-TB Manager implementation in each country were not documented. While facilitators and barriers for eHealth implementation in resource-constrained settings are well known,[16] the objective of this paper is to summarize the tailored implementation approaches given local context, which is a crucial consideration. The paper then summarizes the key lessons learned and implications for other electronic health information systems.

METHODS

We utilized various data sources to document the e-TB Manager implementation experience. First, we searched our institutional memory through two data sources: project documents (trip reports, presentation files, unpublished narratives, technical briefs) and informant interviews with five key project staff who have provided technical assistance on e-TB Manager to various countries since its inception. Second, we retrieved relevant documents from our implementing partners from their project websites (USAID TB Care 1, USAID Challenge TB project). Third, we reviewed concept notes submitted by e-TB Manager implementing countries from the Global Fund website to assess whether there was any relevant information. All project documents were categorized by country and individually analyzed for relevant content.

Findings and Country Summaries

Of the 10 countries using e-TB Manager to record and manage patients suffering from MDR-TB, Azerbaijan, Bangladesh, Nigeria, and Ukraine are also using it to manage drug-sensitive TB cases (table 1). While all countries are using the web-based version of e-TB Manager, Bangladesh is also using the desktop version. The desktop version can synchronize with the online version in case of interrupted electricity or poor internet connectivity.

Key Stakeholders Involved in Implementing e-TB Manager

Table 2 lists the countries where e-TB Manager was first introduced along with the in-country lead partner project. While Management Sciences for Health (MSH) staff, through several USAID-funded programs, led the discussions and coordination in various countries, other technical partners in some countries were also involved in the implementation. The next section summarizes the implementation approach for each country and presents selected findings.

Table 1. e-TB Manager Customized Features Used by Country

| Country	Type of TB Cases Entered	e-TB Manager Modules			Version	Language
		Cases	Medicines	Laboratory		
Armenia	MDR	✓			Web	Armenian
Azerbaijan	DS & MDR	✓			Web	Azeri
Bangladesh	DS & MDR	✓	✓		Desktop and Web	Bangla
Brazil	MDR	✓	✓		Web	Portuguese
Cambodia	MDR	✓	✓	✓	Web	Khmer
Indonesia	MDR	✓	✓		Web	Bahasa
Namibia	MDR	✓			Web	English
Nigeria	DS & MDR	✓	✓		Web	English
Ukraine	DS & MDR	✓	✓		Web	Ukrainian
Vietnam	MDR	✓	✓		Web	Vietnamese

DS = used for drug-sensitive TB

Table 2. e-TB Manager Implementation and Funding

Country	Year Introduced	In-country Lead Partner Project	Supporting/ Implementing Partner	Seed Funding	Additional Funding
Armenia	2009	Primary Health Care Reform, Abt Associates	SPS, SIAPS	USAID	Global Fund, National Government
Azerbaijan	2008	Primary Health Care Strengthening, Abt Associates	SPS	USAID	WHO, Global Fund
Bangladesh	2010	SPS and SIAPS, MSH	WHO	USAID	National Government
Brazil	2004	RPM+ and SPS, MSH	N/A	USAID	National Government
Cambodia	2011	TB Care, MSH	TB Care-KNCV, HIPA project, Palladium	USAID	National Government
Indonesia	2009	TB Care 1 MSH	TB Care 1 and Challenge TB, KNCV	USAID	Global Fund, WHO, National Government
Namibia	2010	SPS and SIAPS, MSH	SIAPS, MSH	USAID	National Government
Nigeria	2011	TB Care 1, MSH	TB Care 1 and Challenge TB, KNCV	USAID	National Government
Ukraine	2009	SPS and SIAPS, MSH	STBCU, Chemonics	USAID	Global Fund, National Government
Vietnam	2011	TB Care 1, MSH	TB Care 1 and Challenge TB, KNCV	USAID	Global Fund, National Government

HIPA: Health Information Policy and Advocacy project
SPS: Strengthening Pharmaceutical Systems project
STBCU: Strengthening TB Control in Ukraine project

Figures 1 and 2 provide quarterly data over a three-year period that reflects the number of cumulative TB cases entered in the countries. The number of cases is higher for countries using e-TB Manager for both MDR-TB and drug-sensitive TB.
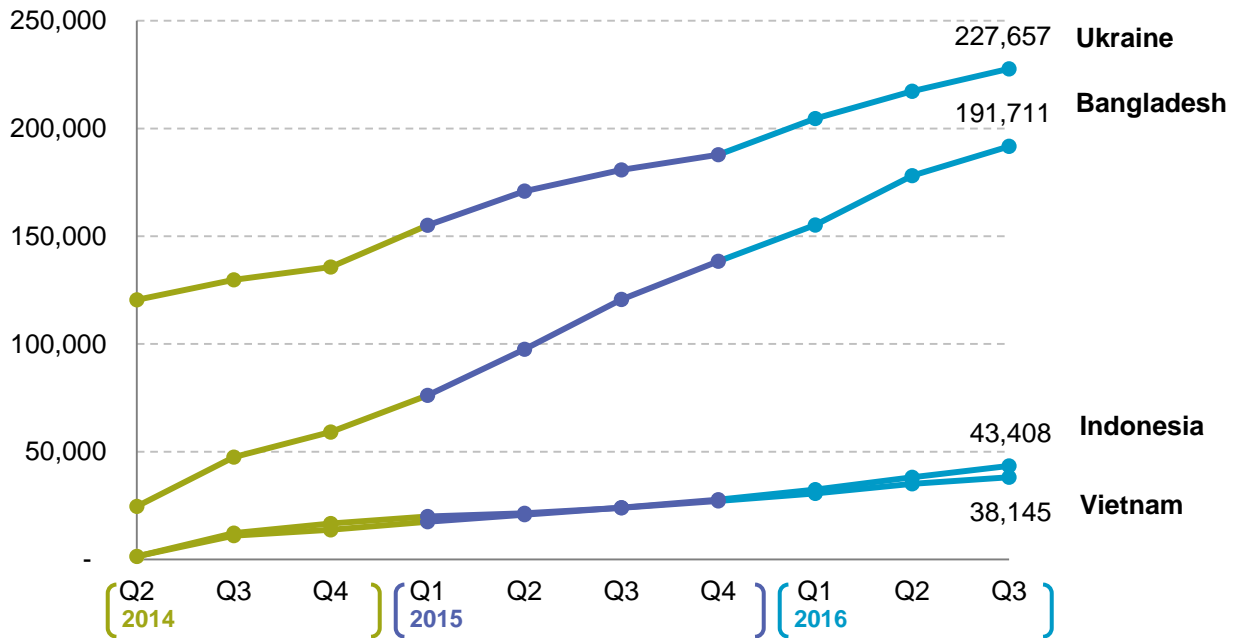
Note: Cumulative number of cases includes all cases entered into the e-TB Manager regardless of patient health outcome

Figure 1: Countries with cumulative TB cases entered: Quarterly Trend Data for 2014, 2015, and 2016
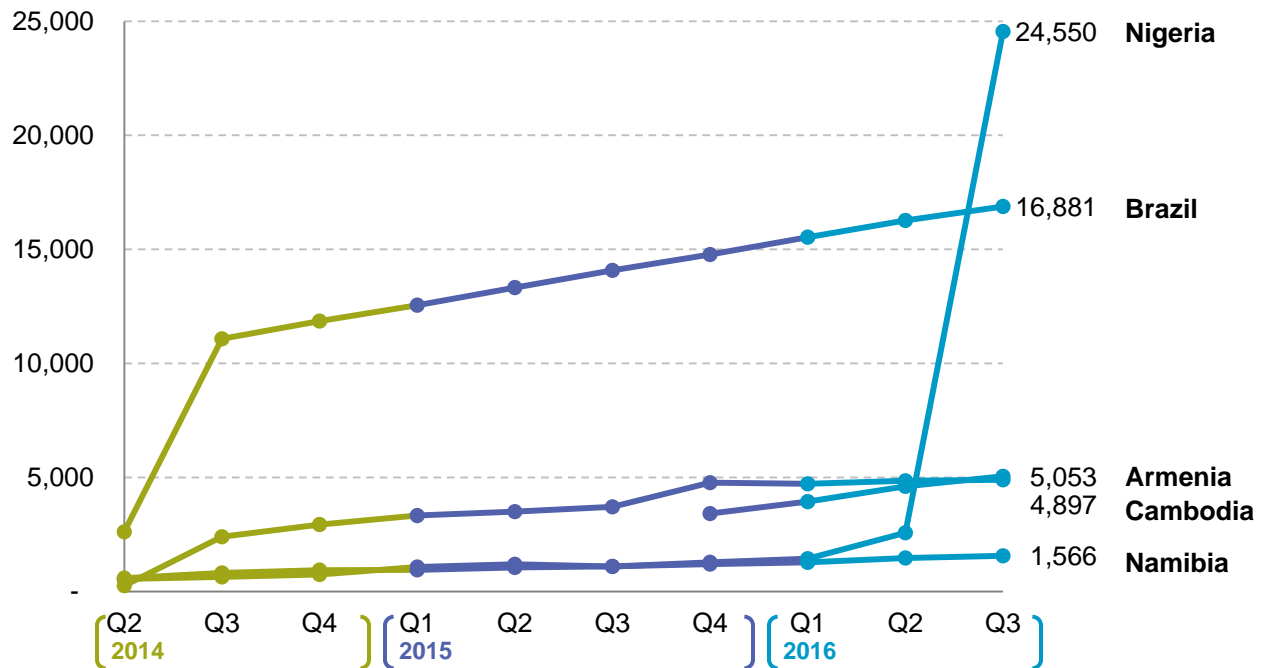
Note: Cumulative number of cases includes all cases entered into the the e-TB Manager regardless of patient health outcome
Armenia: Only four quarters (2015 Q4-2016 Q3) were entered into the e-TB Manager

Figure 2: Countries with cumulative TB cases entered: Quarterly Trend Data for 2014, 2015, and 2016

Figure 3 highlights the number of health facilities (sites) and number of users for e-TB Manager in each country. From 2016 onward, we illustrate the active number of health facilities (sites) and active users defined as having at least one transaction in the previous 12 months.

Number of e-TB Manager Sites:
Quarterly Trend Data for 2014, 2015, and 2016

Number of e-TB Manager Users:
Quarterly Trend Data for 2014, 2015, and 2016
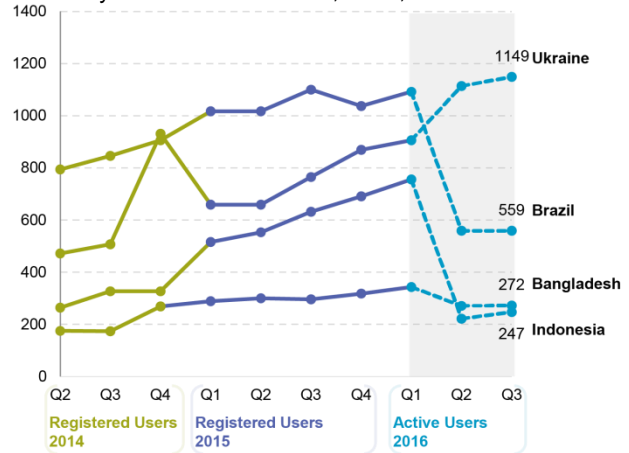
Number of e-TB Manager Sites:
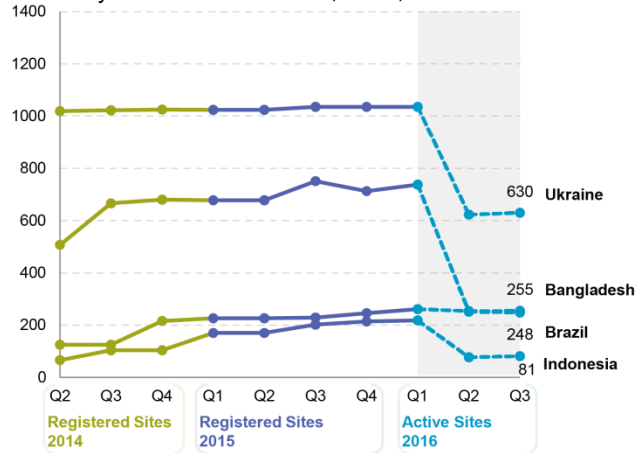Quarterly Trend Data for 2014, 2015, and 2016
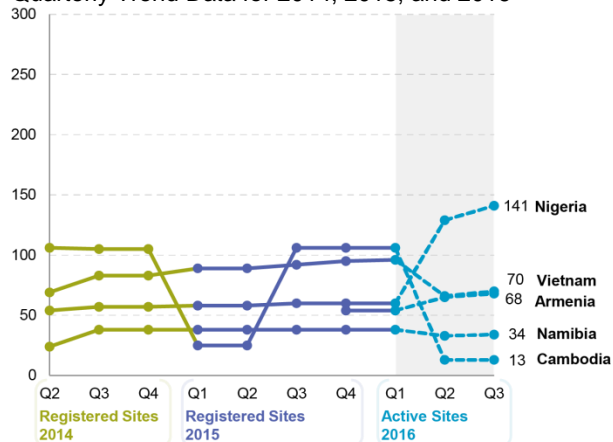
Number of e-TB Manager Users
Quarterly Trend Data for 2014, 2015, and 2016
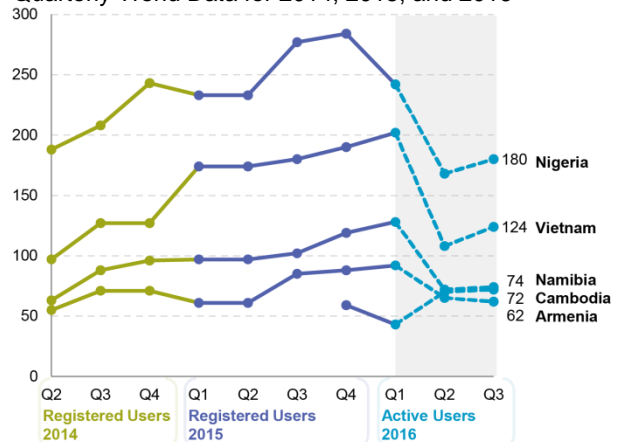
Figure 3: Number of sites (health facilities) and number of users

Armenia

The USAID Europe and Eurasia Bureau allocated funding to introduce e-TB Manager in interested Eastern European countries in 2008. MSH staff organized a regional workshop in Georgia and facilitated initial discussions among national authorities. The workshop reviewed the requirements for a management information system (MIS), identified adaptations for national TB programs (NTPs), developed country-specific plans, and identified technical partners who might support implementation. Armenia's prevailing MIS was a DOS-based information system for recording and managing drug-sensitive TB cases and did not have the capacity to record and manage MDR-TB cases. In 2009, the then director of Armenia's NTP was interested in implementing e-TB

Manager and assigned a database administrator to work with MSH staff to customize and adapt an Armenian version. MSH staff worked with the USAID-funded Primary Health Care Reform project, implemented by Abt Associates, to discuss potential collaboration and interaction between e-TB Manager and the existing and planned health information systems in Armenia.

e-TB Manager was initially piloted for drug-sensitive TB cases using the case management module at the central level (NTP), with information from the TB facilities of Yerevan entered manually from paper forms. Data from the penitentiary sector were also entered in e-TB Manager. The first pilot phase lasted two years because the NTP experienced three director-level changes. This led to uncertainties in next steps during the pilot phase and was very disruptive to implementation as e-TB Manager had to be presented and explained from the start after each staff turnover. However, the prevailing participating NTP staff remained committed and interested in implementation despite internal leadership changes. With new NTP leadership in 2010, e-TB Manager was implemented only for MDR-TB management in collaboration with Médecins Sans Frontières, an organization with a long history of working in MDR-TB treatment programs in Armenia. The second pilot process in early 2010 went very smoothly due to political will and support for e-TB Manager. In the same year, project funding ran out and MSH staff could only provide remote support for technical queries. However, the new director of the NTP embraced e-TB Manager as Armenia's National TB Register and continued to implement e-TB Manager through round 10 funding from the Global Fund, particularly to support the purchase of a server, computers, and internet connectivity for its health facilities. The national government also provided partial funding. In 2014 and beyond, additional financial support from the Global Fund supported infrastructure upgrades as well as updates of e-TB Manager features related to drug management, pharmacovigilance, and laboratory data management.[17] The NTP mandated that health facility staff use e-TB Manager and organized training programs. As of September 2013, e-TB Manager had been installed in 30 of the 93 TB units. By the end of 2014, e-TB Manager was available nationwide.[18] Data from e-TB Manager also supported a master's in public health thesis for a TB-diabetes study.[19]

Azerbaijan

e-TB Manager was introduced in Azerbaijan in November 2008 after national authorities attended the regional workshop in Georgia. The implementation of e-TB manager was endorsed by the directors of the NTP, the Medical Department of the Ministry of Justice, and the Central TB Prison Hospital in Baku. All parties initially agreed that e-TB Manager would be housed and maintained on the server at the National Scientific Research Institute of Lung Diseases, which would also contain joint patient databases and drug management information for the civil and penitentiary systems. The NTP, however, had a number of concerns about computer infrastructure and internet connectivity in the civilian sector, resulting in implementation delays of more than one year and a lack of political will to move the project forward.[20] By contrast, the Ministry of Justice committed funds for new computer equipment and internet connections. The penitentiary sector was very collaborative and enthusiastic from the beginning regarding the implementation of e-TB Manager, as they were much more advanced in TB control than the civilian sector. However the civilian sector's lack of movement to implement the system caused delays as it did not make sense to implement the platform only in the penitentiary sector. After the memorandum of understanding was signed in November 2010, as a result of changes in NTP

management, the NTP was ready to adopt e-TB Manager and actively collaborate. The delay in implementation was noticed by the Global Fund's Office of Inspector General during its diagnostic review of Azerbaijan's TB grants.[21] Recommendations for ensuring the implementation of e-TB Manager to permit monitoring of clinical outcomes were issued.

Once all parties were supportive of e-TB Manager, collaboration became smoother. The USAID-funded Primary Health Care Strengthening Project, implemented by Abt Associates, organized the training programs because it had a prior budget allocation in the 2009 work plan. After the Primary Health Care Strengthening Project ended in 2010, the USAID-funded Azerbaijan Strengthening Health Systems Through Integrated Programs project supported e-TB Manager implementation from 2011 to 2013.[22,23] Due to a Ministerial Order in 2011 requiring scale up of health management information systems, e-TB Manager was implemented in 142 health facilities, beating the country's low-end target of 25 health facilities. Once the main challenge of a lack of political will was overcome, the country took ownership. All training materials and job aids were provided by the Strengthening Pharmaceutical Systems project. After technical and financial support from both the Azerbaijan Strengthening Health Systems Through Integrated Programs project and Strengthening Pharmaceutical Systems projects ended, the NTP sought support from the Global Fund Transitional Funding Mechanism and hired a local consultant to oversee the implementation of e-TB Manager. The Global Fund supported costs for training district-level health administrators and TB coordinators, 70 desktop computers and printers for district-level TB units, salary for an information technology (IT) specialist to upgrade the national TB database, and related operational expenses such as internet connectivity.[24] The IT administrator spent two weeks with SIAPS Ukraine's IT developer and was trained on the IT aspects of e-TB Manager. This south-south training helped to support Azerbaijan in the handover and management of the system after the end of its USAID-funded projects.[25]

Bangladesh

Digital health was a high priority in Bangladesh's Government when e-TB Manager was first introduced in 2010. The 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. Over an eight-month period, the NTP and WHO country officials substantially contributed to the required e-TB Manager customization processes required for Bangladesh's recording and reporting systems. The pilot phase began in November 2010 in collaboration with WHO following an MOU signed on October 1, 2010, by the director of the TB Program in six MDR-TB designated health facilities. Based on lessons learned from the pilot, e-TB Manager was expanded to 26 upazilas (districts and subdistricts) of Bangladesh by July 2013. This gave the NTP confidence to scale up e-TB Manager by issuing a government mandate on the use of e-TB Manager for TB recording and reporting of patient case data. Extensive training sessions were conducted throughout the implementation of e-TB Manager to build staff capacity. The trainees were carefully selected from each district to ensure that both TB officers and health workers were represented. Due to the computer illiteracy of public-sector staff working in TB, basic computer training was provided over 15 days and on e-TB Manager over two days. Subsequently, the training sessions was expanded to 80 additional sites in 33 districts during 2013.

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. Thereafter, SIAPS recognized that countrywide scale up would be possible only with the involvement of all implementing nongovernmental organizations and e-TB Manager user champions from existing sites as role models. A training of trainers (TOT) approach was utilized for 60 participants responsible for training more than 200 health facilities and 950 users across the country in a phased manner. During nationwide implementation, significant bottlenecks in infrastructure (electricity and poor internet connectivity) had to be confronted. SIAPS purchased 24 solar powered kits worth USD 46,000 for installation in 10 priority districts among the 64 implementing districts. A maintenance free valve-regulated, lead-acid battery provide each facility with five hours of backup power and came with a five-year warranty that cost USD 250 per facility. In other health facilities, poor internet speed was associated with longer data entry time and poor data quality. This problem was solved by introducing a desktop version with offline capability and the ability to synchronize data with the web-based version depending on the strength of the internet connectivity. As a result, it only took five minutes for data entry for a single patient case with the desktop, offline version compared to 15 minutes with the web version with a weak internet connection. As of 2016, e-TB Manager was implemented in 218 of 488 upazilas (45% coverage). A performance analysis to measure utilization and completeness of data in the first quarter of 2016 revealed that 83% of sites maintained high performance, and the low performing sites decreased from 12% to 7%. Interoperability of DHIS2 with e-TB Manager was completed so that patient summary data could be easily available in the DHIS2 platform for key indicators.[26] SIAPS developed a transition plan to hand over technical and financial responsibility of continued implementation and increased national coverage to the NTP. A local IT programmer was trained by SIAPS' international IT programmer to ensure continuity and local ownership.

Brazil

In 2003, when national authorities in Brazil discussed options to decentralize MDR-TB treatment, there was a need for a strong information system to track the decentralized program. When USAID committed funding for TB, the NTP requested an electronic information system to help with the decentralization process. MSH was requested by USAID and the NTP to support the transition from paper-based systems to an electronic system. Initially, MSH designed and developed a web-based *drug management information system* to support MDR-TB surveillance. Thereafter, this system became known as e-TB Manager, or "SITE-TB" in Brazil. NTP authorities were familiar with electronic health information systems in general, and there was strong leadership and commitment from inception through the pilot phase with gradual nationwide scale-up. The customization process for data fields linking the paper-based forms was an iterative process. The NTP and various states provided funding for the purchase of computers and internet connectivity. However, despite eventual computer availability in various health facilities and reference centers, computer literacy was low. This challenge was overcome by training staff on computer use. Unlike other countries, Brazil had good infrastructure at reference centers, and internet availability grew quickly. The training sessions on e-TB Manager also provided an opportunity for end users to review and be updated on the latest clinical guidelines with peers covering all regional and state MDR-TB reference centers.

At a 2007 international lung health conference, the NTP Director had presented Brazil's experience in implementing e-TB Manager. Thereafter, there was a growing demand from various countries, donors, other USAID country missions, and international technical partners. MSH began creating a generic version of e-TB Manager that could be used in any country, which coincided with WHO's release of the first clinical guidelines on MDR-TB in 2008. The experience in Brazil enabled MSH to better understand local context with south-south technical assistance from Brazil to other nations worldwide. By the end of implementation in Brazil, MSH had built the capacity of all MDR-TB reference centers and trained health workers in all 27 states using a cascade training methodology (ultimately reaching more than 8,000 health workers). From 63 MDR-TB reference centers in 2004, e-TB Manager was expanded to 138 MDR-TB centers and treatment units by 2012. Between 2004 and 2010, e-TB Manager contributed to a 12% increase in the MDR-TB cure rate.[27] The medicines management module of e-TB Manager helped health facilities track medicine stock levels and mitigate the risk of stock-outs. An independent external performance evaluation of USAID-funded TB activities in Brazil highlighted e-TB Manager as contributing "to increased detection and cure of MDR-TB cases, and significantly strengthened clinical and case management practices at MDR-TB reference centers."[28] The report further states that e-TB Manager "was an important contribution to generating accurate data for decision making, strategic planning and advocacy" and "enriched the quality of information about TB patients, offering a comprehensive database for further research and scientific publications."

Cambodia

Before e-TB Manager was introduced in Cambodia in August 2011, the NTP primarily used Excel spreadsheets for data recording and reporting for laboratory, medicines, and cases. The latter system did not function well, and it was inefficient and challenging to get prompt and quality data from the lower health facility levels to the national level. The NTP, through the USAID TB Care 1 program, requested the introduction of e-TB Manager to improve recording and reporting. Because e-TB Manager has required data fields that force clinicians to enter all required data, the NTP sought to change user behavior for improved data completeness and accuracy. After the provision of infrastructure support (computers, modem, internet connectivity), four health facilities providing MDR-TB treatment were selected for the pilot phase. One of the main challenges that arose during the pilot phase was language. To overcome the language barrier, the web platform and user guide were translated into Khmer so that the international technical advisor could train users and implement the system with interpreter support. By August 2013, with funding from USAID TB Care 1, 11 desktop computers, 11 uninterrupted power supply units, 10 printers, and 12 internet modems were distributed to 9 health facilities and 3 laboratories that were piloting e-TB Manager. The expanded pilot phase from 4 to 11 sites permitted verification of all organizational and user aspects of e-TB Manager. To permit better completeness, accuracy, timeliness, and quality of data entry, the TB Care 1 program hired a full-time consultant to provide on-the-job training and mentorship to all users for three years. The NTP's IT staff were charged with training new users on basic computer operation skills and the use of e-mail to communicate as a precondition before training new users.

In August 2014, before USAID TB Care 1 funding ended, implementing agencies MSH and KNCV had discussions with the Futures Group, which was implementing the USAID-funded Health Information Policy and Advocacy (HIPA) project in Cambodia. In collaboration with NTP authorities, it was agreed to allocate line item funding to support the continued implementation of e-TB Manager for both MDR-TB and drug-sensitive TB as part of the broader TB Management Information System strategy. However, NTP authorities sought concrete examples of expansion in similar challenging and high-disease burden settings before committing to the expanded use of e-TB Manager throughout Cambodia. MSH facilitated four officials from Cambodia and two HIPA project staff to visit Bangladesh health facilities that were using e-TB Manager and other electronic health record systems. The purpose of these south-south knowledge exchange visits was to understand the data collection process, the data entry process into e-TB Manager, data entry challenges, user experiences, data flow from the community to the district level, and data quality checks from the district level to health facilities. Cambodian authorities and HIPA project implementing staff also sought to understand the organizational processes, the governance mechanism, and the role of each stakeholder in the health system for the successful implementation of e-TB Manager and how national authorities were handling electronic health record systems. In 2015 and 2016, the HIPA project had to retrain current users and conduct training for new staff operating e-TB Manager due to turnover of previously trained staff. External technical support by the HIPA project is expected to continue in Cambodia until 2018.

Indonesia

In October 2008, MSH staff presented on the experience of implementing e-TB Manager in various countries at an international conference on lung health in Paris. Following the presentation, Indonesian NTP authorities and implementing partner KNCV TB Foundation requested an assessment visit in Indonesia. At the time, a version of e-TB Manager was being tested in the Philippines and this gave confidence to Indonesian national authorities that the tool could be adapted to the Indonesian context. Following an in-country assessment visit by MSH staff in January 2009, it was decided to establish a working group for pilot implementation planning in April 2009 to coincide with MDR-TB treatment expansion. Translation verification, testing, further customization, and phased training occurred in the second half of 2009. MSH staff conducted comprehensive training sessions in January 2010 for two selected provinces on all e-TB Manager functions to prepare for the pilot, which began in May 2010. By March 2011, the smooth transition from international to local server occurred, and e-TB Manager was found to be 85% functional (10% needing minimal improvements and 5% minor bugs to be resolved). Based on lessons learned from the pilot implementing sites, e-TB Manager was expanded to three new provinces and capacity building for new users was provided by the NTP and country-based KNCV teams without international support from MSH staff.

To improve data quality and timeliness, 11 full-time data officers were hired by the KNCV TB Foundation to support the NTP during the expanded implementation phase in 2011. This intervention solved the challenge of poor data quality. Another intervention to improve data quality and completeness was the implementation of a "paperless policy." Staff at the health facilities had to update the NTP-required paper-based forms for TB case reporting, but

requirements on four other forms were removed for health facilities where data were fully updated in e-TB Manager, thereby creating an incentive to keep the data updated in the system. Gradually, this requirement was waived for other health facilities that complied with data quality expectations. By 2012, e-TB Manager was being used in seven health facilities, and the transition from pilot to intentional scale-up began in 2013 with an expansion to 13 health facilities providing MDR-TB treatment. In 2013, the MSH IT programming staff systematically organized the knowledge transfer processes to the Indonesian IT programmer to provide continued local support. The Indonesian IT programming staff position was created with two years of USAID funding with the expectation that the NTP would eventually allocate a full-time salaried IT programming position to support the nationwide implementation of e-TB Manager. To promote active user engagement and mutual learning, the NTP established an e-mail discussion group and promoted the use of social media to clarify queries on using e-TB Manager rather than strain the national office staff with the burden of answering queries. Data from e-TB Manager are being used to answer research questions to track progress in the programmatic management of MDR-TB.[29] Over the years, several separate electronic systems have been introduced in Indonesia, which has placed a significant burden on the country due to the lack of data exchange. Country authorities are working out a feasible plan for interoperability and a legal framework for health information systems in general.

Namibia

The Namibian NTP had been using an electronic TB register for drug-susceptible TB since 2006. While the prevailing electronic system could generate basic epidemiological reports, it did not address medicine management issues. Medicines were managed using paper-based forms for ordering and distribution; stock cards; and a monthly summary report (expiration dates, stock balance, losses) and it was often challenging to get the paper-based data. National-level authorities would often make time-consuming phone calls to clinicians and nurses to obtain timely data on MDR-TB cases, and the paper-based MDR-TB reports were cumbersome. In May 2010, the Ministry of Health and Social Services through the Directorate of Special Programs requested that the MSH office in Namibia introduce e-TB Manager after learning about its features, particularly for MDR-TB. In August 2010, the process for identifying customization needs and local adaptation began. In April 2011, following testing of the customized version by national authorities, a presentation was made to local stakeholders and partners to ensure buy in. Thereafter, e-TB Manager was piloted in three of 13 regions with training and infrastructure support (computers, modems, routers, internet connection) provided by MSH international and country staff. The government took responsibility for computer literacy training for health care workers. The initial one-year pilot was extended due to several constraints that arose, including the availability of computers, the turnover of trained staff, and funding gaps. There was a transition from one ending project to another new project. By April 2013, the assessment of pilot sites was completed, and the findings guided the final customization process based on user feedback. An agreement of activities and infrastructure needed to cover all 13 regions of the country was developed with the local government. National authorities had a champion in the assigned focal person who encountered user resistance by personally advocating for the benefits of e-TB Manager to all concerned users and encouraging timely data entry.

To facilitate the handover of e-TB Manager to the local government, SIAPS sent a team of experts to provide a final e-TB Manager training and initiate the roll-out of the tool. In October 2013, a handover strategy was developed to transfer maintenance to the government. The monthly costs for internet connectivity, including routers and modems, were supported by the MSH-led project for 18 months. Costs for supportive supervision and on-the-job training for 13 MDR-TB health facilities were initially bridged by MSH and with Global Fund round 10 financing. Further customization of the medicines management module of e-TB Manager was performed to adapt to updated flows and procedures in the country. A final training workshop was organized in October 2013 for 40 health workers, including nurses, doctors, pharmacists, and pharmacy assistants, with a "learning by doing" approach. The trainees brought all patient files with them, entered the data, and learned how to use various modules and features of e-TB Manager for recording and reporting. The live data entry of patient files also facilitated knowledge exchange between health workers from various regions of Namibia, with each sharing user strategies. Following the training, the database was successfully migrated to the host server located at the Ministry of Health and Social Services.

Nigeria

In 2011, the NTP expressed interest to the MSH country office to establish an electronic recording and reporting system, particularly to track MDR-TB cases and the associated second-line drugs and commodities. MSH staff conducted a feasibility assessment in September 2011 to guide the customization process, which took place during two workshops in December 2011. In the first customization workshop, the NTP team, regional supervisors, and other key stakeholders were involved in the customization process for e-TB Manager to meet the country's MDR-TB surveillance and TB control data needs. Subsequently, in the second workshop, the NTP's senior IT staff and laboratory and other TB control technical staff finalized the customized changes in the administration, medicines, and management modules of e-TB Manager. The data entry fields were compared with paper-based MDR-TB guidelines, registers, and other data reporting tools to guide and assist the customization process. This process was completed in February 2012 and in March 2012, eight sites were identified for pilot implementation with funding allocated for internet connectivity and power supply. An intensive hands-on training that targeted health workers, IT personnel, and their supervisors was held to enable the pilot implementation.

A formal review of the pilot implementation experience took place in February 2014. Major obstacles in implementation were limited supervision from the central level, limited frequency of data entry from the lower levels, interrupted or poor internet connectivity, and the lack of a trained team that was fully capable of using e-TB Manager due to high turnover of health worker in the pilot implementing sites. The communication channels between MSH and central-level staff needed to be strengthened for the NTP to better understand e-TB Manager's capacity, how to properly use it, and how to address the remaining problems to have complete success with the system. To overcome this challenge, the MSH country project team was actively involved in building the capacity of NTP and health facility staff on how to use e-TB Manager through supervisory visits and on-the-job training. By July 2014, the level of data completeness was between 85% and 90% when comparing the NTP's official numbers and those registered in e-TB Manager. The NTP, with support from the Global Fund, contracted with a local company to

provide a server of the appropriate bandwidth to ensure proper access and internet service. By June 2015, MSH had handed over e-TB Manager to the NTP. The MSH Nigeria country office implementing the TB Care 1 project was a vital part of improving communication, creating a strong relationship with the NTP, and building capacity for e-TB Manager during the implementation period. Having a strong in-country presence and local leadership to understand the benefits of the system and encourage end users from all over the country to report their data using e-TB Manager helped catalyze the movement needed for e-TB Manager success.[30] Continuing challenges, such as poor internet connectivity, are being addressed through the development of an offline version. A number of partners were involved in the implementation of e-TB Manager in Nigeria, including KNCV, WHO, the Damien Foundation, and the Nigerian Institute for Human Virology.

Ukraine

In 2008, as Ukraine confronted its growing TB and MDR-TB burden, it had no electronic system for its vast network of TB programs managed by various government agencies, including the state penitentiary system. The quality of the existing paper-based information systems varied. TB control was hampered by weak information, tracking, and reporting systems. In response to a request from Ukraine's Ministry of Health, MSH conducted an initial assessment of customization needs for e-TB Manager and developed a version suitable for Ukraine. In 2009, e-TB Manager was piloted in six oblasts (regions). A 2010 WHO review of Ukraine's TB program acknowledged e-TB Manager's beneficial role in supporting management decisions to improve program performance, including information on case notification and treatment outcomes. In 2010 and 2011, MSH continued to refine e-TB Manager based on user and Ministry of Health feedback, stabilized the platform to ensure continuous access, and trained pilot oblast users in data entry and use. In 2012, in accordance with Ukrainian law on patient confidentiality and information security, the State Service of Special Communication and Information Protection issued a security certificate for e-TB Manager. With certification complete, the Ministry of Health designated e-TB Manager as the official "national TB registry." A companion Ministry of Health order specified official adoption, authorization, and requirements for use as well as reports to be produced.

The NTP recognized that training a large number of public-sector health workers for nationwide expansion (24 oblasts) of e-TB Manager would be resource intensive. The training also needed to take into account doctors' poor computer literacy and potential resistance to e-TB Manager. The majority of the trainees (95%) were doctors who had to complete log books for TB recording and reporting. MSH hired a local consulting company specializing in adult learning techniques and TOT methodologies. The focus was to develop the competencies that oblast-level officials would need to run educational programs for adults on e-TB Manager in their oblast. Six TOT sessions were organized in Kiev city between August 2013 and September 2014. It was not possible to organize them regionally due to the Euromaidan Revolution in 2013 and uncertain security in parts of Ukraine during the military conflict and political unrest. Participants had adult learning sessions over 2.5 days using the e-TB Manager manual and learned e-TB Manager during the following two days. The Global Fund and USAID supported the purchase of 534 computers, while internet connectivity was provided by the Government of Ukraine through the oblast. The NTP assigned a dedicated team of supervisors to oversee the nationwide e-TB Manager expansion and ensure that

doctors, nurses, pharmacists, and other health workers were supported and could utilize e-TB Manager. A full-time IT staff was hired to provide real-time helpdesk services on demand via phone, e-mail, and a group discussion forum. Despite the Euromaidan Revolution and socioeconomic crisis, the registry was implemented in all 24 oblasts of Ukraine and the city of Kiev by 2014. As the number of cases in e-TB Manager continued to increase, a data quality assurance protocol was developed to provide for periodic error-free registry and reporting. As of August 2015, 185,760 cases had been entered in e-TB Manager, and the consistency between paper-based and electronically generated reports was approximately 99%. In October 2015, MSH formally handed over the administration of e-TB Manager to the NTP.

Vietnam

Vietnam had an electronic system called VITIMES for managing first-line TB patients, but it lacked the capability for MDR-TB patient management. Following a request from the NTP, e-TB Manager was introduced in March 2010. The process of customization was lengthy and took nearly two years due to an iterative process and testing during the pilot phase in Hanoi. Several doctors and NTP colleagues were initially resistant, and the process of getting their buy-in and acceptance took time and required a demonstration of what e-TB Manager could do. Their feedback on shortcomings of the prevailing version of e-TB Manager was also taken into account during the customization process, which took additional time due to language barriers and a lack of relevant IT skills. The NTP also had initial concerns on how to gain acceptance of e-TB Manager throughout the country, especially in South Vietnam where the burden of MDR-TB was higher than in North Vietnam. Therefore, the largest TB hospital in Ho Chi Minh City was engaged during the second year of customization to ensure that its needs were taken into consideration. To build capacity countrywide, MSH trained staff from the NTP team, who represented seven provinces, and included them in the initial stages of customization and piloting, which in turn promoted ownership and buy-in for the use of e-TB Manager. The country office staff of WHO, USAID, and the Partnership for Supply Chain Management were also involved during the implementation of e-TB Manager.

A technical working group that included WHO and USAID country office staff oversaw the implementation of e-TB Manager during the pilot stage. The technical working group agreed on a roadmap for e-TB Manager implementation to help guide nationwide expansion. In 2012 and 2013, e-TB Manager implementation kept pace with the NTP's increased decentralization of MDR-TB programs in various health facilities in priority provinces. However, there were challenges with poor data quality and a lack of consistency with paper-based records. Health facilities reported poor feedback and technical support that was expected from the NTP. Thereafter, the technical working group designated a core team of four individuals responsible for ensuring implementation success. A google group was established to facilitate communication among all users rather than restrict the helpdesk only to the core team. The NTP hired a full-time IT staff and allocated funding for computers and infrastructure where necessary in selected provinces. The training curriculum needed periodic updates based on user feedback and continued customization of e-TB Manager. The provincial training also enabled the NTP to seek feedback from health facility users on customization needs that might otherwise be overlooked. In September 2013, e-TB Manager was transferred to the local server. The full-time

IT staff gradually took over responsibility for upgrades and troubleshooting from MSH. The NTP conducted refresher trainings to health facilities already using e-TB Manager to address gaps in knowledge and meet user demands. In December 2014, MSH conducted the final technical assistance visit, finalized the sustainability plan, and assisted the NTP with any key areas that required troubleshooting. The NTP also developed a pharmacovigilance component with e-TB Manager to monitor adverse events in patients with bedaquiline-containing treatment regimens. The Clinton Health Access Initiative supported the NTP to link an SMS alert system with e-TB Manager for HIV patients suspected of having TB.

LESSONS LEARNED

Implementing an eHealth tool such as e-TB Manager, particularly in large and complex high-burden TB settings, requires multistakeholder partnerships, organizational agility, and committed resources to ensure its sustained use for patient care. As seen in various country case studies, the adoption of eHealth system such as e-TB Manager was primarily driven by the need to track and manage the growing burden of MDR-TB. Demand for e-TB Manager was met through a combination of donor funds, country needs for decentralized MDR-TB program management, and ease of accessing technical assistance. Our procedural implementation over the years was relentlessly contextual with continuous iterations. We present a few lessons learned across key themes.

Partnership with other USAID-funded programs: As seen in table 1, MSH, through the Strengthening Pharmaceutical Systems program and SIAPS, collaborated with various USAID-funded programs, such as TB Care 1 and Challenge TB, and other programs implemented by partners in Cambodia, Indonesia, Namibia, Nigeria, and Vietnam. Timely coordination and collaboration were essential to ensure that the NTP, as the beneficiary, received seamless technical assistance.

Strong leadership and local champions: While this may be the obvious lesson learned, we note that strong leadership and identification of empowered local champions contributed to the speed of adoption and nationwide expansion of e-TB Manager in some if not all countries. Strong and consistent leadership from either the NTP manager or the designate from the MDR-TB program was necessary to gain confidence during implementation, especially during obstacles. Local champions to support the day-to-day implementation from either the NTP head office or the provinces were necessary, especially during periods of health worker resistance or during interventions to improve data quality.[31]

Demonstration of success in pilot or first phase is crucial: We learned that demonstrating e-TB Manager's utility in the pilot phase or the first phase of implementation is crucial. Even if things do not go as expected, clear communication of solutions, strong leadership, and responsiveness are key. It then becomes easier to increase adoption rates at other health facilities. Understanding local context, demonstrating value, and communicating updated action plans with a timeline must be articulated through the NTP leadership.

Political will is a lever: The experiences in Azerbaijan and Ukraine highlight the importance of political will for the successful implementation of e-TB Manager. In both country contexts, a Ministerial Order mandating use of e-TB Manager gave legitimacy to NTP leaders and champions to expand e-TB Manager use nationwide. Once the main challenge of a lack of political will was overcome, the country took ownership and is now sustaining e-TB Manager without assistance from external partners. By contrast, countries such as Bangladesh, Indonesia, and Nigeria had no Ministerial Order and no top-down approach but relied on a deliberate, iterative process based on their decentralized provincial context.

Value in information for decision making: In all 10 countries, health workers are still entering data in both paper systems and e-TB Manager. To our knowledge, only in Indonesia was a paperless policy for key TB forms established to accommodate growing user feedback on duplication after gaining confidence in data quality over time. During implementation, training sessions, and supervisory visits, the NTP explained and advocated for the use of real-time data access from e-TB Manager to support decision making at various levels. When health workers, managers, and supervisors saw the benefits of accessing data in real time compared to paper-based systems, any initial resistance gradually decreased. Yet, many look forward to a future when paper-based systems can be done away with in favor of the exclusive use of e-TB Manager or any next generation eHealth system. However, more work needs to be done to train and empower health workers to routinely use data for decision making.

Infrastructure provision and computer training were essential: Many public-sector health workers were first-time users or needed training on basic computer skills. Our intervention took into account computer training basics and the learning curve for various cohorts of users.[32] Funding for infrastructure, such as computers, related hardware, and internet connectivity, came from diverse sources. In our experience, health workers who were first-time computer users and with access to the internet embraced e-TB Manager as it gave them an opportunity to learn new skills.[33] However, poor internet connectivity, the breakdown of computer equipment with no replacement, and intermittent electricity are challenges in some settings. In Bangladesh, for example, we installed solar kits in priority districts.[34]

Availability of full-time local IT staff is essential: In the early years, the NTP did not typically have a dedicated IT staff, and most relied on international IT support staff even after the introduction of e-TB Manager in country. While MSH staff, through various USAID-funded programs, provided the needed IT support, our programs advocated for a full-time IT staff to accommodate the growing need for routine IT support. This meant that the NTP had to budget for a full-time IT staff or secure funds from its Ministry of Health. Over time, a full-time IT staff was available either within the NTP or from other donor-funded programs in all implementing countries. With country expectations for interoperability with other eHealth such as DHIS-2, the e-TB Manager platform allows for data exchange with other eHealth systems, thereby needing dedicated IT staff.

Process of scale-up takes several years: In at least 8 of 10 countries, e-TB Manager is now in use in all MDR-TB program sites, major TB hospitals, provincial/state health facilities, and priority districts. This process took at least five years. As one study noted, "*time, money, coordination and context are critical, cross cutting issues – externally funded implementers need time, energy and determination to undertake the multiple activities required to catalyze scale-up.*"[35] Some high-burden countries, such as Bangladesh, Nigeria, and Vietnam, aspire to expand the use of e-TB Manager in district health facilities but need to take into account funding availability, user acceptance, internet connectivity, stable electricity, and changes in organizational behavior, among other factors.

CONCLUSIONS

eHealth or digital health systems are not an end in itself but a means to support countries to better conduct surveillance, monitor, and evaluate their TB programs. e-TB Manager has been institutionalized in these 10 countries with funding for its maintenance and operation sourced from domestic funds or with bridge funding from the Global Fund or other donors in some countries. e-TB Manager is available for download at http://etbmanager.org/, and the source codes and technical documentation will be available for countries to access from MSH's GitHub platform. The latest feature of e-TB Manager accommodates the need for interoperability and integration with widely used platforms such as DHIS2. While user experience analyses on e-TB Manager have been performed, future research could evaluate the effectiveness of e-TB Manager on patient health outcomes and its utility for decision making at the national level and in health facilities.

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