SOCIAL INNOVATION IN HEALTH INITIATIVE

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MOBILE-BASED SURVEILLANCE QUEST USING IT (MOSQUIT)

CONTINENT	Asia
COUNTRY	India
HEALTH FOCUS	Malaria
AREAS OF INTEREST	Digital technology
HEALTH SYSTEM FOCUS	Information systems

MOBILE-BASED SURVEILLANCE QUEST USING IT (MoSQuIT), INDIA

The Mobile-based Surveillance Quest using IT (MoSQuIT) is a digital platform that automates and streamlines malaria surveillance for all stakeholders involved, from health workers in rural India to medical officers and public health decision-makers. MoSQuIT provides quick transfer of information, real-time visibility of malaria incidence, and large-scale analytics for identification and management of epidemic outbreaks.

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ABBREVIATIONS

ASHA	Accredited Social Health Activists
C-DAC	Centre for Development of Advanced Computing
CQ	Chloroquine
ICMR	Indian Council of Medical Research
IT	Information technology
MoSQuIT	Mobile-based Surveillance Quest using IT
NMCP	National Malaria Control Programme
NVBDCP	National Vector Borne Disease Control Programme
R&D	Research and development
RDT	Rapid Diagnostic Test
RMRC	Regional Medical Resource Centre
Rs	Indian rupees
SMS	Short Message Service
SP	Sulfadoxine/ pyrimethamine
US$	United States dollar

CASE INTRODUCTION

India's health system faces the challenge of monitoring and assessing the spread of infectious diseases in a large population of over 1.2 billion people. Malaria, in particular, poses a tremendous challenge for the entire public health system in India, especially in the country's Northeast region where incidence and mortality are disproportionately high compared to other parts of the country. In 2013, the number of malaria cases was reported to be 0.88 million and the number of deaths 440 000 (National Vector Borne Disease Control Programme, 2013). However, experts have warned that official malaria figures underestimate the burden significantly; incidence is said to be between 9 and 50 times higher, and mortality around 13 times greater than officially reported (Hay, Gething & Snow, 2010; Dhingra et al., 2010). This indicates that the real burden of malaria in India is unknown, despite the importance of this data for the effective allocation of resources and health system response efforts (Shah et al., 2011). Without correct and current data, disease patterns are often misunderstood, health programmes do not accomplish their goals, and resources are incorrectly allocated (Unite for Sight, 2016).

The Centre for Development of Advanced Computing (C-DAC) is a government agency of the Indian Ministry of Communications and Information Technology that conducts cutting-edge research and development (R&D) in information technology (IT) and electronics. C-DAC's projects leverage the organization's technical expertise to tackle pressing social challenges in India. One of these projects is C-DAC's digital platform for malaria surveillance, Mobile-based Surveillance Quest using IT (MoSQuIT). MoSQuIT automates and streamlines the otherwise manual malaria surveillance process undertaken by the National Vector Borne Disease Control Programme's (NVBDCP) Accredited Social Health Activists (ASHAs) in rural India. It was developed to address the challenges that the Indian health system faces in monitoring and managing malaria, especially in remote rural areas. MoSQuIT has four main objectives: 1) provide a real-time snapshot of malaria incidence in a community; 2) detect changes in malaria incidence distribution to initiate an appropriate health system response; 3) ensure transparency and accountability across the value chain; and 4) measure the effectiveness of anti-malaria interventions and assess health system needs (e.g. stocks of medical supplies) in real time. MoSQuIT uses the guidelines and policies that underpin the national surveillance programme, delivered by ASHA workers.

A pilot study was conducted across 50 villages for 18 months to demonstrate the effectiveness of the platform. C-DAC is now exploring the deployment of MoSQuIT through the public health system, and adapting the technology to serve other health challenges in India, such as the surveillance of tuberculosis.

The government feels that since data are not collected, they thought that the malaria cases are not there. But due to such a system now, previously we were getting information on about 10 cases and now [we are] getting 100 cases. It is a big achievement for the surveillance system. (Dr Ganesh Karajkhede, Domain Expert, C-DAC)

1. INNOVATION AT A GLANCE

Organization Details

Organization name	Centre for Development of Advanced Computing (C-DAC)
Founding year	1988 (MoSQuIT piloted in 2011)
Founder's name (Nationality)	Dr Vijay Bhatkar (Indian)
Current head of organization	Professor Rajat Moona
Organizational structure	Government Agency (Not-for-profit)
Size	MoSQuIT was implemented by a team of 25

Innovation Value

Value proposition	The Mobile-based Surveillance Quest using IT (MoSQuIT) is a digital platform that automates and streamlines malaria surveillance for all stakeholders involved, from health workers in rural India to medical officers and public health decision-makers. MoSQuIT provides quick transfer of information, real-time visibility of malaria incidence, and large scale analytics for identification and management of epidemic outbreaks.
Beneficiaries	People living in rural areas around India where the public health system struggles to manage the incidence of malaria. Health workers and decision-makers involved in the surveillance and management of malaria.
Key components	• Real-time snapshot of malaria incidence in a community • Detection of changes in malaria incidence distribution to initiate an appropriate health system response • Transparency and accountability across the value-chain for malaria surveillance • Measuring the effectiveness of anti-malaria interventions and real-time assessment of health system needs (e.g. stocks of medical supplies)

Operational Details

Main income streams	Grants from the Indian government, revenue generating activities such as educational programmes and product sales
Cost per person served	US$ 12 per person screened, including US$ 0.5 variable costs and US$ 11.5 of fixed costs based on an 18-month pilot. The per-person cost would decrease proportionally with an increase in number of people screened.

Scale and Transferability

Scope of operations	Technology research and development conducted through the C-DAC office in Pune, India; Deployment in 50 villages of the Dibrugarh district of Assam, with 3000 people screened through the platform over a period of 18 months during the pilot study.
Local engagement	Collaboration with the Regional Medical Research Centre (RMRC)/Indian Council of Medical Research (ICMR) at the Tengakhat Primary Health care Centre (PHC), Dibrugarh district of Assam, India.
Scalability	• Designed to fit the needs of public health system in India • Requires technology, human resources and a supply chain for medication/diagnostic tests to be in place to be replicable across geographies • Train-the-trainer approach required to implement the solution at scale; digital training tools are designed to enable this process.
Sustainability	• Education of all stakeholders on the benefits of technology and data is required for long term adoption of solution by health system • MoSQuIT is aligned with national initiatives (Digital India and the National Supercomputing Mission) aimed at strengthening digital health infrastructure to support integration of innovative solutions

2. CHALLENGES

India's health system faces the challenge of monitoring and assessing the spread of infectious diseases in a large population of over 1.2 billion people. Malaria, in particular, poses a severe and complex challenge for the health system in India. The financial burden of malaria in India has been estimated to be around US$ 1.9 billion, with 25% spent on treatment and 75% due to lost earnings (Gupta & Chowdhury, 2014). Incidence of malaria peaked in the 1950s (0.8 million deaths and 75 million cases), was nearly eliminated in the early 1960s following the introduction of the National Malaria Control Programme (NMCP), and increased again in the 1970s (6.45 million cases in 1976) (Das et al., 2012). In 2013, the number of malaria cases was reported to be 0.88 million and the number of deaths 440 000 (National Vector Borne Disease Control Programme, 2013). However, experts have warned that official malaria figures underestimate the burden significantly; incidence is said to be between 9 and 50 times higher and mortality around 13 times greater than officially reported (Hay, Gething & Snow, 2010; Dhingra et al., 2010). This indicates that the real burden of malaria in India is unknown, despite the importance of these data for the effective allocation of resources and health system response efforts (Shah et al., 2011). Lack of available data, compromised surveillance, late diagnosis, and poor access to antimalarials all impede management of the disease in remote areas.

Without correct and current data, diseases are often misunderstood, health programmes do not accomplish their goals, and resources are incorrectly allocated (Unite for Sight, 2016). Although surveillance systems in developing countries often fail due to limited available resources, lack of knowledgeable staff, disorganization, and poor infrastructure for finding and reporting cases, ministries of health and finance and donor agencies are increasingly recognizing that data from effective surveillance systems are essential in allocating resources and evaluating programmes (Nsubuga et al., 2006).

The National Vector Borne Disease Control Programme (NVBDCP), a government programme in India, is tasked with the control of vector-borne diseases such as malaria. The NVBDCP's main strategies include: 1) early diagnosis and treatment of patients; 2) integrated vector management to reduce transmission; and 3) supportive interventions to promote behaviour change and build the capacity of the health system (Das et al., 2012). An important component of the NVBCP is the training and employment of Accredited Social and Health Activists (ASHAs), who are health workers certified to perform malaria diagnosis (through rapid diagnostic tests) and administer treatment (through antimalarials).

Malaria surveillance in heavily affected regions is particularly important, not only to facilitate an appropriate health response, but also to prevent an endemic emergence of drug resistant malaria. Malaria is endemic to the Northeast region of India, including the states of Arunachal Pradesh, Assam, Mizoram, Manipur, Meghalaya, Nagaland, Tripura and Sikkim. Although the region constitutes only 4% of India's population, it suffers from up to 10% of the country's total malaria incidence and nearly 40% of malaria mortality (Dhiman, Baruah & Singh, 2010). Several challenges give rise to the disproportionate disease burden including the area's rocky terrain, poor infrastructure, and shortage of medical officials – all of which hinder drug distribution and the circulation of epidemic data. Exacerbating these challenges, drug resistance in the parasite endangers malaria efforts in the Northeast region of India. Resistance of P. falciparum to chloroquine (CQ), a key component in antimalarials, was originally reported in 1973 and is said to stem from neighbouring countries such as Bangladesh and Burma. Although national antimalarial drug policy in India dictates that treatment with sulfadoxine/pyrimethamine (SP) should be used to target CQ-resistant malaria, reduced efficacy of SP has been recorded in the northeastern region of India (Dhiman, Baruah & Singh, 2010).

Several new developments in surveillance strategies may address the challenges described above. The rapid global reach of telecommunications, media and Internet has challenged formal national disease surveillance authorities' monopoly on disease surveillance information (World Health Organization, 2016). Despite the potential hazards of false reporting and reporting bias, non-traditional sources of data hold tremendous potential as complementary epidemic intelligence context to traditional surveillance sources (Brownstein et al., 2008). Information technology and informatics can contribute greatly to the development of a coherent, integrated approach to surveillance systems, and technology can facilitate the collection, analysis and use of surveillance data in many ways (Nsubuga et al., 2006). For example, mobile phones can accelerate data collection, wireless Internet can transform access to information and communication for health care workers and officials, telemedicine can permit sharing of data with international medical specialists, advances in geographic information system software can enable better analysis of surveillance data, and increasingly sophisticated algorithms and visual displays can improve the ease of use of surveillance data (Nsubuga et al., 2006).

Although Internet-based online media sources are becoming an important tool for global infectious disease surveillance, critical gaps persist, such as the large infectious disease burden and risk in regions that generally have the least advanced communication infrastructure. Therefore, achieving global coverage requires attention to creating and capturing locally feasible channels of communication, and increasing accessibility through user-interfaces in additional languages and low-bandwidth display options (Brownstein et al., 2008). A truly open and accessible system can assist users in overcoming existing geographical, organizational, and societal barriers to information (Brownstein et al., 2008).

3. INTERVENTION AND IMPLEMENTATION

3.1. A DIGITAL PLATFORM FOR MALARIA SURVEILLANCE

The Centre for Development of Advanced Computing (C-DAC) is a government agency of the Indian Ministry of Communications and Information Technology that conducts cutting-edge research and development (R&D) in information technology (IT) and electronics. C-DAC's projects leverage the organization's technical expertise to tackle pressing social challenges in India.

One of these projects is C-DAC's digital platform for malaria surveillance, Mobile-based Surveillance Quest using IT (MoSQuIT). MoSQuIT automates and streamlines the otherwise manual malaria surveillance process undertaken by the NVBDCP's ASHA workers in rural India. It was developed to address the challenges that the Indian health system faces in monitoring and managing malaria, especially in remote rural areas. MoSQuIT has four main objectives: 1) provide a real-time snapshot of malaria incidence in a community; 2) detect changes in malaria incidence distribution to initiate an appropriate health system response; 3) ensure transparency and accountability across the value-chain; and 4) measure the effectiveness of anti-malaria interventions and assess health system needs (e.g. stocks of medical supplies) real-time.

MoSQuIT was designed to be integrated into the existing surveillance framework set up by the NVBDCP in India. It uses the guidelines and policies that underpin the national surveillance programme for malaria and fills in execution gaps through its technology-based platform. The ASHA workers are equipped with mobile devices and as they perform their original malaria surveillance duties, they also input data into the electronic platform. Medical officers do random cross-checks to ensure quality control and accuracy. A group Short Message Service (SMS) facility on the platform allows for easy coordination of stakeholders and facilitates rapid communication.

With mobile devices, people can actually go and enter the data right there and then … and then it immediately gets made available into the databases and therefore much better visibility is available. And that, I think, is a major technology enabler for this kind of monitoring. (Professor Rajat Moona, Director, C-DAC)

MoSQuIT's digital system allows stakeholders at various levels of the delivery process to access information in real time (stored at the server). It improves both the speed of information travel and transparency. A schematic representation of MoSQuIT's structure is provided below.

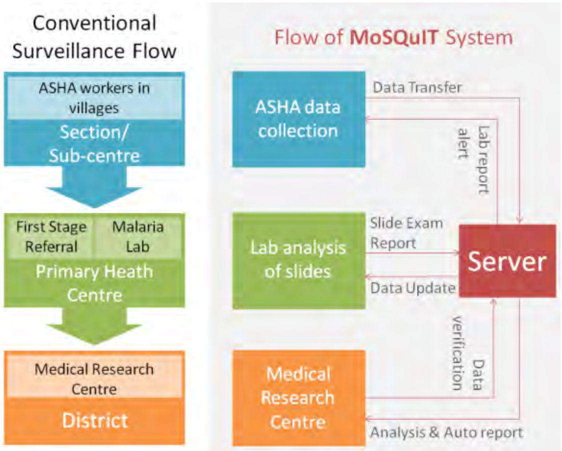

Figure 1: Malaria surveillance. Left: a graphical representation of the flow of information within conventional surveillance as performed by the Indian public health system. Information transfer between stakeholders is manual. Right: a graphical representation of the flow of information within MoSQuIT; processes have been automated through interactions with a centralized digital system.

Between mid-2012 and the end of 2013, the Regional Medical Resource Centre (RMRC) implemented MoSQuIT in 50 villages with a combined population of approximately 50 000 people. An existing server at the RMRC hosted the data repository and existing staff working on malaria surveillance were trained to operate the new system. Due to C-DAC's limited implementation capacity, it was only able to run the MoSQuIT platform during the 18-month pilot project as a proof of concept. C-DAC is now exploring deployment of MoSQuIT through the public health system, and adapting the technology to serve other health challenges in India, such as the surveillance of tuberculosis.

3.2. USER-CENTRED DESIGN

[A] very important thing was continuous discussion with the end user … So it's not that we have just developed something at our end and we are trying to push it there. This is not what we have done. We have continuously been in communication with [the end user] … Also, we keep taking feedback from them; the moment we design something we keep giving, using Skype we keep demonstrating this product to them. So they say, 'This we can understand. This we cannot understand. Can you make this change? Can you do this?' (Lakshmi Panat, Principal Technical Officer, C-DAC)

MoSQuIT addresses the needs of multiple stakeholders involved in the surveillance process at various levels of the health system.

ASHA workers in villages

MoSQuIT allows ASHA workers to collect patient data through a mobile phone application and upload this information directly onto a central server, rather than relying on manual paper forms. The platform also provides training videos (e.g. 'How to Use Rapid Diagnostic Tests'), audio clips (for precautionary measures during epidemics), and health games (encouraging health prevention). MoSQuIT also delivers lab results for each patient, providing ASHA workers with quick feedback on the malaria status of the community.

Malaria lab

Through MoSQuIT, lab results can be uploaded straight onto the central server, making results available to authorized ASHA workers in the community and facilitating timely action.

Medical officer and public health governance/research staff

Automated analysis on the server transforms individual patient entries into a real-time snapshot of the levels of malaria in a community. This information allows medical officers to identify, prevent or manage malaria epidemics quickly. Additionally, the system analyzes a wide range of malaria indicators and highlights significant trends, e.g. geographical distribution of incidence, health care performance, etc.

4. ORGANIZATION AND PEOPLE

C-DAC was founded in 1988 by the Ministry of Communications and Information Technology as a R&D hub with the goal of making India a competitive force in the world of IT and electronics. Gradually, C-DAC centres were founded in various parts of the country, cultivating a wide range of expertise and applications. Today, C-DAC's portfolio covers projects in domains including: high performance computing, health care informatics, multi-lingual computing, cyber security, electronic devices and software technology. Under the health care informatics domain, C-DAC undertakes projects related to health information sciences, such as health education, information management systems, inventory control, surveillance systems, bio-simulations and modelling systems.

Due to its governmental agency status, C-DAC benefits from organic partnerships with other governmental institutions, such as the Indian Council of Medical Research (ICMR). C-DAC also engages in commercialization of its products, such as the traditional medicine product Ayusoft[1], and the holistic health care software platform iCare@Home[2]. This varied collaborative structure is reflected in the external and internal sourcing of new projects at C-DAC. Often, domain experts approach C-DAC directly. However, C-DAC employees can also bring up new ideas through an internal funding competition.

In 2011, MoSQuIT was conceived through this internal process. Professor Rajat Moona, Director General of C-DAC, highlighted that the team's dedication to creating an impactful solution was crucial in its selection for internal funding: *"We are normally dependent on government to provide funding for our projects, but this particular project was completely funded by our internal resources. If there is an enthusiasm, there is a passion to do this, then I think we just have to enable that."* The proposal quickly attracted collaboration from the RMRC in Dibrugarh, Assam, India, which is part of the ICMR. As one of the six regional centres of the ICMR, the RMRC conducts biomedical research on a variety of topics and is responsible for improving health care delivery in the eight states of Northeast India. The C-DAC and RMRC collaboration ensured that development of innovative solutions captured the needs of the user at all levels along the public health chain. A team of 12 IT professionals and a medical doctor at C-DAC worked closely with public health practitioners from the ICMR to understand the needs of the health system and design an appropriate solution. It was a long but fruitful process of iterating every function of the platform with ICMR before a final version was developed. The close relationship between practitioners and beneficiaries created a uniquely collaborative and motivating environment. The participation of the ICMR in the development process was crucial on multiple levels: 1) the organization brought expert understanding of the relevant public health challenges; 2) as a research leader in malaria surveillance, the ICMR provides training and advice for Health Departments at the state level. Hence, this close co-creation process has allowed C-DAC to focus its technical efforts not only on the requirements of beneficiaries and health practitioners, but also to align its solution with the expectations of the health system.

The energy and dedication of the large team behind MoSQuIT has been critical in maintaining continuous communication with the end-user and responding to feedback.

The biggest ingredient of this [project] is people and their passion to do this … I think this organization is primarily a research organization, rather than a commercial organization, and once we understand this we work not for making money but for doing projects which are relevant, which are research oriented, which are actually going to be societal in nature, our outputs are programmes that can reach into the society and can do a

[1] Ayusoft is a digital system for traditional medicine designed for use by hospitals, practitioners and researchers.

[2] iCare@Home is iCare@home is a suite of health care informatics-based solutions designed for home monitoring of disease.

betterment of the society – then our people get excited. (Professor Rajat Moona, Director, C-DAC)

C-DAC has received recognition for its work on MoSQuIT, including awards from several digital health competitions, such as the mBillionth Award in 2013, which honours best practice in the mobile and telecom industries in South Asia. Additionally, the work was also presented at several conferences, including the 14th World Congress on Public Health in 2015. MoSQuIT has also received the SKOCH Digital Award 2013. The Skoch Awards celebrate human excellence and agents of change in Indian society.

5. BUSINESS MODEL AND PROJECT COSTS

As an organization, C-DAC has a mixed funding model: 40% of its funding comes from governmental grants and 60% from revenue generating activities, including product sales and educational programmes. C-DAC's involvement in education started modestly (60 students annually) and has since grown to nearly 10 000 students receiving technical training in IT-related subjects annually.

At this stage of development, C-DAC has estimated its implementation costs based on the 18-month pilot that ran between 2012 and 2013. The variable costs of the pilot, including ASHA workers' remuneration and mobile charges, amounted to approximately Rs 83 000 (US$ 1 250) for 3 000 people screened. This included mobile service provider costs for the data plan and SMS packages given to each ASHA worker of Rs 300 per month. Additional fixed costs, including IT set-up and maintenance, amount to approximately Rs 2 300 000 (US$ 35 000). The cost of server space is based on current market value estimates, as provided by C-DAC, since RMRC provided free server space for the purposes of the pilot. The base cost of the software and licensing fee that C-DAC will be charging implementers of its solution varied depending on the roles and responsibilities undertaken by the implementing partner and the level of support required by C-DAC. This will be determined in the next stage of implementation.

6. OUTPUTS AND OUTCOMES

6.1. IMPACT ON HEALTH CARE DELIVERY

Improving health care delivery processes

Between May 2012 and December 2013, C-DAC piloted the MoSQuIT system across 50 villages, and recorded outcomes in various categories. A direct comparison between MoSQuIT and the conventional paper-based system revealed substantial time savings related to data transfer (instantaneous versus 21 days); lab result transfer (one day versus seven days); visibility on stock availability (instantaneous versus seven days); epidemiological report generation (one hour versus one month). Additionally, MoSQuIT provided real-time tracking of stakeholder activity, including ASHA workers' data collection and lab analysis, which is currently impossible with the conventional system.

The conventional malaria surveillance system suffers from huge delays in information transfer, as well as information loss between the field, lab facilities, medical officials and decision-makers.

Multiple aspects of MoSQuIT's system are beneficial to the health system:

- **Improving information travel**: paper-based records take a long time to travel between stakeholders; the digital system reduced this time and provided instant visibility.
- **Coordinated response**: the efficacy of the NVBDCP malaria surveillance protocol relies on

successful communication between various stakeholders, such as ASHA workers, lab technicians, medical officers etc.; MoSQuIT streamlines this process by improving visibility, and communication, between stakeholders.

- **Detecting epidemic outbreaks:** analytics on the system compare real-time levels of malaria incidence to historical data, helping to identify outbreaks and trigger health system responses.
- **Strengthen supply chain**: MoSQuIT allows for monitoring of drug stock levels, allowing supply to be targeted and demand-driven.

Improving quality of care through data-driven decisions

MoSQuIT's system collects and processes multi-dimensional surveillance data, including geographical distribution of malaria incidence and effectiveness of treatment. Such information has the potential to strengthen the response of the health system on both the patient and population levels. It allows health workers to make data driven decisions to deliver appropriate and timely treatment to patients. It also allows policy-makers from public health organizations to identify outbreaks early and target medical resources to areas of greatest need.

Multi-faceted impact assessments of social innovations that improve various aspects of the delivery process can be challenging. C-DAC has performed an internal cost-benefit analysis of MoSQuIT, identifying a range of advantages over the traditional paper-based surveillance system. Overall, it found that the MoSQuIT system was 14.6 times more beneficial than the conventional paper-based system of malaria surveillance. However, an independent study capturing both patient-specific metrics (time until diagnosis, morbidity and mortality, etc.) as well as health system metrics (time per case, number of errors per 100 cases, etc.) will be required to validate the holistic impact of the solution. As a next step, C-DAC is exploring opportunities to conduct a large scale clinical trial to fully validate MoSQuIT's impact on patient mortality or morbidity.

6.2. COMMUNITY AND BENEFICIARIES

MoSQuIT is designed to benefit rural populations who might be affected by malaria as well as the stakeholders involved in the delivery of malaria surveillance and management. MoSQuIT helps rural populations access malaria diagnosis and treatment in a reduced time. MoSQuIT enables ASHA workers to receive quick feedback, both on patient lab results and personal performance. This last benefit, combined with the comprehensive training provided to ASHA workers, has proven to be crucial in maintaining a high standard of work. *"Previously we've gone through some of the papers filled by them; almost 30-40% of the data is blank in that, because they do not have a clear-cut idea of what surveillance is. But during training we give information on the objective of this thing and what will happen to this [information]… So then, the number of cases increases."* (Dr Ganesh Karajkhede, Domain Expert, C-DAC) Providing training on the MoSQuIT platform to the ASHA workers also helps them see the ultimate purpose of their work. They understand how the system works and how they fit into it. *"When we are gone for training there… giving training to 50 people… when they saw that the data is going to the server, on the screen, so we could see the joy on their faces. That simply is motivating and inspiring."* (Mr Nigod Dhurke, Technical Expert, C-DAC)

Large scale epidemiological data collected via the system allows for almost real-time visibility on malaria incidence. Traditional surveillance sometimes leaves substantial gaps in the disease map. *"The government feels that since data are not collected, they thought that the malaria cases are not there. But due to such a system now, previously we were getting information on about 10 cases and now [we are] getting 100 cases. It is a big achievement for the surveillance system."* (Dr Ganesh Karajkhede, Domain Expert, C-DAC)

These data can be used by the research community to elucidate deeper insights, including evolution of drug-resistance patterns. The granularity of medical data that MoSQuIT enables is unprecedented, and would provide researchers with a more detailed view of epidemiological patterns.

Per a formal testimonial signed by the RMRC on 12 June 2013, the organization recommends the large-scale deployment of MoSQuIT in conjunction with the existing NVBDCP across India. The Council also highlights the potential applicability of the technology to a broader range of diseases, including HIV/AIDS, diarrhoea and dengue fever.

7. SUSTAINABILITY AND SCALABILITY

The effectiveness and long-term implementation of C-DAC's solution within the public infrastructure of India requires high levels of user compliance and acceptability. There are several components that need to be in place for MoSQuIT to sustainably improve surveillance services for malaria:

- **Technology**: availability of mobile phones and a network of acceptable quality and at affordable cost;
- **Human resources**: well-trained health care workers, laboratory technicians, medical officers;
- **Health system infrastructure**: coordination between stakeholders including hospitals, primary care clinics, etc.;
- **Supply chain**: efficient delivery channels for medication as well as Rapid Diagnostic Test Kits (RDT);
- **Governance**: policy for providing incentives for health workers and coordinating stakeholder participation.

Deployment of MoSQuIT at scale is also associated with certain infrastructural requirements. On the one hand, MoSQuIT requires a public health system capable of providing human resources (e.g. ASHA workers) and translating the information acquired through the technology into actionable decisions. On the other hand, the platform also requires a digital network that can accommodate the unobstructed use of the technology by various stakeholders. Currently, two large-scale government initiatives, Digital India and the National Supercomputing Mission, are well aligned with this requirement. Digital India is committed to improving access to services for all citizens by strengthening digital infrastructure, including the provision of high-speed Internet in rural areas; the National Supercomputing Mission is dedicated to creating high-performance computing infrastructure to facilitate better analytics for development projects of national relevance.

As a technology agency, C-DAC relies on strategic partnerships with implementers to disseminate its solutions within the health system. The state governments in India are the main implementers of surveillance solutions for many infectious diseases. Innovators in this space therefore work within public-private partnerships. Implementation of MoSQuIT at scale would require commitment from government institutions at state and/or national level.

Stakeholder coordination will be necessary to ensure that the information acquired through MoSQuIT is translated into action. This includes synchronizing current supply chains for malaria medication and Rapid Diagnostic Tests with MoSQuIT output, which would require more targeted and efficient supply. Additionally, large scale epidemiological reports generated by the digital system should be utilized by decision-makers to inform strengthening of outbreak response.

C-DAC has a unique communication channel to the Indian government that can facilitate scalable implementation of the solution. *"Since we are actually, in some sense, part of the government, for us, interfacing with the government is much easier. So what happens is we do a small project, so something of this kind, we can actually go and reach out to the ministry and say this is what we have done... Our scaling up typically means that we have to now search for partners. So we search for partners, we give them the technology, we give them the means, and then they actually start implementing."* (Professor Rajat Moona, Director, C-DAC)

C-DAC has identified that a train-the-trainer approach will be required to transfer competencies from the R&D team to future implementers. Carefully designed training tools, including instruction videos and materials, are therefore included in the platform to support this process.

The same technology can actually be implemented not just for malaria but it can be implemented for all kind of other things, for example: looking at tuberculosis; looking at anaemia; looking at pregnancies, especially the complicated ones; looking at vitamin deficiencies; looking at malnutrition. … This technology can actually be used to solve a variety of other things as well, and therefore it actually has a very high potential. … So therefore it can actually become a very, very important tool for handling outbreak of diseases, as well as containment of lifestyle kind of diseases. (Professor Rajat Moona, Director, C-DAC)

Beyond MoSQuIT, C-DAC is exploring the possibility of adapting the platform to other health care domains, such as tuberculosis and maternal and child health. At this stage, C-DAC is planning to produce separate platform modules to serve each individual disease. However, in the future, data consolidation across diseases might be possible through the Indian unique identification number, Aadhaar. The number would link medical data collected on the same patient through different public health schemes (e.g. malaria surveillance, and maternal and child care) and enable a holistic view of an individual's health. This would allow for data-driven decisions on an individual and population level.

8. IMPLEMENTATION LESSONS

Using interdisciplinary expertise for social change

The development of MoSQuIT illustrates the ability of a technology organization, such as C-DAC, to seed projects for social change. C-DAC has successfully leveraged its governmental agency status to establish partnerships that enlist public health experts in the development of innovative solutions from day one. It is this combination of technological and public health expertise that has catalysed the creation of a technology innovation that captures the immediate needs of the health system.

Leveraging existing structures to create appropriate solutions

In their work alongside the public health system, C-DAC's team has learned that the most novel and advanced solutions are not necessarily the most effective and appropriate ones. *"Technological solutions should operate within the bounds of existing policies, protocols and infrastructure to ensure acceptance by the health system."* (Dr Karajkhede, Health Domain Expert) Hence, the solutions developed at C-DAC focus on removing inefficiencies and alleviating pain points whilst preserving the structure in place. Additionally, through years of experience working on social innovation projects, C-DAC has learned how to build momentum around an idea, translate this into a product and gather enough evidence to attract the attention of policy-makers. On a product level, MoSQuIT is designed to integrate organically into existing public health infrastructure, resolving inefficiencies and strengthening human capabilities through technology. As implementers, state governments in India have specific evidence requirements, linked to the current set-up of the health system. Leveraging access to state agencies, such as the ICMR, C-DAC has learned how to align its product development with scaling opportunities offered by local government.

Overcoming challenges

C-DAC's team has identified multiple challenges that could be posed by implementing their technology at scale and mitigated such difficulties through its design. One challenge faced by MoSQuIT is the trade-off between disease specificity and scalability. Multiple communicable and non-communicable diseases require surveillance; thus, a system that can be easily adapted to accommodate surveillance for multiple conditions would be both cost-effective and time-efficient for the health system. However, surveillance of various diseases is governed by different protocols and associated with different challenges. For example, malaria screening relies on the collection of blood smears collected by ASHA workers and sent to a lab for analysis; cardiovascular diseases screening, on the other hand, requires blood pressure measurements performed by ASHA workers and interpreted remotely by an expert clinician or an automated algorithm. Therefore, successful integration within the existing health care infrastructure requires disease-specific personalisation. Currently, MoSQuIT looks to address this challenge through its modular structure, which allows functionality to be transferred across diseases, as well as personalisation of these modules to the disease-specific public health needs.

Another challenge is integrating technology into existing systems. As Lakshmi Panat, Principal Technical Officer at C-DAC, highlights: *"Sometimes we feel that we have brought the technology a little ahead of time."* (Officer, C-DAC) Ultimately, public understanding of the significance of making data-driven decisions needs to catch up with the capabilities that sophisticated software systems like MoSQuIT can offer. The need for improved understanding extends to the policy- and decision-makers working on the provision of social services. C-DAC has addressed the challenge of technology capacity building from the bottom-up, by working closely with the user throughout the development process to ensure their needs are rightly met, and the top-down, by offering education services in IT that equip people with a wide range of technical skills.

CASE INSIGHTS

1. Disease surveillance efforts can be strengthened through a streamlined technology platform that gathers data from different care providers along the patient care continuum. Integrated data collection coupled with real-time analytics can help detect disease outbreaks and trigger a quicker health systems response. In addition, it enhances transparency and communication between different care providers.

2. A human-centred design approach emphasizes the involvement of different users and iterates the capabilities of the platform according to the needs of these users. This helps to create a product or process that is context appropriate and user-friendly.

3. Interdisciplinary teams and partnerships enable more effective solutions to be developed by leveraging the combination of different expertise and perspectives. MoSQuIT has been developed through a close collaboration between a technology agency (C-DAC) and a public health research body (ICMR). This mix of expertise has resulted in a product carefully tailored towards the needs of the health system and optimized for use by all stakeholders involved in malaria surveillance.

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