2.1 Technical Application

Client Registry Investment for the Government of Zimbabwe

Two-Sentence Overview

This work will concretely advance Zimbabwe's vision for a unified, country-wide, patient-level data system by building on the Impilo platform (the Zimbabwean-designed and built national EHR platform) to create a central client registry (CR) for the Ministry of Health and Child Care (MoHCC) as well as package and distribute the improved CR as an open-source global good to benefit all. The MoHCC and Vital Wave will achieve this through an iterative and collaborative process by drawing on their existing partnership, complementary skills and expertise, and coordination with the broader digital health community.

High-Level Budget Summary

This section will be completed in the application finalisation step.

Executive Summary

Over a period of ten months, the MoHCC will work closely with the Vital Wave team to accomplish the following:

1) strengthen the Zimbabwe digital health system through the creation of a central CR based on the existing component of the Impilo platform in accordance to global standards (e.g., OpenHIE), and

2) package and distribute the standalone CR as an open-source global good to be used in other low-resource settings.

Zimbabwe offers a unique opportunity to develop and contextualise a CR solution to benefit the MoHCC and the global digital health community at large. Recently, the MoHCC created a unified vision for a national, locally built EHR (Impilo), which has high-level support under the Permanent Secretary for Health and Child Care. Multiple government agencies, donors, and implementing partners have backed this vision, which centers on a patient-level system as a central component of the national digital health architecture. Most importantly, this vision and the unification of stakeholders has already realised initial funding investments. Therefore, the advantages to this project opportunity and approach are numerous:

Supports and benefits complementary investments: The funding from this project will support and benefit from complementary investments made by other donors such as PEPFAR/CDC, UNFPA, Cordaid Memisa, the Global Fund, and GAVI to improve Impilo system functionality, develop new modules, and extend deployment to additional health facilities. Alignment and support of investments such as this, exemplifies The Principles of Donor Alignment for Digital Health as well as increases the overall impact of investment funds.

Builds on existing, testable technology already in operation: The MoHCC has already driven the design and initial implementation of the Impilo CR as a component of the Impilo EHR system. This locally appropriate solution was derived through a human-centered design approach, focusing on health worker and facility needs. Any enhancements made can be tested and deployed at the 146 health facilities already using the Impilo platform, resulting in a robust, tested and validated CR and global good that is fit-for-purpose.

Strengthens overall Zimbabwe health system including COVID-19 response, chronic disease management, and medical research: A central CR will benefit other areas of the health information system. For instance, it will provide valuable patient identification data and services for direct-to-beneficiary applications now being rolled out for the national COVID-19 response, including self-registration, suspected case reporting, and contact tracing. It will yield the ability to uniquely identify patients across multiple service delivery points and systems to improve longitudinal tracking of clients including linking mother and baby pairs, as well as the ability to provide de-identified clinical data for research. It will also provide visibility into silent transfers of patients with chronic disease (e.g., HIV and TB) between facilities which would otherwise be recorded as patients lost to follow up.

Together, the consortium partners will work collaboratively on all activities to build capacities of MoHCC staff and leverage their current partnership, such as work to establish a Community of Practice for the Impilo platform to accelerate progress toward global good packaging and dissemination. In addition, the MoHCC and Vital Wave are already successfully executing work throughout the COVID-19 pandemic. Best practices and established project processes will be employed for this opportunity as well.

Consortium Team

The MoHCC of Zimbabwe is currently working closely with the Vital Wave team through funding from the Bill and Melinda Gates Foundation to conduct a countrywide EHR landscape analysis, with the aim of creating a more coherent digital health architecture. Within this context, the two organisations have formed a strong partnership. For this opportunity, the two organisations will join forces, each bringing a unique set of complementary skills to ensure success.

MoHCC Overview:

The MoHCC will serve as the **Consortium Lead**, driving the overall strategic direction and execution of the project. The MoHCC brings strong government leadership and existing alignment across the ministries and partner organisations as well as the ability to advocate with peers in other country governments. In addition, the MoHCC brings a skilled software development team with applied experience in Docker containerisation, event-sourcing architecture, and interoperability-layer implementation. This is bolstered by their well-established software development operations and user-centered processes for patient-level system design, testing, and implementation. This includes access to a cohort of 146 health facilities actively using the current version of the CR (within the Impilo EHR system), allowing immediate implementation of developments in low-resource settings. Concurrent investments by other donors will increase the number of active health facilities over the course of the project, leading to a direct increase in its impact.

Examples of Previous Work:

- *Impilo EHR deployment:* Since 2015, the MoHCC and development partners have developed, piloted, and rolled out the Impilo EHR system in 146 facilities in 8 rural districts and 3 cities including Harare City. Following data quality and completeness evaluations conducted at the end of 2019 in pilot sites, the Impilo EHR has been endorsed by the MoHCC as an effective replacement of two legacy patient-level data systems, including eight paper-based registers and a Microsoft Access-based system, which are now being phased out in favour of electronic-first data entry into the Impilo EHR. The Impilo EHR has also successfully demonstrated extract, transform, and load (ETL) capabilities for pushing data into aggregate DHIS2 systems. With wide support by development partners and donors, the Impilo EHR is now being scaled up nationally, as per plans outlined in the 2020-2-23 National EHR roadmap.
- *COVID-19 Case Tracking:* Immediately following initial cases of COVID-19 reported in South Africa, several new applications for COVID-19 case reporting and visualisation, and contact tracing were developed by the MoHCC Impilo development team and the Harare Institute of Technology (HIT). The MoHCC has now deployed the Impilo EHR at international ports of entry to Zimbabwe for COVID-19 screening and tracking of all international travellers and is collaborating with HIT to

exchange patient-level data between the Impilo EHR and a mobile-based self-reporting and alerts application and a national dashboard for case reporting.

- *DHIS2 (multiple projects):* The MoHCC currently manages several national instances of DHIS2 including for its malaria case-based surveillance system, its neglected tropical disease (NTD) mass drug administration (MDA) programme, and its aggregate monthly health system performance monitoring and evaluation programme. Extensive experience using, maintaining, and contributing to DHIS2 as a widely used global good exists within the MoHCC and local development partners. Additionally, the MoHCC has successfully developed microservices as part of the Impilo platform to extract, aggregate, and push data into programme specific DHIS2 instances from the Impilo EHR.

Team Members:

Dr. Gibson Mhlanga, Acting Secretary for Health and Child Care: Dr. Mhlanga has served as Chief Director and Principal Director for over 14 years where he is responsible for setting the overall strategic direction for the Preventive Services Directorate of the MoHCC and overall management and coordination of national programmes and policies for disease prevention and control including in the areas of Epidemiology and Disease Control, AIDS & TB Control, Family and Child Health Services, Environmental Health Services, Government Analyst Services, National Health Research and Radiation Protection Services. Dr. Mhlanga has recently taken on the role of Acting Secretary for Health and Child Care during the COVID-19 pandemic and is the senior government leader overseeing the national rollout of the Impilo EHR and related digital health technologies. Dr. Mhlanga was trained as a medical doctor and holds a Master of Public Health from the University of Zimbabwe and a Master of Business Administration from the National University of Science and Technology, Zimbabwe.

Dr. Simukai Zizhou, Provincial Medical Director, Mashonaland East: Dr. Zizhou has served as Provincial Medical Director (PMD) for over 14 years, where he has overseen and advocated for the implementation of the Impilo EHR system across the Mashonaland East province. Dr. Zizhou now serves as provisional Chairperson for the Integrated EHR Taskforce whose responsibilities include establishing supportive policies for the national deployment of the Impilo EHR system and related technologies, liaising with other governing bodies, and coordinating input and buy in with all external stakeholders including international donors and implementing partners. Dr. Zizhou was trained as a medical doctor at the University of Zimbabwe with specialisation in applied epidemiology and holds a certification in monitoring and evaluation from the University of Witswatersrand, South Africa, and a Master of Public Health from the University of Nairobi, Kenya.

Dr. Robert Gongora, National EHR Coordinator: Dr. Gongora has led the implementation of the MoHCC's Impilo EHR system since its inception as a pilot project in the Mashonaland East province in 2015, where he served as the District Medical Officer (DMO) for the Mutawatawa District Hospital in the Uzumba-Maramba-Pfungwe (UMP) District until 2018, when he took on the new role of National EHR Coordinator to coordinate national scale up activities. As a medical doctor trained at the University of Zimbabwe and through his experience as DMO and pioneer for EHR in Zimbabwe and studying eHealth and Telemedicine Management, Dr. Gongora brings a first-hand perspective on the needs of health professionals and the requirements for digital health technologies in resource-constrained settings.

Manes Munyanyi, Deputy Director, Health Information and Surveillance: Mr. Munyanyi focuses on the coordination of health information and surveillance systems for the MoHCC. Specific areas of his work have included leading the development of the national health information strategy, data management and surveillance for disease outbreaks such as cholera, and the upgrade and customization of DHIS2. Prior to this role, he worked as a manager, then director coordinating health information activities for the Midlands province. In this position he both received and provided numerous trainings in disease surveillance and response. Mr. Munyanyi brings a wealth of knowledge of digital health applications including DHIS2, ODK, EPI Info, CommCare, and more. This is bolstered by his technical skills in programming languages, database applications, and healthcare terminology standards including HL7 and OpenHIE. Mr. Munyanyi has a Master of Science in Information Systems Management from Midlands State University and is currently pursuing coursework in data science, bio statistics, and health informatics with the Johns Hopkins School of Public Health

The MoHCC's Impilo software development and operations team is comprised of nine software developers, including an interoperability lead and systems architect, a web user interface lead, and a mobile development lead with skills and experience in microservices architecture, Docker deployments, Consul, RabbitMQ, Java, JHipster, Angular, and AngularJS, as well as a technical support lead and six national technical support specialists.

Vital Wave Overview:

Vital Wave will serve as **Technical Assistant and Coordinator**. The firm will support client management and coordination across stakeholders as well as provide technical assistance to the MoHCC. Aspects of this work will include applying OpenHIE CR specifications and data standards to the Impilo platform, provision of technical trainings to MoHCC staff, facilitating testing and feedback processes with the wider global community, and packaging and distributing the Impilo CR as a global good. Within digital health, Vital Wave is a recognised leader in designing and implementing digital health solutions at a national scale for low-resource environments. For 15 years, Vital Wave has designed digital health solutions, led national implementations, and contributed to the global goods space, including engagement in the OpenHIE Leadership Committee, Africa CDC Task Force, and stewardship of the DSME Community. The firm's approach to facilitation and coordination extends to its work with national governments, which enables the transfer of skills and strengthening of local capacity.

Examples of Previous Work:

- *HIS Evaluation in Zimbabwe:* Vital Wave is currently working with the MoHCC to conduct a country-wide EHR landscape analysis, which will be contextualised within the overall health information system (HIS), as well as integrate global inputs and learnings. The purpose of the study is to understand gaps and opportunities in the use of patient-level data via EHR and linked HIS to plan, deliver, and monitor health services, while reducing duplication of efforts and the use of redundant systems and resources. Ultimately, its results will directly inform the government's roadmap for its national EHR implementation and strategy for harmonizing investments and funding discussions with donor organisations, such as the Global Fund, CDC, and UNDP.

- *Digital Solutions for Malaria Elimination Community of Practice:* This community was originally born from a Vital Wave strategic facilitation and landscape assessment that identified priority features and capabilities required for mobile tools to successfully support malaria surveillance activities. It has now grown to include 153 members from 39 organisations across the world. Through the DSME Community, the firm actively drives community engagement, curates information and advocacy materials, connects different industry members, and identifies concrete areas of opportunity for partnership and funding. Collaborative community efforts have resulted in the creation and dissemination of new global goods, including: a Common Geo-Registry for managing geographic data over time across multiple information systems; an Android code library called the Geospatial Widget which allows Android application developers to embed an interactive, map-based interface into their applications (now integrated into DHIS2 Tracker, CommCare, and the OpenSRP-based Reveal application); and a common data dictionary for malaria data.

- *Improving Data Use in Sub-Saharan Africa:* Vital Wave was engaged to improve information systems and increase the use of data in health care delivery in Malawi and Ethiopia. In Malawi, the firm supported the Ministry of Health by reviewing all technical systems supporting national HIV/AIDS programmes and developed a strategic plan for system integration to reduce data fragmentation. In Ethiopia, Vital Wave supported the Ministry of Health by developing and implementing a new national strategy for transforming healthcare delivery through data use—including plans for an integrated national HIS architecture and governance structure, costing for a DHIS2 national rollout, and two foundational systems to support interoperable information exchange between health system stakeholders.

- *Beyond Scale Guide Creation:* Vital Wave partnered with DIAL, BBC Media Action, Esoko, and the Johns Hopkins University Global mHealth Initiative to create Beyond Scale, a global good to help guide country-based NGOs and early-stage digital technology companies for their next stage of

growth. Beyond Scale contains seven modules that offer a series of key steps brought to life by real-world examples from digital development organisations working towards scale and sustainability. Useful tools and templates are linked throughout and provide actionable tips to help readers apply the guidance in their own work.

For more examples of related work, please visit www.vitalwave.com.

Team Members:

Derek Treatman, Engagement Manager: Mr. Treatman is an engineer and recognised leader in the digital health field. His work in complex, resource-poor settings has focused on applying readily available technologies to meet local needs and strengthening national health systems. Mr. Treatman brings extensive experience leading multi-partner, multi-country digital initiatives that have resulted in dozens of implementations across the globe. He regularly supports governments and development partners through research and strategy creation, software design and development, and implementation. Mr. Treatman's recent work includes the creation and contribution to digital global goods and platforms including a common geo-registry platform for managing geospatial reference data, a common data dictionary for malaria data, and an implementation guidance toolkit for deploying digital tools for malaria elimination. He has been leading Vital Wave's current assessment work in partnership with the MoHCC and has an intimate understanding of the Impilo platform. Lastly, he is also an active member of the OpenHIE community. His combination of technical skills, relationship with the MoHCC, understanding of the current landscape, and experience developing and distributing digital global goods will bring value to this project.

Pierre Dane, Technical Analyst: Mr. Dane is a health technologist with a background in software development and database engineering. He has worked across many functions, encompassing software and database engineering, solutions architecture and programme and grant management. Mr. Dane is currently a technical lead for Vital Wave's work to oversee the development of a suite of interoperable digital tools to support malaria elimination. In this role, he has also contributed to the development and distribution of digital global goods including a common data dictionary for malaria data, and a geospatial widget now integrated into DHIS2 Tracker, CommCare, and the OpenSRP-based Reveal mobile application. Mr. Dane is also supporting Vital Wave's current work with the MoHCC as a technical advisor and has an in-depth understanding of the Impilo technology stack and architecture. He began his technology career working in data warehousing at one of South Africa's largest hospital groups and spent ten years working in London across several sectors including insurance. Upon returning to South Africa, Mr. Dane served as Software Development Manager and Director of Technology at Jembi Health Systems. Mr. Dane's vast experience in digital health tools, particularly in low-resources settings, will bolster his contributions to this work.

Blessing Manyiyo, Technical Analyst (based in Zimbabwe): Mr. Manyiyo's technical skills extend from the concept and strategy phase through to solution design and deployment. He is particularly well versed to translate technical requirements into prototypes and minimum viable products. This is complemented by his ability to conduct system and business analyses. Mr. Manyiyo is currently conducting field-based research for Vital Wave. Prior to Vital Wave, Mr. Manyiyo provided technical support on concept design, development, and deployment of remote patient monitoring systems for chronic disease management. In Zimbabwe, he managed several technical projects for Econet Wireless. He also worked extensively on the design and deployment of health information system components and mobile health solutions. Mr. Manyiyo's local knowledge combined with his technical skills will contribute to the success of this project.

Vital Wave will likely also employ two local developers in Zimbabwe in addition to the team members listed above.

Note: Full CVs for each team member can be provides upon request.

Background or Problem Statement

A common problem, in Zimbabwe and other resource-constrained countries, is the sustainable operation and maintenance of critical digital health technologies. When custom technology is developed from the ground up, especially in the public health sector through international donor funding, it may fail to be maintained when donor funding runs out, and the ongoing costs for routine maintenance and upgrades can no longer be supported.

Global goods, open source software products with a large, active community of implementers and contributors, offer a solution to this problem, by sharing peer-based support, resources, and software updates and improvements. However, many global goods are developed in wealthy countries with reliable internet connections, experienced software developers, and knowledgeable experts in robust data standards, profiles, and terminologies. When these technologies are imported from abroad, they are often not fit-for-purpose, requiring extensive customisation to suit local needs and international experts to set up and operate. Over time, they often fail to be maintained by local staff without the necessary experience or time to support their ongoing operation.

Global goods must be “shelf-ready” and fit-for-purpose. They must have the ability to be contextualised and adapted to individual country contexts by readily available local staff and local developers and they must function in areas where internet connectivity and grid power are unreliable or non-existent. Therefore, a country-driven approach that leverages an existing, fit-for-purpose solution that already works in facilities without reliable sources of power and connectivity will have the greatest chance of success in other low-resource settings.

Figure 1: Impilo EHR System

The Impilo EHR system is a ‘Made in Zimbabwe’ EHR system developed within the MoHCC, which employs modern, industry-standard system architecture and open-source technologies and follows global best practices for information exchange using a robust-event sourcing framework. The architecture of the system follows global best practices for information exchange based on the Open Health Information Exchange (OpenHIE) architecture, where captured data are stored in, and accessed from, standardised repositories via a central interoperability layer (currently internal components within the Impilo EHR system). The development team already follows best practices for development operations including deploying images to Docker Hub when they release new versions.

Additionally, as a result of the current work between the MoHCC and Vital Wave, a new roadmap for national EHR implementation has been published and circulated within Zimbabwe. The Impilo code base has been approved (as of 11 June 2020) for licensing under the open source GNU Affero General Public Licence v3 (AGPL 3), migration to public GitHub repositories is planned, and new governing structures are being put in place to establish a community of practice to disseminate and obtain contributions to the open source code with collaborators on the local and global stage.

Packaging and sharing the Impilo EHR and related technologies as open source global goods to share with other potential implementers within Zimbabwe, the African content, and the world are national digital health objectives for the MoHCC. The timing of this Digital Square investment opportunity is paramount. It

will help the MoHCC improve the Impilo CR component to fully adhere to OpenHIE specifications, produce a packaged global good version for use in other contexts, and help establish a growing global community to support, sustain, and continuously improve a truly fit-for-purpose CR.

Ultimately the project will result in the following outputs:

- Enhancement of the Impilo CR component, adapted to OpenHIE specifications, made configurable for adaptation to other country settings,
- A production-ready, containerised CR package that has been fully tested against OpenHIE CR specifications in an Instant OpenHIE sandbox, in compliance with Instant OpenHIE contribution policies,
- Increased capacity at the country level for use of HL7 standards (focused on but not restricted to FHIR), IHE profiles, and OpenHIE best practices and architecture, and
- A complete implementation package for deploying and configuring the open-source CR product and supporting materials disseminated globally for use in other low-resource settings.

Digital Health Technologies

The following table provides an overview of key digital health tools, technologies, and standards that the project will be utilizing or investing, as well as the interactions between them. Table A provides an illustrative list of health information systems in Zimbabwe expected to be the "early adopters" of Impilo CR services.

The Impilo EHR system, from which the Impilo CR will be derived, will be the first live integration to be established and will be used to test and validate that the Impilo CR meets OpenHIE CR workflow specifications. Concurrently, the MoHCC will explore proof of concept integrations with other patient-level data systems in Zimbabwe, including another EHR used in private-sector facilities, another facility-based pharmacy software, and mobile applications used by community health workers or directly by patients for programmes including nutrition and COVID-19 surveillance.

Table A: Illustrative Consumer Digital Health Technologies in Zimbabwe

Health Information System and Organisation	Purpose	Approach
Impilo EHR MoHCC, Preventive Services Directorate	National EHR system from which the Impilo CR will be created.	Integration between the Impilo EHR and the standalone Impilo CR will be the first established as a proof of concept and for testing standard CR workflows
Bahmni EHR Population Services International (PSI)	EHR system used in private "new start facilities" that offer services for HIV/AIDS patients	Explore integration of Impilo CR with private-sector EHR solution as proof of concept for integration with another commonly used OSS EHR solution
RapidPro MoHCC, Family Health Department, Nutrition Services Programme	Nutrition surveillance and other ad hoc data collection needs for nutrition programme	Explore submission of nutrition programme data to Impilo EHR system using Impilo CR identifiers as proof of concept for linking programme-specific data sets with national EHR

SENAITE MoHCC, Curative Services, Laboratory Services	Laboratory information managements system (LIMS) for management of patient-based lab test data for public health facilities	Explore use of Impilo CR for patient search and authentication for the LIMS system as proof of concept for use by supplemental patient-level systems in public facilities
Electronic Logistics Management Information Systems (eLMIS) MoHCC, Pharmacy Services Department	Pilot system for facility-based pharmacy stock management and patient dispensation	Explore use of Impilo CR for patient search and authentication at pharmacy point of care as proof of concept for use by supplemental patient-level systems in public facilities
Go.Data MoHCC, Epidemiology and Disease Control Directorate	Outbreak investigation tool for field data collection being deployed for COVID-19 response	Explore use of Impilo CR for patient search, authentication, and registration as proof of concept for interface with field-based health worker mobile applications
COVID-19 Alerts MoHCC and Harare Institute of Technology (HIT) collaboration	Mobile application for patient self-reporting of COVID-19 symptoms	Explore use of Impilo CR for patient search, authentication, and registration as proof of concept for interface with direct to patient mobile applications

As presented in Table A, there are a wide variety of applications and viable integrations with existing digital health technologies being used today in Zimbabwe, providing several near-term opportunities to test and refine Impilo CR functionalities and supported workflows. This investment will be “African-led”, ensuring not only that context-appropriate processes, functionality, and software are developed, but that immediate value will be brought to the Zimbabwean national digital health ecosystem. Proof-of-concept integrations in Zimbabwe can be further used to package the Impilo CR as a global good for deployment in other countries and to present compelling case studies as well as promote its adoption.

Furthermore, the Impilo CR will be built upon a stack of OSS technologies and international data standards. The Impilo CR technology stack and architecture will be modelled on the existing stack and architecture of the Impilo EHR system, thus reusing as much existing code as possible. Figure 2 and Table B below present the proposed architecture, technology stack, and data standards and profiles to be used in the Impilo CR. The Impilo EHR platform already provides configuration scripts to set up metadata, and the existing production dataset will be de-identified, randomised, and obfuscated to provide a large real-world dataset for training and testing of matching algorithms and features in the user interface.

Figure 2: Proposed Impilo CR Architecture

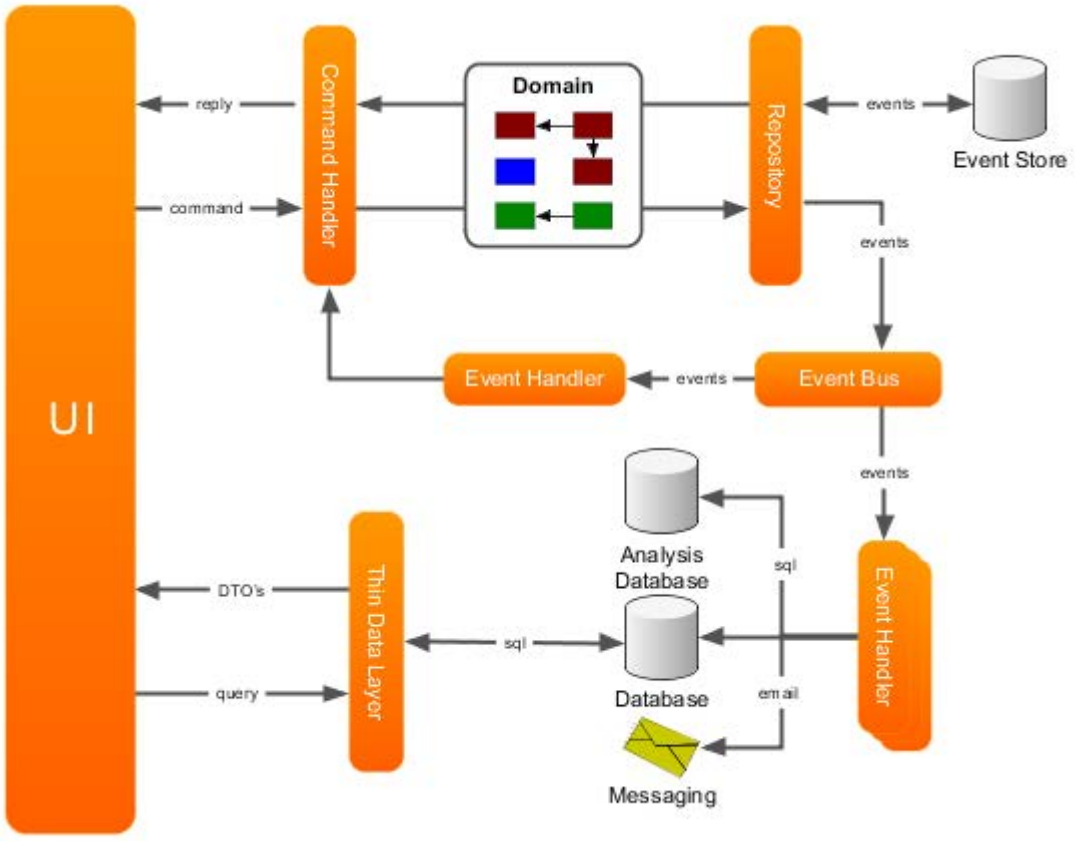


Table B: Proposed Impilo CR Technology Stack and Data Standards

Impilo CR Technology Stack	Data Standards and Profiles

• GitHub: code repository
• Docker: deployment container and script
• RabbitMQ: messaging service to convert input/output data between relational structure and PIXm/PDQm standard
• MySQL: CR database
• MongoDB: event store database
• Angular: coding framework for front-end user interface (UI)
• Axon: framework used for micro service, CQRS, and event sourcing architecture
• Apache Camel: Event messaging abstraction
• Lombok: Annotated runtime code generator to minimise boiler plate code
	• HL7 FHIR: all data exchanged via Impilo CR will be structured as FHIR resources, including:
	  • Patient
	  • Operation
	  • Parameter
	  • OperationOutcome
	  • Bundle
	• OpenHIE CR Workflows: requirements for supported workflows for Impilo CR development and testing
	• Patient Identifier Cross-Reference for Mobile (PIXm): profile to be used by Impilo CR API for referencing patient identifiers
	• Patient Demographics Query for Mobile (PDQm): profile expected by Impilo CR for search and update queries from consumer systems

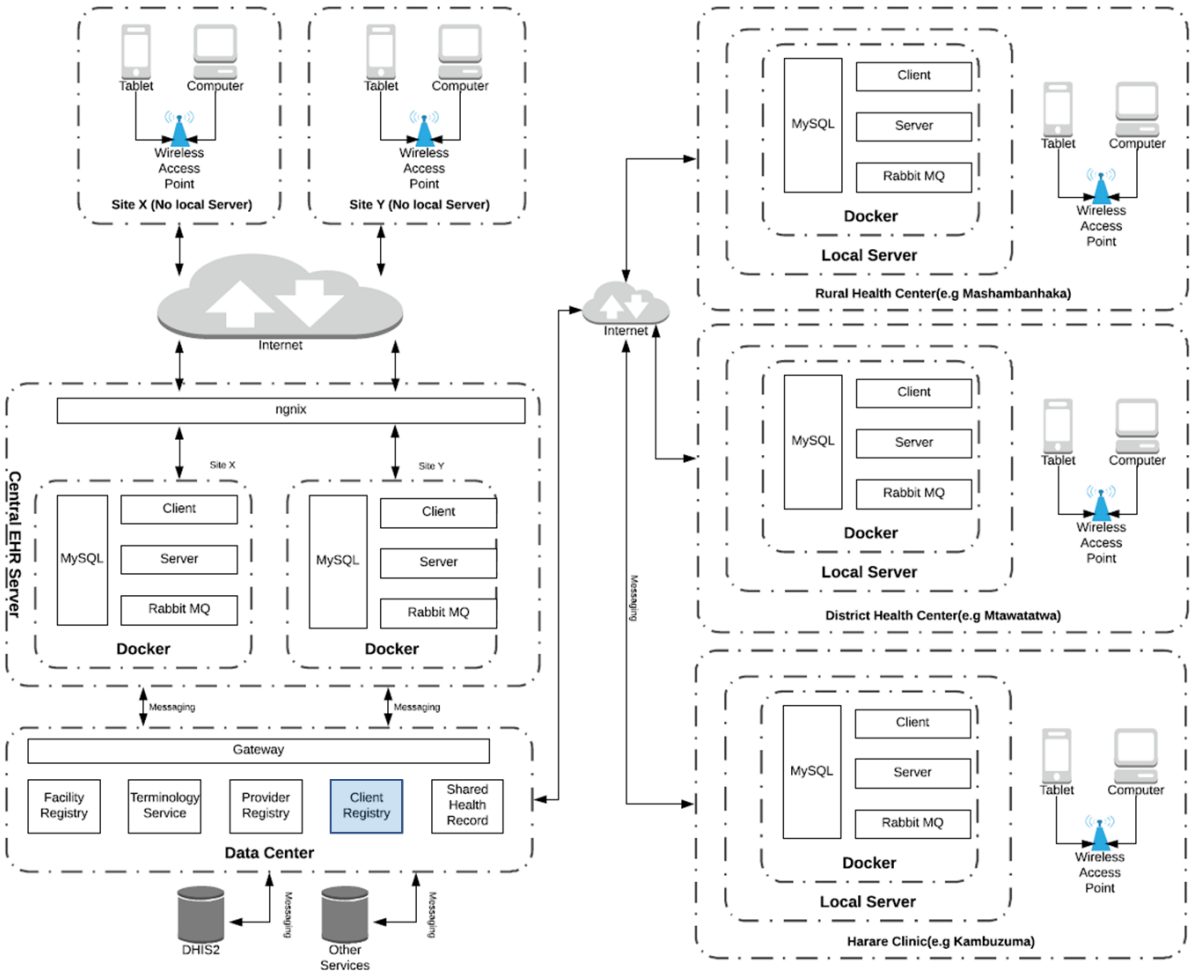
The architecture and technology stack have already been developed for the Impilo EHR thus reducing the effort that will be required for initial development. Extraction of the CR from the Impilo EHR and establishing the Impilo CR as a standalone system with its own interface will require the development of a new UI built in Angular. Additionally, microservice mediators must be written for the enterprise service bus (currently based on Axon and Apache Camel with RabbitMQ) to transform records to/from the Impilo CR MySQL database from/to appropriately structured HL7 FHIR resources (e.g., Patient) that will be made available through the Impilo CR API following PIXm and PDQm profiles.

Note that an initial decision to use a relational database in the existing technology stack and leverage microservices to transform data to/from FHIR resources upon request/response via the API is proposed over the implementation of a FHIR server for document storage. This approach is expected to minimise early development effort required, leverage existing hardware in facilities and software expertise on the MoHCC development team while building new capacity in FHIR data standards, and avoid undertaking massive structural changes in the technology stack. However, alternative approaches will be considered as part of the proposal finalisation and initial project planning process. Following specifications from the FHIR Exchange Module to define the interfaces and health information message exchange will allow other systems implementing FHIR to transact with the CR.

Relevant FHIR ValueSets will be used where necessary and will be mapped to existing terminologies used by the Impilo EHR. The national data dictionary will be enriched with concepts from other participating information systems and mapped to FHIR ValueSets or other international terminologies where appropriate.

A local instance of the Impilo CR will be implemented in every health facility where the Impilo EHR is currently deployed, using the same server hardware and software deployed for the Impilo EHR. Similar to the Impilo EHR, the Impilo CR will synchronise its data with the central Impilo CR instance if and when internet connectivity is established. Figure 3 below presents the current Impilo EHR system architecture, which will serve as a model for the Impilo CR architecture. The “Client Registry” highlighted in blue in Figure 3 is currently an internal component of the central Impilo EHR instance, which will be extracted as a standalone system (using the same technology stack and architecture) and deployed in separate Docker containers.

Figure 3: Impilo EHR System Architecture



Use Cases and User Stories

This intervention will produce an open source, standalone Impilo CR solution that supports standard OpenHIE CR workflows described on the OpenHIE wiki, here. The Impilo CR will support a variety of use cases defined for Zimbabwe, as well as those sourced from other ministries of health and members of the OpenHIE community at large. A key activity of this project will be to socialise the software development roadmap and proposed use cases with the OpenHIE community to obtain feedback and suggestions, ensuring the end product will be widely applicable in contexts outside of Zimbabwe.

Table C below presents several illustrative use cases for the Impilo CR that best support near-term needs for Zimbabwe's primary healthcare system. Table D below presents several illustrative user stories for key actors who will benefit from implementation of the Impilo CR. A key requirement for this system is support for offline-first use cases, given widespread constraints on accessibility and reliability of internet connectivity in Zimbabwe. The Impilo CR will be designed to function first locally and offline, and second on a transactional basis with a central instance of the Impilo CR. It will therefore be designed to anticipate and handle duplicate records as a regular fact of operation.

Table C: Illustrative Use Cases

Use Case	Description
Patient linking and de-duplication	Support routine identification and linking of duplicate client records and retrospective merging of duplicate records within the Impilo CR, including data that may be routinely submitted on hard disk from offline-only facilities. Client systems will be reliably notified of linkages or merges made at central level.
Linking of datasets between disparate systems	Enable multiple, disparate patient-level datasets to be linked or merged using CR identifiers or identifiable data (e.g., in a clinical data warehouse).
Linking of mother and baby pairs	Improve longitudinal tracking of clients for health workers through linking of mother and baby pairs.
Tracking silent transfers of patients with chronic disease	Provide visibility for programme managers into silent transfers of patients with chronic disease (e.g., HIV and TB) between facilities which would otherwise be recorded as patients lost to follow up.
Improving civil registration and vital statistics (CRVS) data	Provide visibility into birth and death events to improve accuracy of population counts for programme planning and resource allocation.
De-identifying clinical data for research	Support expunging identifiable data to allow sharing of de-identified data with research partners for clinical research.

Table D: Illustrative User Stories

Actor(s) *As a(n)…*	**User Story** *… I want to be able to…*
Impilo CR System Administrator / Data Manager	Make sure the Impilo CR is operational and monitor its transactions (both with external systems and other local / central instances of the Impilo CR).
	Routinely curate Impilo CR data using tools to rapidly identify, link, and merge data from duplicate records, in an intuitive way.
	Easily implement relevant matching algorithms using a ‘plug-in’ or ‘algorithms-as-a-service’ framework, to ensure that regional person-naming conventions are catered for.
	Support / guide external system teams to integrate with the Impilo CR (both with offline-first, facility-based systems and online-first central systems) and use its services to register, authenticate, or obtain client identifiers or demographics.
M&E Officer	Determine the number of unique patients from any patient-level dataset that received a certain service or that meet certain criteria to assess health facility performance and burden of disease.

	Aggregate patient-level data from one or more patient-level systems by demographic (e.g., age, gender) or other linked data points (e.g., HIV status, diagnoses) to track health outcome indicators.
	Monitor new patient registrations and patient record updates to assess health facility performance.
Facility-based Health Worker / Pharmacy Technician / Laboratory Technician	Search for (first locally, then with central Impilo CR instance if internet connectivity is available) and authenticate a patient's identity before recording the details of an encounter / dispensation / lab test. Ensure that duplicate patient record creation is minimised.
	Flag multiple records as potential duplicates if identified when searching for a patient or authenticating identity, so the duplicate records can be reviewed, linked, and merged if appropriate by the Impilo CR System Administrator / Data Manager.
	Count the number of unique patients for whom I provided a service during a particular day / time period to track my personal performance.
Community-based Worker	Authenticate the identity of a client before sharing or communicating sensitive information via SMS or WhatsApp.
	Enable linkage of patients seen in the community with the public health CR and clinical information systems.
	Uniquely identify other individuals based on demographic information reported by a client for COVID-19 contact tracing and generate notifications and alerts to those individuals through the COVID-19 Alerts application.
Client	Register for mobile- or community-based health services using my mobile phone, and reliably authenticate my identity.
	Report symptoms of a suspected COVID-19 case for myself, a family member, or a friend to ensure they receive medical attention if needed and ensure an accurate understanding of disease prevalence and transmission in my area.
	Be alerted if I have come in contact with someone who is suspected of or has tested COVID-19 positive.

Following the implementation of the Impilo CR in Zimbabwe and piloting it for use cases including, but not limited to those illustrated above, the Dockerfile, Docker container image, Docker Compose script, deployment and configuration documentation, test dataset, and case studies documenting pilot implementation results and value in Zimbabwe will be published publicly and made available to the OpenHIE community. Potential implementations of the "shelf-ready" Impilo CR package envisioned globally include:

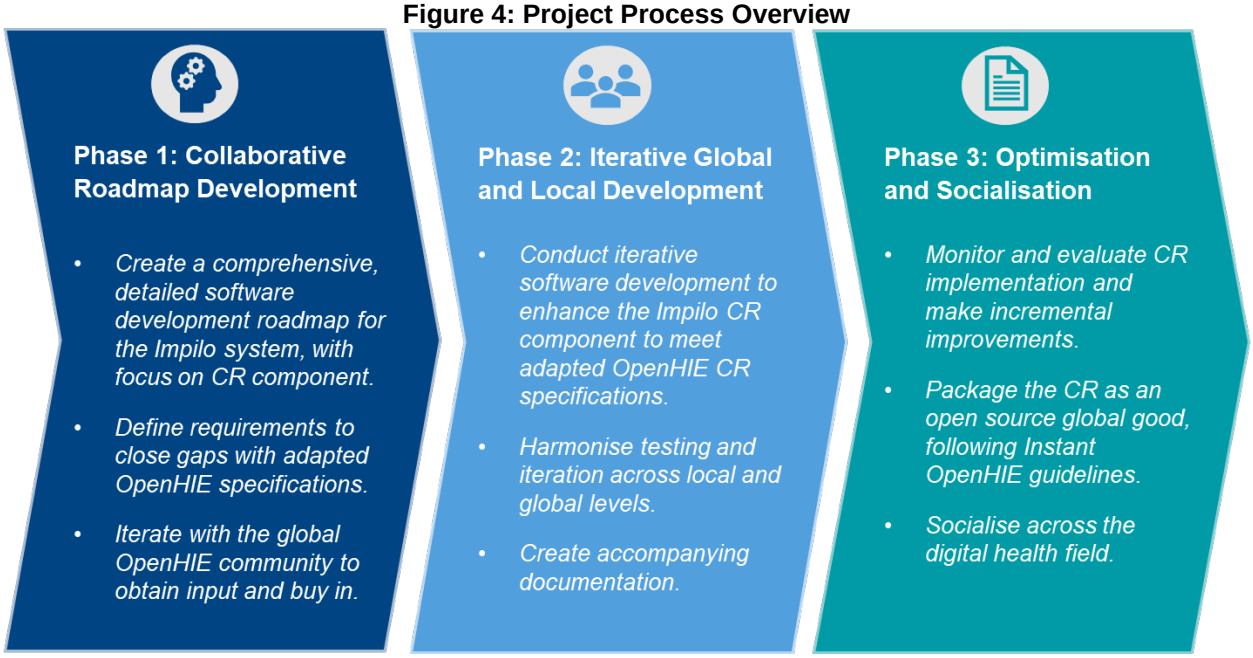
- Implementation as a central or local CR solution for other public sector health systems or facilities.
- Implementation as a central or local CR solution for a private-sector provider network (not necessarily linked with the public health system).
- Replacement of other proprietary or open-source FHIR compliant CRs, notably in contexts where offline-first technologies and processes are required.

- Rapid deployment and setup of a CR in a sandbox environment for testing with other technologies targeting OpenHIE compliance.

Objectives and Activities

The MoHCC and Vital Wave will collaboratively work together over the three phases shown in Figure 4 to achieve the project goals.

Figure 4: Project Process Overview



Each phase below provides detail on objectives and associated activities that will lead to the project outputs and goals.

Phase 1: Collaborative Development of Technical Specifications and Roadmap

Objective 1.1: Create a comprehensive, detailed software development roadmap for the Impilo CR, aligned with the Impilo EHR roadmap.

- *Activity 1.1.1: Expand the existing Impilo EHR software development roadmap to include a dedicated roadmap for the Impilo CR component and identify and document all necessary developments in the roadmap to extract the CR component and enable it to function as a standalone system that formally interacts with the Impilo EHR via its API.*
- *Activity 1.1.2: Facilitate a technical training for the Impilo development team on data standards including PIXm, PDQm, and relevant FHIR resources and identify and document all necessary developments required to support proposed data standards and profiles via the Impilo CR API.*
- *Activity 1.1.3: Validate the technical specifications against OpenHIE CR workflow specifications and document any necessary changes that will be required to the Impilo CR API.*
- *Activity 1.1.4: Identify and document all necessary developments required to build a light-weight user interface for managing client records including record matching, linking, merging, and splitting.*

- *Activity 1.1.5: Identify and document enhancements to allow configuration and deployment in other settings, including pluggable client-matching algorithms, identifier formats, and an interface for web-UI translation.*

Objective 1.2: Align technical specifications and roadmap with OpenHIE standards and guidelines.

- *Activity 1.2.1: Assess and update the existing continuous integration and deployment process and deployment artefacts (which already produces tagged releases, Dockerfiles, and an easy-to-use Docker Compose script) to fully align with Instant OpenHIE contribution policies, as needed.*
- *Activity 1.2.2: Socialise the roadmap with the global OpenHIE community via the CR and DevOps sub-communities to solicit input and validation on roadmap and documented technical specifications.*
- *Activity 1.2.3: Identify members of the OpenHIE community who are interested and able to test iterative deployments of the Impilo CR and provide feedback.*

Phase 2: Iterative Global and Local Development

Objective 2.1: Iterative development of the standalone Impilo CR solution at the local and central level.

- *Activity 2.1.1: Execute iterative development and release of Impilo CR versions. Roadmap and target features for releases will be defined during Phase 1 and will follow a release progression similar to the following illustrative example. Note that each release may be comprised of several iterative development sprints.*
    - *v1: Impilo CR deployed in separate Docker containers alongside Impilo EHR release*
    - *v2: Full support for PIXm, PDQm, and relevant FHIR resources in Impilo CR API*
    - *v3: Compliance with OpenHIE CR workflows validated*
    - *v4: Light-weight UI for Impilo CR system administration / data management*
    - *v5: Enhancements to improve configurability for global goods package*
- *Activity 2.1.2 (concurrent with 2.1.1): Execute iterative testing of each release in local instances in select pilot facilities and in central instance.*
- *Activity 2.1.3: Scale up deployment of tested and accepted releases to all health facilities currently using the Impilo EHR in Zimbabwe.*

Objective 2.2: Harmonise iterative development of the Impilo CR solution at the global level.

- *Activity 2.2.1 (concurrent with 2.1.1): Publish iterative releases in public repositories, alongside Docker files, configuration scripts, and test data for testing by third parties.*
- *Activity 2.2.2 (concurrent with 2.1.1): Present iterative releases to OpenHIE sub-communities and engage OpenHIE community members to test and provide feedback.*
- *Activity 2.2.3: Seek OpenHIE endorsement and/or IHE certification (e.g., through a connectathon event).*

Phase 3: Optimisation and Socialisation

Objective 3.1: Measure and evaluate the CR to make any incremental improvements.

- *Activity 3.1.1: Continuously monitor and evaluate quality and uniqueness of Impilo CR patient records in central instance and select local instances.*
- *Activity 3.1.2: Document and make iterative improvements (via enhancement and change requests to roadmap) to Impilo CR UI, client matching, and linking algorithms based on local and central feedback in Zimbabwe to ensure system administrator / data manager ability to maintain data integrity.*
- *Activity 3.1.3: Document and make iterative improvements to Impilo CR UI, configuration features, and API based on global feedback from OpenHIE community members and sandbox testing with other OpenHIE components to ensure OpenHIE CR workflows and Instant OpenHIE contribution policies.*

Objective 3.2: Package a complete version of the Impilo CR as an open source, publicly accessible global good.

- *Activity 3.2.1: Create packaged version of the CR in accordance to Instant OpenHIE guidelines, accompanied by user manuals, developer documentation, API documentation, and system administrator technical support documentation.*
- *Activity 3.2.2: Develop and execute against a socialisation plan, broadcasting the global goods across the digital development field through conferences, related media, relevant websites, and creation of explanatory collateral and case studies.*
- *Activity 3.2.3: Continue to integrate global feedback and contributions into the open source Impilo CR code base and package as a regular part of ongoing software development and operations.*

The activities above will help create a new global good that has been designed and developed, in context, to meet the needs of national health systems at scale with limited resources. It will produce a deployable open source software package and supporting documentation that can be deployed in other areas without reliable sources of power and connectivity, and further improved by new implementers through additional contributions to its code and sharing of lessons learned.

It is important to note that the activities defined above do not represent a new project that must be started from scratch and transitioned to another entity to maintain following the completion of this investment. Rather, this investment allows these activities to become a dedicated part of an existing software development roadmap for a digital health technology that is already owned, operated, and managed by the Zimbabwe MoHCC and has a dedicated development team and multiple years of funding from different funding sources. This additional investment will produce a “shelf-ready” global good built on this existing technology. Additionally, the value of this investment will extend beyond the duration of this project as the MoHCC continues to incorporate future contributions from the global community to further improve the global good for all.

Community Feedback

The consortium will engage with the broader digital health community for feedback and input throughout the project process as well as socialise its outputs. This will be done in an iterative and continuous manner and will result in the following:

- Input into use case identification and development of requirements to ensure the global product will be fit for purpose and interoperable with commonly used platforms in other low- and middle-income countries.

- Community-based contributions to ensure sustainable evolution of the product, so it can be implemented in other countries. This will help to start building a community that can use and contribute to this software product after the lifetime of this scope of work.
- Validation and buy-in from the broader community into the global product. This will be achieved through garnering their input and building awareness. This can also include aligning the project with community guidelines such as the Principles for Digital Development and Digital Investment Principles, resulting in connections and a reduction in the potential for duplicative investments.
- Ability to showcase concrete work and products that are being successfully designed and implemented by national governments in low-resource settings.

To achieve this, the consortium will engage with several communities including, but not limited to, those listed in Table E below.

Table E: Overview of Community Engagement

Community	Purpose of Engagement	Sample Activities
OpenHIE Community	Elicit input into the technical specifications for the Impilo system.	Series of discussions with members of the OpenHIE implementers networks and CR sub-community to provide updates and solicit input into approach and design. Participation and presentation of approach on OpenHIE CR sub-community calls (bi-monthly). Posts on the OpenHIE Discourse platform to share details on testable releases and to solicit feedback. Share documented case studies from pilot testing in Zimbabwe. Suggest a dedicated feedback session at the 2021 OpenHIE meeting.
Other EHR Communities (e.g., Bahmni, OpenMRS)	Ensure other EHR platforms can reference the subset of clients in the Impilo system.	Host a “connectathon” with other EHR applications to ensure the Impilo CR can be leveraged by others. Posts on the OpenMRS Talk (and its Bahmni subgroup) platform to share details on testable releases and to solicit feedback.
Global Digital Health Network	Validate the use cases and create exposure to an “African-made” product that can be used in other countries, especially those with connectivity constraints. Also promotes and socialises Instant OpenHIE and the concepts embodied in the OpenHIE architecture.	Organise and present on a webinar to showcase Impilo technologies and opportunities to test, use, and contribute to them. Present or hold a virtual working session at the Global Digital Health Forum. Create socialisation materials to share across the network (e.g., blog/article post).

Schedule

The following is a high-level work plan. All work will be completed at each organisation's respective location. In addition, due to the highly inter-related and collaborative nature of this work, both partners will be contributing to all activities listed below. The team name listed in the activity column indicates the primary organisation responsible for managing day-to-day progress on that activity, even though both partners are involved in execution of all activities.

Activity	Team Location	Month									
		1	2	3	4	5	6	7	8	9	10
Bi-weekly client management progress and update calls	Vital Wave, USA / MoHCC, ZI	x	x	x	x	x	x	x	x	x	x
1.1.1: Expand the Impilo EHR software development roadmap to include a dedicated roadmap for the Impilo CR component	Vital Wave, USA / MoHCC, ZI	x	x								
1.1.2: Facilitate technical training and document enhancements to the Impilo CR API to support data standards and profiles	Vital Wave, USA		x								
1.1.3: Validate technical specifications against OpenHIE CR workflow specifications	Vital Wave, USA		x								
1.1.4: Document developments for light-weight user interface	Vital Wave, USA		x								
1.1.5: Document enhancements to allow configuration and deployment in other settings	Vital Wave, USA		x								
1.2.1: Assess and update the process and deployment artifacts to fully align with Instant OpenHIE	MoHCC, ZI		x								
1.2.2: Socialise the roadmap with the global OpenHIE community	Vital Wave, USA			x							
1.2.3: Identify members of the OpenHIE community to test and provide feedback	Vital Wave, USA			x							
2.1.1: Execute iterative development and release of Impilo CR versions	MoHCC, ZI				x	x	x	x	x		
2.1.2: Execute iterative testing of each release in local instances	MoHCC, ZI				x	x	x	x	x		
2.1.3: Scale up deployment of tested and accepted releases	MoHCC, ZI							x	x	x	x

2.2.1: Publish iterative releases and deployment artefacts in public repositories	MoHCC, ZI				x	x	x	x	x		
2.2.2: Present iterative releases to OpenHIE sub-communities	Vital Wave, USA						x		x		
2.2.3: Seek OpenHIE endorsement and/or IHE certification	Vital Wave, USA									x	
3.1.1: Monitor and evaluate quality and uniqueness of patient records	MoHCC, ZI				x	x	x	x	x		
3.1.2: Document and make iterative improvements based on local and central feedback	MoHCC, ZI				x	x	x	x	x		
3.1.3: Document and make iterative improvements based on global feedback	Vital Wave, USA				x	x	x	x	x		
3.2.1: Create packaged version in accordance to Instant OpenHIE	Vital Wave, USA									x	
3.2.2: Develop and execute against a socialisation plan	Vital Wave, USA										x
3.2.3: Continue to integrate global feedback and contributions	MoHCC, ZI									x	x

Deliverables

Deliverable	**Month/Quarter Due**
Phase 1, Objective 1: Project kick-off meeting	M1
Phase 1, Objective 1.1, Activity 1.1.1: Standalone software development roadmap for the Impilo CR system published	M2
Phase 1, Objective 1.1, Activity 1.1.2: Facilitated technical training on data standards and profiles and updates made to roadmap	M2
Phase 1, Objective 1.2, Activity 1.2.2: Initial presentation of roadmap to OpenHIE community	M3
Phase 2, Objective 2,1, Activity 2.1.1: First version of standalone Impilo CR released for testing	M4

Phase 2, Objective 2.2, Activity 2.2.2: First presentation of published release made to OpenHIE sub-communities	M6
Phase 3, Objective 3.2, Activity 3.2.1: Final version (under this investment) packaged as a global good	M8
Phase 3, Objective 3.2, Activity 3.2.2: Global dissemination activities	M10

Global Good Maturity Model Assessment

Core Indicator	Sub-indicator	Global Good Maturity Model for digital health software tools. Version 1.3		
		Low	Medium	High
Global Utility	**Country Utilisation**	x		
	Country Strategy	x		
	Digital Health Interventions		x	
	Source Code Accessibility		x[1]	
	Funding and Revenue			x
Community Support	**Developer, Contributor and Implementor Community Engagement**			x
	Community Governance		x	
	Software Roadmap		x	
	User Documentation		x	
	Multi-Lingual Support		x	
Software Maturity	**Technical Documentation**		x	
	Software Productisation		x	
	Interoperability and Data Accessibility		x	
	Security		x	
	Scalability		x	

[1] The source code has just been approved by the MoHCC on 11 June 2020 for licensing under the open source GNU Affero General Public Licence v3 (AGPL 3) and migration to public GitHub repositories is planned prior to the start of this project. Assessment has been scored provisionally to account for this update.