Stepwise Toolkit for Planning & Budgeting Interoperability of Digital Health Solutions

DICE | Digital Health Centre of Excellence

The DICE consortium

Table of Contents

Introduction

Countries have increasingly understood the importance of undergoing digital transformation of health systems to achieve Universal Health Coverage, improved quality of care, and resilient and sustainable systems for health. At the Seventy-third World Health Assembly, countries endorsed the Global strategy on digital health 2020-2025[i]. To support countries on this journey of digital transformation, WHO has published a series of guidance documents. The WHO Guideline: Recommendations on digital interventions for health systems strengthening[ii] provides recommended digital health interventions based on critical evaluation of the evidence. As a companion to these guidelines, the Digital Implementation Investment Guide (DIIG): Integrating Digital Interventions into Health Programmes[iii] is a practical guide to support the implementation of these digital health interventions. This is further accompanied by the DIIG: quick deployment guide[iv], which is a shortened manual with fillable worksheets that can be used during planning workshops.

This, even shorter, stepwise toolkit on interoperability is intended to:

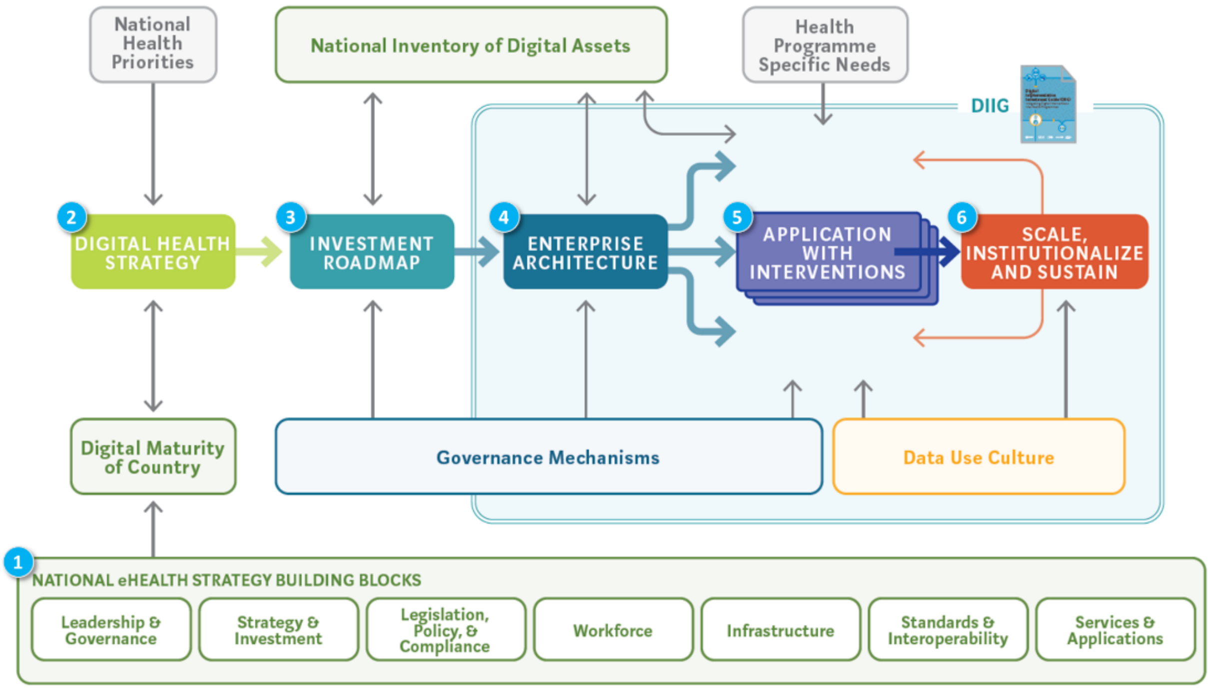
- Provide an overview of the key components critical to planning and implementing interoperable digital health interventions within the broader context of digital transformation in a country.
- Highlight critical budgeting considerations when planning for national, interoperable digital health implementations.
- Provide an overview of additional guidance available for a more detailed examination into the concepts presented in this document.

This toolkit is written for individuals who need to understand the importance of interoperability and its key components to be able to invest in national systems accordingly.

Essential components of digital health implementations

When implementing a digital health intervention, it is critical to understand that it will be deployed within a larger ecosystem of applications, or digital health solutions, that make up a dynamic digital health enterprise. Thus, it is critical to understand the current context in a country and establish the strategic foundation essential for successful use of digital technologies for health systems strengthening in a country. Figure 1 provides an overview of the essential processes for national digital health implementations.

Figure 1 Essential processes of national digital health implementations.



1. **National eHealth Strategy Building Blocks.** The foundational information and communications technology and enabling environment that are essential to any digital health implementation. The National eHealth Strategy Toolkit[v] provides a detailed description of this foundational layer and how to strengthen it through a national digital health strategy.

2. **Digital Health Strategy.** Depending on the digital maturity of the country and the national health priorities, a digital health strategy (or eHealth strategy) provides an overarching plan that describes high-level actions required to achieve national health system goals. There are a variety of tools available to assess the digital health maturity of a country, such as the Global Digital Health Index[vi], the Health Information Systems Interoperability Maturity Toolkit[vii], and the Navigator for Digital Health Capability Models[viii], which help identify the appropriate maturity models to use given assessment needs. Any national digital health implementation should fit within the strategic objectives outlined in a national digital health strategy.

3. **Investment Roadmap.** An investment roadmap based on the digital health strategy is required to inform resource allocation and a stepwise approach to strategically implement digital health technologies more broadly. This investment roadmap should be constructed under transparent governance mechanisms and be informed by the existing national inventory of digital assets. The DIIG[iii] provides an overview of key considerations for an investment roadmap in *Chapters 5: Plan the implementation*, *6: Link the digital health implementation to the enterprise architecture*, and *7: Develop a budget*. This can be further informed by the SDG Digital Investment Framework: A Whole-of-Government Approach to Investing in Digital Technologies to Achieve the SDGs[ix] and the Digital health platform handbook: building a digital information infrastructure (infostructure) for health[x].

4. **Enterprise Architecture.** The digital health enterprise architecture is a blueprint of how business processes, data, systems, and technologies work together to achieve a shared set of health system

goals. An enterprise architecture is critical to ensuring that the complex ecosystem of digital health solutions can work together harmoniously to achieve the same goals without wasting resources on redundant functionality and services. There are four categories of enterprise architectures along a continuum of digital maturity and investments that are necessary to increase maturity towards architecture exchange.

a. **SILOED**: Composed of stand-alone application(s) with inability to scale beyond a specific health use case.

b. **MUD (Monolithic Un-architected software Distributions)**: Haphazardly structured systems that are characterized by an evolving agglomeration of functions, originating without a predetermined scope or design pattern, which accumulate technical debt requiring higher costs for feature development, scaling, and maintenance over time.

c. **INTEGRATED**: This architecture design reflects two or more applications that are directly connected to one another for purposes of data exchange, without an intermediary. Often, this requires additional development for one or more of the applications to be able to exchange information with each other. This still results in technical debt due to the quadratic growth in costs, as each additional digital system implemented will require direct connection, or integration, to all the other applications that exist in the broader ecosystem.

d. **EXCHANGED**: Consists of multiple applications using interoperability standards to connect through a health information exchange, operating in a coordinated manner. With all applications leveraging the same interoperability standards, the benefits of economies of scale can be realized as each additional digital system will be able to exchange data with all the other applications in the broader ecosystem without additional changes to the actual application.

Additional resources that can be leveraged to inform the process of establishing an enterprise architecture include the TOGAF® Standard[xi].

5. **Application with Interventions.** The health programme-specific needs should inform the design of the digital health applications that deliver or execute the digital health intervention with the appropriate health content. The WHO Recommendations on digital interventions for health systems strengthening[ii] can help inform the appropriate digital health intervention, and the WHO SMART Guidelines[xii] can help inform the health content requirements. For example, the Digital adaptation kit for HIV: operational requirements for implementing WHO recommendations and standards within digital systems[xiii] provides software-neutral, operational, and structured documentation based on WHO clinical, health system and data use recommendations to systematically and transparently inform the design of digital systems intended to be used at the point of care for HIV. These applications should be reflected in the enterprise architecture. It is also critical to ensure that there are change management practices in place to establish a data use culture to benefit from the data that will now become available through these applications[xiv].

6. **Scale, Institutionalize, and Sustain.** After successful implementation of a specific application, it should be evaluated in order to scale-up usage of the application and institutionalize and sustain its usage as part of the health system. WHO has published guidance on Monitoring and evaluating

digital health interventions: a practical guide to conducting research and assessment[xv] as well as the MAPS toolkit: mHealth assessment and planning for scale[xvi] to help guide this step.

Overview of interoperability

Interoperability is the ability of different applications to access, exchange, integrate and use data in a coordinated manner to provide timely and seamless portability of information. Interoperability is commonly split into four broad areas: syntactic interoperability, semantic interoperability, organizational interoperability, and legal interoperability.[xvii] A fully interoperable healthcare system encompasses all four areas of interoperability in a multi-faceted approach.

Standards provide a common language and set of expectations to help achieve interoperability between systems.[xviii] There are several standards that are used and adopted in healthcare. Examples provided are open standards, meaning they are publicly available and maintained through a collaborative process, and have evidence of global adoption. Rules or data models that are defined for one specific software application is *not* considered a "standard".

Syntactic Interoperability: Refers to the way technology enables two or more systems to communicate or share structured data, thus allowing different types of software to work together. Syntactic standards are used for specifying data formats to be shared. Examples include:

- **Health Level 7 (HL7®) Fast Healthcare Interoperability Resources (FHIR®):** An open standard developed by HL7® for exchanging healthcare information electronically. This standard provides standardized resources to form a basis for communicating the structure and meaning of clinical data.[xix]
- **Integrating the Healthcare Enterprise (IHE) Profiles:** Provide a standard framework for sharing information needed by care providers and patients, across clinical workflows and information infrastructure. IHE Profiles organize and coordinate implementation of various communication standards.[xx]
- **Digital Imaging and Communications in Medicine (DICOM):** An international communication protocol and file format for exchanging medical images across systems and facilitates the development and expansion of picture archiving and communication systems.[xxi]
- **GS1 Standards:** Provide common language to identify, capture and share supply chain data and exchange metadata about medicinal products, devices, commodities, and vaccines.[xxii]
- **TOGAF® Standard:** An enterprise architecture framework developed by The Open Group that helps standardize and de-risk the enterprise architecture development process.[xi]

Semantic Interoperability: Refers to the way in which two or more systems connect and share data elements in a meaningful way that each system understands (i.e., data representation standards). Semantic standards include terminology and classification standards, such as:

- **International Classification of Diseases and Related Health Problems 11th revision (ICD-11):** A medical classification list developed by WHO; contains codes for diseases, signs and symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or diseases.[xxiii]
- **Logical Observation Identifiers Names and Codes (LOINC®):** A universal code system created by Regenstrief Institute; used for laboratory and clinical tests, measurements, and observations.[xxiv]
- **Systematized Nomenclature of Medicine-Global Patient Set (SNOMED-GPS):** is the openly available subset of SNOMED Clinical Terms, which is a clinical health terminology product from

SNOMED International. It enables the consistent, processable representation of clinical content in electronic health records.[xxv]

Organizational Interoperability: Refers to the way different organizations collaborate and align their business processes, responsibilities, and expectations to achieve commonly agreed and mutually beneficial goals. Initiatives that may facilitate organizational interoperability include defining standard operating procedures, governance, business process coordination across organizations, and more. Examples include:

- **Digital adaptation kit for HIV:** Outline key workflows and user personas that highlight areas for integration across the different health domains.[xxvi]
- **WHO Consolidated guidelines on person-centred HIV strategic information: strengthening routine data for impact:** Provides guidance on the collection and use of person-centred data across the HIV cascade.[xxvii]
- **WHO TB Knowledge Sharing Platform:** Compiles all WHO consolidated guidelines on TB, operational handbooks, and training catalogues on TB in once place.[xxviii]

Legal Interoperability: Refers to the legal frameworks that facilitate smooth data usage and exchange between different organizations working across different jurisdictions (e.g., regions, countries). Legal frameworks need to consider individuals' rights to privacy and access to their healthcare data; mechanisms for ensuring data and privacy protection; and secure data processing and storage.

- One example is the **European Union's (EU) Article 14 of Directive 2011/24/EU[xxix]**, which established the eHealth Network to provide a platform for EU Member States to negotiate and establish interoperability across EU countries.

Despite the vast number of standards that exist today, there may be numerous challenges that can confound the ability to achieve interoperability. Some of these challenges relate to standards and include incompleteness of specifications, lack of clarity, poor maintenance and lack of version control and varying quality for each standard. Efforts to harmonize and consolidate the wide range of existing standards are underway.[xxx]

Role of interoperability within a digital health enterprise

Interoperability is not only critical for driving cost efficiencies and reducing fragmentation across different digital systems, but it is also necessary to support the continuity of care as health service users engage at different points of care in the health system.

If systems are not interoperable, data cannot be easily sent from one system to another when an individual moves from one health facility to another. When data can be shared, meaningful interpretation would be difficult as the systems would not be able to interpret or decode the data shared. This results in an incomplete understanding of an individual's or population's health needs, which can lead to poorer health outcomes and higher costs required for data extraction and analysis.

Below are some case studies of countries that are working towards more interoperable systems and being able to exchange data accurately and effectively – regardless of health programme area.

Case Study 1 – India Ayushman Bharat Digital Mission (ABDM)

Data involved in health service delivery and public health is complex given the various file formats generated (e.g., lab reports, imaging, prescriptions, health records) and must be treated in a confidential manner given the sensitivity of that information. However, this is further complicated by the fact that the stakeholders involved have very different needs for that data, and subsequently different requirements for the digital system collecting, processing, and managing that information.

To address this challenge, the Government of India launched the Ayushman Bharat Digital Mission (ABDM) to establish **an open, interoperable digital health ecosystem that determines the health data standards and core service modules for the various digital health applications to connect to, enabling seamless data sharing across those various digital health applications** (**Error! Reference source not found.**)[xxxi]. ABDM works by exchanging data with relevant applications and systems through the use of unique identifiers and a Health Information Exchange and Consent Manager Gateway to allow for secure sharing of data across digital health solutions, or user applications. ABDM also uses the interoperability standard HL7® FHIR® to set interoperability requirements and specifications in a FHIR Implementation Guide[xxxii], as specified in India's National Digital Health Blueprint (NDHB)[xxxiii]. All solutions in conformance with the NDHB are required to support data records that conform to the standard formats provided in the NDHB.

The work that led to the NDHB was done by a committee established by the Ministry of Health and Family Welfare, consisting of individuals from the Ministry of Health and Family Welfare, local state governments, Ministry of Electronics and Information Technology, and the National Institution for Transforming India (NITI Aayog). There were four sub-groups in the committee: Scope, principles & services; Building blocks & Unique Health Identifiers (UHID); Standards & regulations; and Institutional framework.

Based on the overall vision of India's National Health Policy (2017) and the National Health Stack proposed by NITI Aayog, this committee conducted a landscaping analysis and survey of leading practices and drafted a report. This report was then made available for public comment in July 2019 for feedback from industry professionals and organizations, and a stakeholder consultation was conducted in August 2019. Feedback from over 70 organizations and individuals was incorporated into the document, and the NDHB is considered to be a living document.

India views the infrastructure supporting ABDM as a public good and recognizes that it needs to be financed accordingly. To appropriately finance this work, the government of India intends to partner with private sector institutions (e.g., MedTech companies) to ensure ABDM can add value to public and private sector activities using a not-for-profit transactions-based "toll pricing model"[xxxiii].

With the implementation of ABDM, over 40 million health records of Indian citizens have been digitized and linked to individuals[xxxiv]; and over 52 digital health applications are now able to exchange data with each other[xxxv]. The vision of ABDM is "To create a National Digital Health Eco-system that supports Universal Health Coverage in an efficient, accessible, inclusive, affordable, timely and safe manner, through provision of a wide range of data, information and infrastructure services, duly leveraging open, interoperable, standards-based digital systems, and ensuring the security, confidentiality and privacy of health-related personal information."[xxxi]

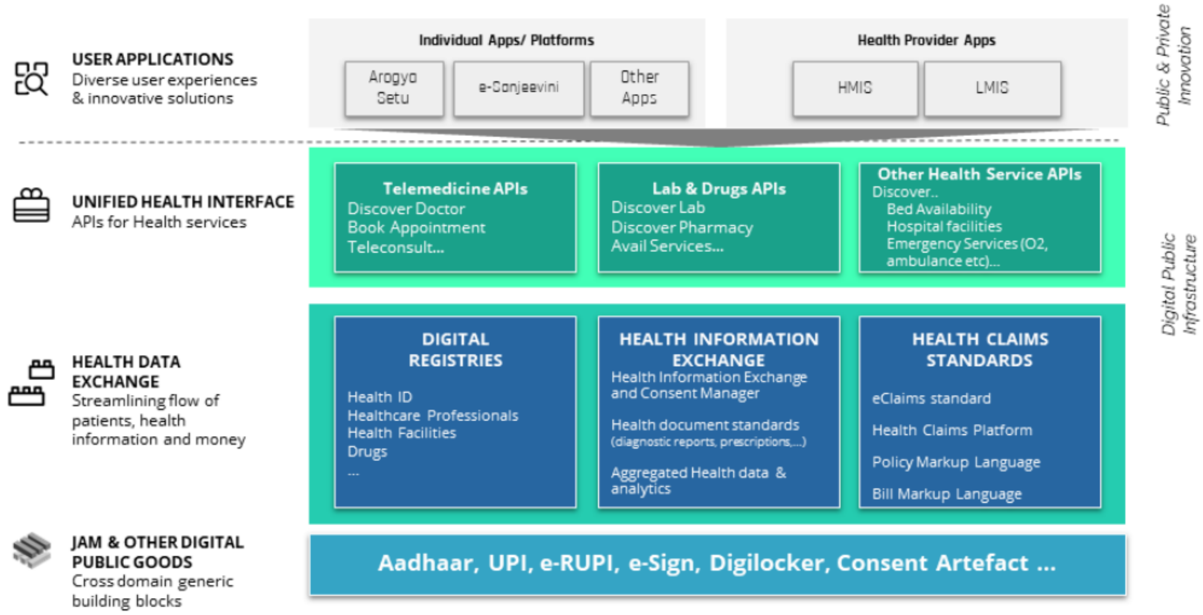


Figure 2 ABDM Stack[xxxi]

Case study 2 – Indonesia Blueprint for Digital Health Transformation Strategy 2024

Central and local governments in Indonesia have collectively developed over 400 applications related to health, and an innumerable number of applications have been developed by private vendors and health institutions. This resulted in fragmented health data sources that are inaccessible by health workers for continuity of care; incomplete health data available for evidence-based policy making; and inefficiencies caused by an abundance of overlapping administrative applications.

In 2020, the Minister of Health of the Republic of Indonesia (Permenkes RI) established regulation No. 21 that required health governance reform, including the need for digital health transformation across all health information systems. The Blueprint for Digital Health Transformation Strategy 2024 lays out an **architecture that leverages the interoperability standard, HL7 FHIR to exchange data across multiple systems** (**Error! Reference source not found.**), under the Indonesia Health Services Platform, called SatuSehat[xxxvi].

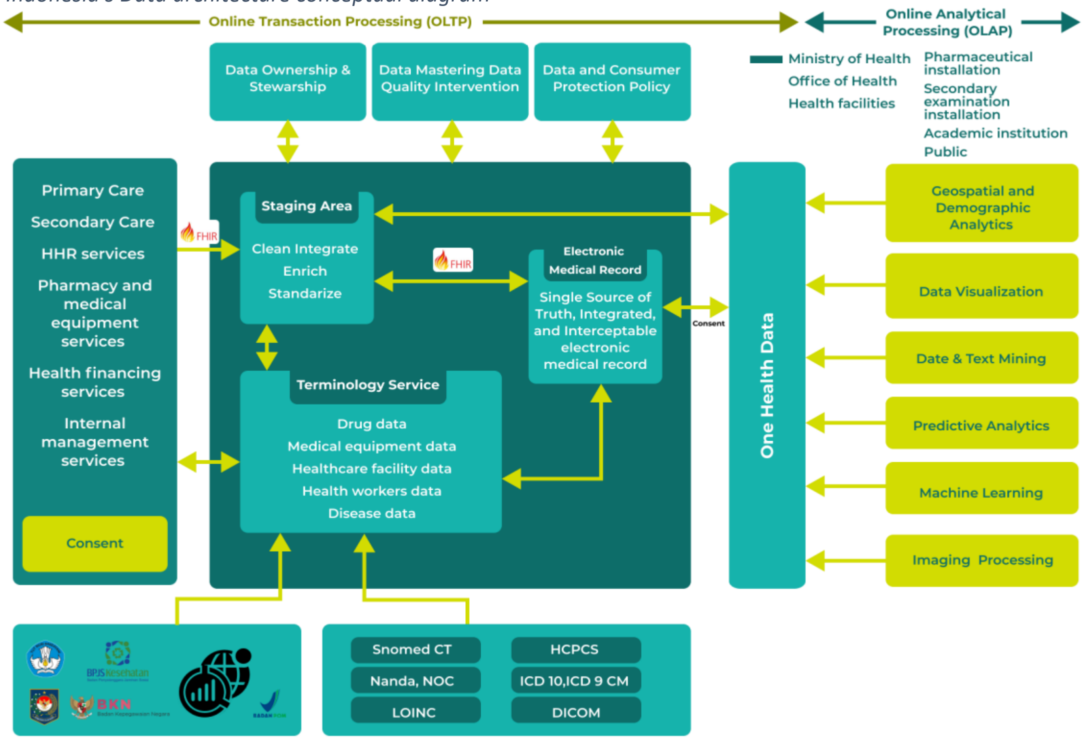
The SatuSehat platform reduces the need for patients to fill out registration forms when transferred to another health facility and enables continuity of care as health service providers at the referral facility are able to access the patient's medical records established prior to the referral[xxxvii].

The work on developing the blueprint for Digital Health Transformation Strategy 2024 was led by a special Digital Transformation Office (DTO) within the Ministry of Health in collaboration with health programme "tribes" that include: primary care, secondary care, pharmacy resilience, health resilience, health financing, health human resources, international management, and biotechnology. This work was supported by the United Nations Development Programme (UNDP), the Government of Japan, and the United States Agency for International Development (USAID).

In 2022, Indonesia has been able to establish data exchange across 133 health facilities (90 community health facilities, Puskesmas; and 43 hospitals) through information entered into the Puskesmas Management Information System (SIMPUS) and Hospital Management Information System (SIMRS).

Indonesia is targeting the integration of all their health facilities with the SatuSehat platform by end of 2023[xxxviii]. The work required to realize this vision is still ongoing.

Figure 3 Indonesia's Data architecture conceptual diagram[xxxvi]



Case study 3 – Rwanda Health Information Exchange Systems (RHIES)[xxxix]

In 2019, Rwanda had already implemented a large number of nationally used digital systems for health, but there was a need for digitized HIV case-based surveillance data. However, this data was being collected using a mix of paper-based processes and digital health solutions, such as LabWare, OpenMRS, NIDA, and DHIS2. To be able to use these data for reporting purposes, all of this then had to be manually entered by the data manager into DHIS2. **These systems had no way to share data across systems for automated reporting, leading to a heavy workload of duplicative data entry into a digital system.**

These systems were harmonized through the creation of an interoperability layer (using OpenHIM), mediators to integrate the various systems, a client registry, and a facility registry, in alignment with the Open Health Information Exchange (OpenHIE) framework. OpenHIE supports interoperability by creating a reusable open enterprise architecture blueprint that countries can use to establish an interoperable enterprise. The architectural framework introduces a service-oriented approach which leverages health information standards, enables flexible implementation by country partners and supports interchangeability of individual components.[xl]

This resulted in the ability for patient information to be automatically pushed into OpenMRS from LabWare, NIDA, the client registry and the facility registry, which then enabled case-based surveillance data to be automatically pushed to DHIS2 and linked to individual patient histories. This resulted in a reduced workload as duplicative, manual data entry processes were replaced with automated data entry processes. This work was a collaboration between SAVICS, Rwanda Biomedical Centre, Rwanda Ministry of Health, OpenMRS, DHIS2, LabWare, Rwanda Information Society Authority, OpenHIM, and Docker.

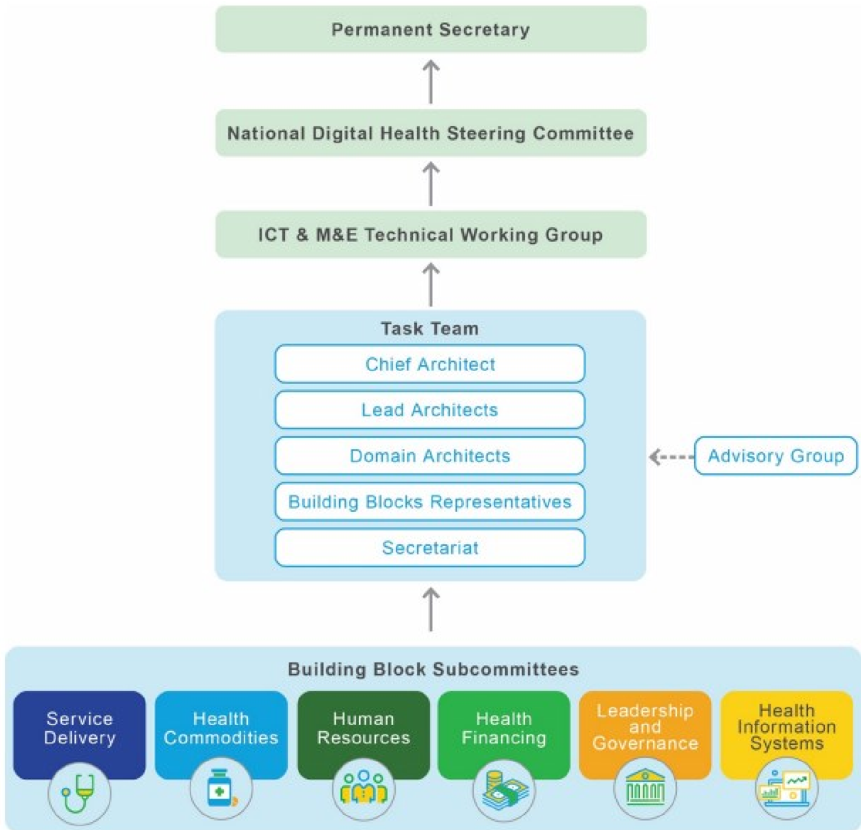
Case Study 4 – Tanzania Health Enterprise Architecture & Data Use Partnership

The Tanzania Data Use Partnership (DUP) is a government-led initiative to improve the health system through better use of health information with new digital health systems, establishment of governance mechanisms, and policy reform[xli]. Key outputs of DUP include The United Republic of Tanzania Ministry of Health, Community Development, Gender, Elderly and Children (MOHCDGEC) Digital Health Strategy 2019 - 2024, Digital Health Investment Roadmap 2017 - 2023, and the Tanzania Health Enterprise Architecture (TzHEA) September 2020 version 1[xlii].

The development of the Tanzania Digital Health Investment Road Map was led by MOHCDGEC and the President's Office of Regional and Local Government (PORALG), with support from the Bill & Melinda Gates Foundation and in collaboration with numerous other governmental (e.g., eGovernance Agency, National Health Insurance Fund) and non-governmental agencies (e.g., PATH, health management teams, health facilities, training institutions)[xliii], set forth 17 investment priorities for the government of Tanzania across foundational, high impact, and quick win activities. $1.21 million was dedicated to "put in place an enterprise architecture, including governance, guidelines, and standards for interoperability".

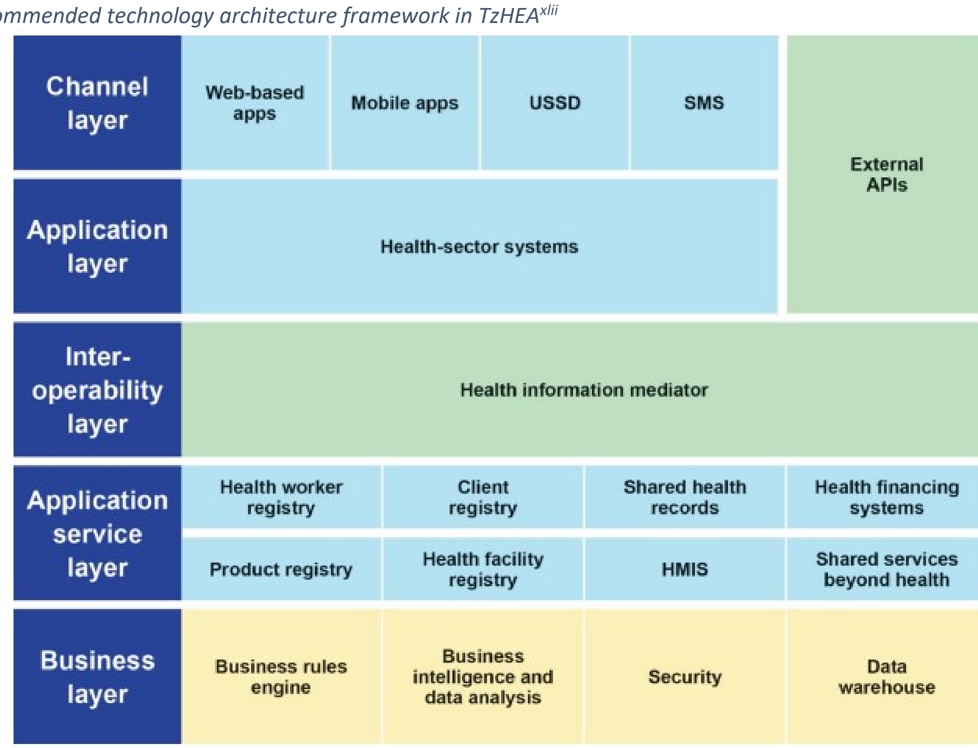
As part of this, TzHEA was published in 2020 to provide standards for information exchange; and reduce duplicative efforts, inefficient use of resources, and overall fragmentation. The MOHCDGEC had a dedicated task team consisting of representatives from PORALG and other relevant governmental agencies (e.g., regulatory bodies), and other stakeholders (e.g., district information communication technology officers; public and private hospital management teams; training institutions; professional councils; health programs verticals; and development and implementing partners[xliv]). **The task team conducted extensive consultations with stakeholders at all levels of the health system to establish TzHEA, which remains a versioned document.** Figure 4 provides an outline of the governance structure used to develop TzHEA, which resulted in the enterprise architecture framework seen in Figure 5. TzHEA also planned for institutionalization of governance structures needed for implementation, which included terms of reference for the Tanzania Health Enterprise Architecture Subcommittee.

Figure 4 Governance structure for development of TzHEA[xlii]



ICT: Information and communication technology; M&E: Monitoring and evaluation; TWG: Technical Working Group.

Figure 5 Recommended technology architecture framework in TzHEA[xlii]



API: Application programming interface; HMIS: Health management information system; SMS: Short message service; USSD: Unstructured supplementary data service.

Impact of *not* investing in interoperable systems

Although the idea of planning and implementing standards-based, interoperable systems may seem time consuming and costly, it is critical to understand that investments in digital systems that lack interoperability have very real consequences that can negatively impact health outcomes. An example of this was clearly seen during the response to the Ebola epidemic from 2013 – 2016. USAID's report on "Fighting Ebola with Information: Learning from the Use of Data, Information, and Digital Technologies in the West Africa Ebola Outbreak Response", highlighted a number of instances where a lack of interoperability led to missed opportunities and a delayed response[xlv]. In one case, a lack of interoperability between a system tracking health worker payments, and a separate system tracking their hours, blocked payments from going to nurses and burial experts, working with a higher risk of contracting the virus, ultimately leading many of them to refuse to continue working. Another example highlighted how non-aligned standards meant systems could not effectively communicate and led to health facilities being inadequately equipped with supplies, including personal protective equipment. Additionally, some systems that were open source and standards-based, at that point had only been deployed as standalone systems, resulting in the same issues of siloed data. Critical systems, including those for contact tracing, case management, surveillance, and care, were all negatively affected by issues that result from standalone systems. Before data sets could be used together in a meaningful way, work was required to map and align data models across systems. The report cited how inconsistent or incorrect use of unique identifiers also made it much more difficult--and not always possible--to fully combine data sets (e.g., with multiple patients sometimes being given the same identifier, so the identifier no longer was unique) and affecting systems used for contact tracing, lab, care, and burial data. While the examples in the report came from an emergency setting, related challenges exist in disease prevention, treatment, and care settings, which are made worse over time without investment in interoperable systems.

Planning and implementing an interoperable system

The steps for planning and implementing an interoperable digital health system require high-level planning at a national level to ensure coordination and consistency (i.e., organizational and legal interoperability), while also implementing the semantic and syntactic standards into the digital solutions that are designed to address health systems' challenges and meet health program needs. These steps are summarized below:

1. **Assess the current state and enabling environment and identify health system challenges and needs** by conducting an inventory of existing or previously used software to understand opportunities for reuse and interoperability requirements.
2. **Define the future state and strategic plan** by formulating a digital health strategy, investment roadmap, and enterprise architecture blueprint inclusive of overarching interoperability needs for achieving desired outcomes. Plan and identify appropriate digital health interventions to improve health system processes and address programmatic needs. This should include a plan for phasing out and/or updating existing systems to meet interoperability requirements.

3. **Address existing gaps in the enabling environment** such as governance, legislation, policy, and regulatory frameworks. Key components that would promote adoption of standards include data protection, privacy and security principles; requirements and expectations for health

information exchange across the health sector, including identified interoperability standards; and policies on the use of unique identifiers for patients, health care providers and facilities[xlvi].

4. **Plan specific implementations of applications, tools, and services as outlined in the enterprise architecture blueprint** by developing implementation specific budgets, establishing workplans, and by determining health content requirements appropriate for the implementation. Ensure the use of content is aligned with identified standards for the future state.

5. **Implement, maintain, and scale** the interoperable system. This should include development, set up, testing, deployment, and roll-out of the system. This should specifically include the steps needed to conduct conformance testing for interoperability. Identify risks and appropriate mitigation measures. Create feedback loops that feed into maintenance and planned updates to the system.

6. **Monitor and evaluate the implementation** to ensure the interoperable system is functioning as intended and has the desired effect. Data-driven adaptive change management should be fostered along with a culture of data use.

Engagement of key stakeholders

Engaging key stakeholders early in the implementation process for the purposes of governance, management, and day-to-day operations is critical for success. This is often done by establishing working groups for each workstream. The scale of the working groups and workstreams are dependent on the resources available. Table 1 provides an example RACI (Responsible, Accountable, Consulted, and Informed) matrix that outlines the key stakeholders and their roles through all the phases of planning, implementation, scale-up, and sustainment.

Decision makers: Person or group of individuals who are responsible for making strategically important decisions, including the overall direction and governance of the digital implementation.

1. **Product owner:** It is often recommended that there is a single "**product owner**" who is the arbiter and makes the final decision on the direction of the digital health solution.

2. **Government sponsor(s):** A senior government official who provides oversight of an implementation and ongoing operations at the national level. This can be from a single Ministry (e.g., Ministry of Health), or more often a collaboration across government agencies where there are sponsors from each entity, including the Ministry of Health, Ministry of Information and Communications Technology, and authorities for civil registration and vital statistics.

3. **Funders and technical agencies:** Provide the necessary monetary and human resources to support digital health implementation. The funder offers project and innovation funding, as well as strategic and technical expertise. This can include Ministry of Finance, donor organizations, and multi-lateral organizations.

Management & operations: Individuals who are responsible for executing and operating the digital solution(s) on a day-to-day basis, based on the strategic direction of decision-makers.

4. **Project manager:** Manager who oversees the day-to-day tasks required for implementation, communicates with the decision makers and ensures that the system is deployed on time and on budget.

5. **Enterprise architect:** Ensures that the planned digital health implementation can operate within the current IT infrastructure, recommends new infrastructure investments and ensures that the digital health solution can be deployed sustainably.
6. **Health programme lead(s):** Person or group of individuals who are responsible for guiding and determining the health content required to be included in the digital health solution(s) (e.g., HIV, TB, and Malaria programme managers; monitoring & evaluation programme lead).
7. **Analysts:** Business analysts, policy analysts, systems analysts, and monitoring & evaluation analysts who are responsible for conducting landscape assessments and requirements gathering.
8. **Software developers:** Develop, implement and maintain the software
9. **Technical support staff:** Provides technical support to users and troubleshoots software and hardware issues.
10. **End-users:** Individuals, such as a health workers or health service users, that interact directly with the digital health solution.

Table 1 Sample RACI Matrix

Implementation Phase	Planning	Development & Setup	Testing, Integration & Interoperability	Deployment	Scale-up	Sustained operations & maintenance
Decision makers	A	A	A	A	A	A
Project manager	R	C	C	C	C	R
Enterprise architect	R	C	R	C	C	R
Health programme lead	R	C	C	C	C	R
Analysts	C	R	I	I	I	I
Software developers	C	R	R	C	R	C
Technical support staff	C	I	I	R	I	R
End-users	C	C	C	C	C	C

R = Responsible, A = Accountable, C = Consulted, I = Informed

Additional details can be found in Chapter 2.1 of the DIIG[iii].

Checklist for an interoperable system

Using the National eHealth Building Blocks[v], the following components are required for achieving interoperability across systems:

1. **Leadership & governance** are required for coordination at the national and sub-national levels:
   - ☑ **Enterprise architecture blueprint**: Is there a reference architecture designed to guide the development of services and applications, supporting key workflows?
   - ☑ **Stakeholder engagement**: Are there plans to engage key stakeholders and keep them engaged throughout the process?
   - ☑ **Programme management & operations**: Is there an overarching management, operations and support plan that will provide oversight and coordination to ensure reliability, availability, and sustainability of interoperable systems?
   - ☑ **Monitoring & evaluation**: Is there a plan for adaptive management, course correction based on the results, and a plan to continuously monitor and assess outcomes of use?

- ☑ **Multi-sector engagement**: Are there mechanisms to engage sectors outside of the health sector (e.g., civil registration and vital statistics)?

2. Strategy & investment are critical for developing and sustaining operations:
   - ☑ **Digital health strategy**: Is there an overarching digital transformation strategy in place to guide the development of the interoperable system in response to health systems goals and challenges?
   - ☑ **Costed implementation plan**: Is there a contextually relevant and financially justifiable plan in place for prioritization and allocation of investment in digital health?
   - ☑ **Funding**: Is a funding mechanism available for the priorities outlined in the costed implementation plan?
3. Services & applications are needed to address the needs of health service users, health care providers, managers, and administrators. This includes key technical solutions as outlined and recommended in the OpenHIE architecture[xlvii]:
   - ☑ **Registry services** that are used to provide mutually exclusive and collectively exhaustive terminologies that are used throughout the digital health enterprise. Key registries required for interoperable systems include: (1) terminology services; (2) client or patient registry; (3) facility registry; (4) health worker registry; and (5) product catalogue.
   - ☑ **Interoperability services** that orchestrate the exchange of data across the various components in an enterprise architecture. This includes authentication services for secure transmission and delivery of data, interlinking services that link health workers to facilities, and entity mapping for linking or reconciling duplicate records.
   - ☑ **Business domain services** are tools used to address cross-cutting health systems-level needs, with the potential to combine health data exchange across multiple point of service tools. Examples include, health management information systems, logistics management information systems, and finance and insurance systems.
   - ☑ **Point of service tools** that are used by health service users, health care providers, managers, and administrators for clinical and public health purposes. Examples include, community health information systems, electronic medical records, lab systems, and pharmacy systems.
   - ☑ **Health content requirements** are the health content that reflect the data, public health, and clinical requirements that will live on the various point of service tools. The health content requirements should be informed using evidence-based guidelines and guidance documents, and the functional requirements should be informed by using human-centered design requirements gathering methodologies. One example of this is the WHO SMART Guidelines publications, which can be used to provide standardized health content requirements ready for adoption into digital point of service tools[xii].
4. Standards & interoperability are required to provide a specification for consistent and accurate collection and exchange of health information, with limited room for interpretation. Without standards, technology implementers will implement their own "standard" that varies across systems. It is recommended to adopt international, open standards to negate licensing costs that come with some standards and to build the foundation of potentially connecting to other digital health systems across borders, as people migrate and travel to other countries.

- ☑ **Syntactic standards**: Are there data structure standards that govern how datasets are stored and presented? Please see the Overview of interoperability section above.
- ☑ **Semantic standards**: Are there common terminology and classification standards that govern how data is defined and coded? Please see the Overview of interoperability section above.
- ☑ **Security standards**: Are there cybersecurity standards (e.g., standards for encryption, authentication, and authorization) to ensure data protection and security of data?
- ☑ **Customization & update of legacy systems**: Is there a plan to migrate or sunset an existing system so that they meet interoperability standards as outlined in the enterprise architecture blueprint?
- ☑ **Unique identifiers**: Do unique identifiers already exist for individuals, facilities, and health care providers to allow for linking records? For patients, this can enable person-centered care, when also coupled with privacy and security considerations.

5. Infrastructure is required as the foundation for information exchange across digital systems.
    - ☑ **Testing infrastructure**: Are there systems and mechanisms set up for testing services and applications for interoperability and conformance to standards to ensure they can exchange data with other systems?
    - ☑ **Connectivity**: Although some point of service applications can be operated offline, connectivity will be needed for interoperability. Is there network infrastructure to allow for data exchange across systems? If not, is there a plan to address lack of connectivity?
    - ☑ **Computing infrastructure**: Is there physical computing infrastructure (e.g., servers or cloud services) to support exchange of health information?
6. Legislation, policy & compliance is a foundational part to support the governance and operations of an interoperable system.
    - ☑ **Legislation**: Are there regulatory frameworks that govern how health information is collected, stored, accessed, and shared?
    - ☑ **Privacy protection policies**: Are there policies in place that support data protection and use of personal data? This can include policies governing data access, data management, privacy, and security.
    - ☑ **Interoperability policies**: Are there policies that establish which interoperability standards are to be used and mechanisms for compliance with those standards?
    - ☑ **Clinical safety**: Are there legal mechanisms to ensure oversight for clinical safety and management of risks?
    - ☑ **Policy oversight**: Are there policies to oversee how the system adheres to health and other broader policies?
    - ☑ **Accreditation & regulation**: Are there criteria for products and services established that include the requirement for interoperability with other systems? Is there an accreditation mechanism to quality assure and regulate the solutions available in the country?
7. Workforce is critical to ensuring there is a team of people available to support the entire ecosystem and implementation of the interoperability blueprint.

☑ **Local technical capacity**: Are there staff with the necessary skills, experience and knowledge required to design, build, operate, support, manage, and maintain an interoperable system?

How to budget for interoperable systems

When investing in a digital health solution, there are two distinct approaches: (1) short-term investments, which focus on rapid development and deployment to address an immediate need; or (2) long-term investments, which require more time and resources dedicated to planning, designing, and deploying solutions based on a future enterprise architecture. The first approach tends to have lower up-front costs with impact more quickly realized but will end up with higher maintenance and operational costs in the long term as solutions are often not built with scalability in mind. The second approach requires much higher upfront costs but leads to a more sustainable solution with reduced maintenance and operational costs in the long term due to the benefits of economies of scale and scope.

Understanding the **total cost of ownership**, or the resources required to support a digital health intervention throughout its entire life cycle, will help make more informed purchasing decisions and to ensure a system can be sustained after its release. When considering the total cost of ownership and developing a budget, it is important to consider costs associated with different phases of implementation. Total cost of ownership includes not just the initial investment but also the costs to scale and sustain the system after the implementation (e.g. for three to five years after deployment).

The different phases of implementation include planning, development & set-up, testing, integration & interoperability, deployment, scale-up, and sustained operations & maintenance. Management, staffing, and governance are required across all phases. The key cost drivers to account for in an investment roadmap for interoperable systems are outlined and listed by phase in Table 2. Note that this table is not a comprehensive list of costs, and additional guidance can be found in the DIIG, and Understanding Total Cost of Ownership for Digital Health, a budgetary reference document[xlviii].

Table 2 Key cost drivers for achieving interoperability

Cost Category & Cost Drivers	Description	Implication of not investing
Up-front Costs		
Planning		
Project planning • Scope of health interventions • Amount of travel and meetings required for requirements gathering • Number of participating stakeholder organizations required for buy-in • Organizational overhead of involved organizations	Costs associated with landscaping analysis of existing applications, high level scoping, resource planning, forming project team and working groups, establishing an architectural blueprint, and specifying requirements for integration, migration and reporting requirements with other systems (i.e. requirements gathering). This could also include costs associated with assessing the current state of the enabling environment, developing or updating policies, as necessary and aligning with national strategies (e.g., digital health, disease programmes).	Insufficient investment in planning leads to increased chances of risks, inefficient use of resources, delays in timeline and scope creep leading to additional costs in later stages, and potential project failure.
Development & Setup		
Software development and customization • Complexity of features and functionality required • Translation required	Costs associated with software development and adaptation of the core software to enable country needs. More complex features will require additional staff time dedicated to development. Customization may be necessary to allow for integration or interoperability with existing systems.	Insufficient investment in development and customization leads to software that does not meet the unique requirements of the country or the end-users, and potentially a system with a lot of bugs - subsequently leading to lower adoption rates, preventing scale.
Installation and configuration • File size of the software application • Sophistication of hardware • Speed of internet connectivity	Costs associated with installing, initial configuration of settings and user accounts, data clean up and conversion to migrate data and setup of custom schemes	Poor up-front set up can lead to incomplete installation or data leakage, leading to costly rework later.
Deployment		
Roll-out • Number of end users • Size of targeted geographic area • Quality of transportation infrastructure	Costs associated with transporting the needed hardware to sites, communications, initial training, and marketing costs.	Overlooked roll-out can lead to significant delays in adoption, poor first impressions to end-users and an overall lack of awareness on the purpose of the system and how to use it.
Recurring Costs		
All Phases		
Management and staffing • Complexity of intervention	Costs associated with necessary human resources for each phase and with managing the project, typically	With insufficient investment in management and staffing of an implementation, there is a high

• Full-time Equivalents (FTEs) needed • Staff training needed • Turnover • Program timelines • Overhead	the costs of project manager role, software development team, business analysts, solution architect, staff training and capacity building.	chance of failure due to: un-skilled and poorly trained staff, overworked team, unrealistic deadlines given resources, and an overall lack of resources.
Governance • Number of stakeholders needed for co-ordination • Number of approvals needed • Amount of travel and meetings required for buy-in, co-ordination, and approvals • Translation required	Resource or time costs associated with overall digital health governance, including developing vision, guidelines, strategic plans, continued maintenance of working groups, and implementation oversight. This could also include costs associated with sharing learnings with a larger community or participating in a community of practice, which is critical for open-source solutions to reduce tragedy of the commons.	Lack of investment in governance, coordination, and oversight leads to high sunk costs due to redundant investments, inefficient use of funds available, lack of quality across tools deployed, and potentially adverse effects of poorly designed and deployed tools. Lack of investment in governance of and contributions to open-source solutions and communities will lead to unmaintained software.
Development & Setup		
Hardware • Data storage requirements • Number of devices needed • Reuse of existing hardware • Sophistication of device(s) needed	Costs associated with data storage and number of physical devices needed (e.g., mobile phones, computers, tablets, servers, chargers, power cords, etc.)	Overlooked investment in hardware can lead to poor adoption of the software tool, leakage of data due to poor quality devices, and inability to store all the data collected through the digital health solution.
Licensing & Subscription (if applicable) • Scale of implementation (e.g. number of end users, number of devices, etc.)	Costs associated with software licensing fees, standards licensing fees, subscription fees, software updates and upgrades, and/or membership dues to be a voting member of standards bodies. The larger the implementation the lower the cost per end user, but the higher the costs will be overall.	Not all software or standards will have licensing fees. However, oftentimes, there are fees associated with software required for cybersecurity and/or device management. Thus, not funding this would lead to a system exposed to cybersecurity threats, system downtime and higher costs required for updating and maintaining software.
Testing, Integration & Interoperability		
Quality Assurance Testing • Number of updates • Complexity of features and functions	Costs associated with testing of the system prior to deployment. Each time a new feature is developed, there will need to be testing conducted to ensure usability.	Lack of time dedicated to testing prior to deployment will lead to higher costs after deployment due to the inevitable bugs discovered in a system.
Interoperability with other systems • Established standards or lack thereof • Maturity of interoperability standards used • Existing data or terminology standards	Costs associated with interoperating with existing systems including the labor necessary to set up communications between the new and existing systems, including testing for standards compliance.	Limited sufficient investment in interoperability with other systems will lead to a siloed or MUD enterprise architecture, which will lead to higher costs when attempted to connect systems post-facto, while data exchange and data use needs remain.

Data collection and use • Existing data sharing policies • Level of adoption of standards in systems • Interoperability of systems	Costs associated with establishing data sharing agreements and policies, and necessary tools to support integration of systems when data needs arise.	Without sufficient investment in interoperability with other systems, there will inherently be higher costs required for data collection and use, leading to limited or no data exchange between systems. This leads to large amounts of data that need to be stored that cannot be decoded for meaningful information or used for decision-making. Without intentional investment in improving data collection processes, health workers will need to dedicate time and resources dedicated duplicative data entry rather than health service delivery.
Deployment		
End user testing • Amount of travel and meetings required • Translation required	Costs associated with collecting end-user feedback and addressing feedback. This is a recurring cost as each new feature developed should be tested by the end users (in addition to quality assurance testing conducted by the technology team).	Without sufficiently engaging the end users in testing the software in a controlled environment before large scale deployment, there is a high likelihood that the system will not be adopted by the end-users at scale as there could be unmet needs due to missing critical functionality.
Infrastructure • Internet costs • Reliability of electricity • Frequency of breakdowns in connectivity • Number of end users • Size of data collected and stored	Costs associated with infrastructure including electricity, data center hosting, and connectivity (i.e., voice and data fees).	Not investing in infrastructure will inevitably lead to unplanned investments needed for required infrastructure as infrastructure is foundational and a prerequisite to any deployment. This could lead to lack of connectivity of and between end-users.
Training • Baseline skillset & existing capacity gaps • Amount of travel required • Gaps in existing training materials and curriculum • Scale and frequency of training needed	Costs associated with the development of a training framework that includes working with connected systems, technical training to build capacity working with standards. This is a recurring cost as it requires consistent training as the system is updated.	Lack of training can lead to the inability of applying interoperability standards correctly, duplication of efforts, lack of resiliency through dependence on individual staff, inadequate software adoption, limited data use, and poor data quality.
Scale-up		
Activities related to expanding reach • Number of end users • Complexity of intervention • Size of data collected and stored	Costs associated with defining the scope and scale of expansion and deployment activities (e.g. additional staff, additional hardware). Scaling could mean adding support and translations for new localizations and building support for variability in workflows, such as differences across facilities.	Insufficient investment in scale means that the interoperable system will not benefit from economies of scale, whereby costs per user is decreased and cost for impact on health outcome is increased. Without investment in scale-up activities, a country's needs are not fully met.

• Amount of information needed to disseminate		
Knowledge transfer • Complexity and scope of intervention • Number of stakeholders needed for co-ordination	If an external vendor(s) is used, costs associated with transferring ownership from the external vendor(s) to the local team (e.g., government). This includes costs required to dedicate resources to documentation.	Lack of investment in knowledge transfer activities will increase dependency on a few individuals, potentially leading to vendor lock-in. This puts the sustainability of the system at risk.
Sustained Operations & Maintenance		
Hardware maintenance • Number of end users and devices managed • Sophistication of the device • Amount of travel needed for on-site maintenance support • Environmental factors (e.g., heat, dust)	Costs associated with maintenance of hardware, ongoing administration including tracking of devices and replacement.	Without continued investment in maintenance of hardware, there is an increased likelihood of unforeseeable issues like hardware damage and significant data loss. This will lead to system downtime, and end-users could stop using the system altogether.
Software maintenance • Number of end users • Number of bug fixes needed • Anticipated updates released per year	Costs associated with fixing bugs, adding features, maintaining customizations, upgrading to new versions and checking for security vulnerabilities routinely and proactively. Software updates should be mindful of updates to the interoperability standards as well, in order to maintain conformance.	Insufficient investment in software maintenance will lead to increased likelihood of errors and system malfunctions, which reduce system performance. Without consistent updates to the system, it may no longer be relevant to the end-user.
Monitoring & evaluation • Complexity, scope, and scale of intervention	Costs associated with monitoring and evaluating the usefulness of the digital health solution on health program efficacy and impact.	Without continuous monitoring and evaluation of digital health solutions, there is a high likelihood of continued investments in systems that are no longer relevant to health programme needs.

Frequently Asked Questions

How do we get started? Before making an investment in digital health, it is critical to start with planning for sustainability. The sections on essential processes for digital health implementations and how to budget for interoperable systems provide an overview on key components to be considered in an investment roadmap. These sections can be used to identify key cost drivers and inform resource allocation across different phases of implementation to help make informed purchasing decisions, ensuring longer term sustainability of a digital health solution. It may be useful to also start with engaging in communities of practice to learn from the experiences of other countries working towards interoperable systems (see the role of interoperability within a digital health enterprise section). Learning networks, such as the Global Digital Health Network (GDHN), Health Informatics in Africa (HELINA), Asia eHealth Information Network (AeHIN), Global Digital Health Partnership (GDHP), and many others provide a community for sharing real experiences, lessons learned, and best practices.

How do I select a vendor to develop the interoperable system? Choosing the right vendor to develop the digital health system is critical for success. The steps to conduct a vendor assessment include assessing country needs, setting goals, issuing a request for proposals (RFP) and comparing vendors using evaluation matrix tools. Planning an Information Systems Project toolkit provides a scoring matrix for vendor selection[xlix]. Additionally, Annex 5.1 of the DIIG provides key interoperability-related questions that can be used to guide discussions with vendors and to inform a proposal scoring rubric.

How do I determine what might be appropriate and achievable for the country context? The MEASURE Evaluation Health Information Systems (HIS) Interoperability Maturity Model Mapping Tool identifies the major components of health information system interoperability[l]. Use the maturity model and accompanying Toolkit to identify an appropriate architecture for bringing systems together[li].

Where can I go to find interoperability-related training? The Self-paced Digital Health: Planning National Systems Course includes training to support stakeholders in achieving a digital health enterprise architecture that is scalable, sustainable, and interoperable. The OpenHIE Academy is another free, community-supported initiative to build capacity for better health information exchange architecture processes[lii].

Where can I get technical assistance to develop and improve digital health systems? WHO Country Offices and the Digital Health Centre of Excellence (DICE) provides coordinated technical assistance to countries to support the sustainable and scalable deployment of digital health solutions[liii]. DICE can also support coordination between donors and development partners at the regional and global levels. The knowledge base contains a variety of documents related to digital health including assessments, strategies and monitoring and evaluation documents[liv].

Where can I learn more about digital health solutions deployed in a country? The Global Goods Guidebook describes a number of digital health solutions, along with countries where they have been deployed[lv]. In addition, WHO's Digital Health Atlas, a digital health technology registry platform, aims to strengthen the value and impact of digital health interventions, improve coordination, and facilitate institutionalization and scale. This can be used to review and catalogue a country's implemented digital health solutions[lvi].

Where can I find digital health-related training? MEASURE Evaluation, working collaboratively with the Global Evaluation and Monitoring Network for Health (GEMNet-Health), developed a free, short course for health information system professionals, the Health Informatics for Low-and Middle-Income

Countries course[lvii]. Take this course to become familiar with the most commonly found concerns and solutions in digital health. This course is hosted on the Digital Square learning platform[lviii].

Where should I look to find what's in the national digital health enterprise architecture? To know if components such as registries are in use in the country, this may be in a country's digital health strategy or enterprise architecture framework, if available. The WHO Digital Health Atlas also can be used to review and catalog a country's implemented digital health solutions. Annex 6.1 in the DIIG includes a template for linking a digital health implementation within the broader digital health system architecture, if needed.

Additional resources

In addition to the resources already referenced, the following additional resources are available for those interested in a deeper dive into digital health.

Normative guidance

- Classification of digital health interventions v1.0: a shared language to describe the uses of digital technology for health

Toolkits & practical guidance

- Digital Square's Total Cost of Ownership Tool (https://digitalsquare.org/tco-tool)
- Digital Square's and Vital Wave's Digital Health Investment Checklist (https://static1.squarespace.com/static/59bc3457ccc5c5890fe7cacd/t/608745ac8cbfb267e5168606/1619477933242/Digital+Health+Donor+Checklist.pdf)
- Principles for Digital Development (https://digitalprinciples.org/principles/)
- MEASURE Evaluation's Health Information Systems Stages of Continuous Improvement Toolkit (https://www.measureevaluation.org/his-strengthening-resource- center/his-stages-of-continuous-improvement-toolkit)

Case studies

- Ghana: Building a Strong and Interoperable Health Information System for Ghana
- Haiti: Reaching Health Standards and Creating a Client Registry in Haiti
- Malawi: Aggregating Fragmented Health Data in Malawi
- Nigeria: Nigeria Data Exchange Architecture for the National Data Repository
- Pakistan: National Digital Health Framework of Pakistan
- Uganda: Building a Strong and Interoperable Digital Health Information System for Uganda
- Zambia: Addressing Immunization Service Delivery Issues in Tanzania and Zambia

Acronyms

ABDM	India Ayushman Bharat Digital Mission
AeHIN	Asia eHealth information network
API	Application programming interface
BMZ	German Federal Ministry for Economic Cooperation and Development
DHIS2	District Health Information Software 2
DICE	Digital Health Center of Excellence
DICOM	Digital Imaging and Communications in Medicine
DIIG	Digital Implementation Investment Guide
DTO	Digital Transformation Office, Ministry of Health
DUP	Data Use Partnership
EU	European Union
FHIR®	Fast Healthcare Interoperability Resources
FTE	Full-time Equivalent
GEMNet-Health	Global Evaluation and Monitoring Network for Health
GS1	Global Standards 1
HIS	Health Information Systems
HIV	human immunodeficiency virus
HL7®	Health Level 7
HMIS	Health Management Information Systems
ICD-11	International Classification of Diseases 11th Revision
ICT	Information and communication technology
IHE	Integrating the Healthcare Enterprise
LOINC®	Logical Observation Identifiers Names and Codes
MAPS	mHealth Assessment and Planning for Scale
M&E	Monitoring and evaluation
MOHCDGEC	Tanzania Ministry of Health, Community Development, Gender, Elderly and Children
MUD	Monolithic Un-architected software Distributions
NDHB	National Digital Health Blueprint
NIDA	National Identification Agency
NITI	National Institution for Transforming India
OLAP	Online analytical processing
OLTP	Online transaction processing
OpenHIE	Open Health Information Exchange
OpenHIM	Open Health Information Mediator
OpenMRS	Open Medical Record System
PORALG	President's Office of Regional and Local Government
RACI	Responsible, Accountable, Consulted and Informed
RHIES	Rwanda Health Information Exchange Systems
RI	Republic of Indonesia
SDG	Sustainable Development Goals
SIMPUS	Indonesia's Puskesmas Management Information System

SIMRS	Indonesia's Hospital Management Information System
SMART	Standards-based, Machine-readable, Adaptive, Requirements-based, and Testable
SMS	Short message service
SNOMED-GPS	Systematized Nomenclature of Medicine - Global Patient Set
SOP	standard operating procedure
TB	Tuberculosis
TOGAF®	The Open Group Architecture Framework
TWG	Technical Working Group
TZHEA	Tanzania Health Enterprise Architecture
UHID	Unique health identifier
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USSD	Unstructured supplementary data service
WHO	World Health Organization

Glossary[1]

ADAPTIVE MANAGEMENT. The process of building in the ability to respond to change using incremental, steady iteration to continually improve a digital health implementation.

DIGITAL HEALTH. Digital health is the systematic application of information and communications technologies, computer science, and data to support informed decision-making by individuals, the health workforce, and health systems, to strengthen resilience to disease and improve health and wellness.

DIGITAL HEALTH APPLICATION. The software, ICT system or communication channel that delivers or executes the digital health intervention and health content.

DIGITAL HEALTH ENTERPRISE. The business processes, data, systems and technologies used to support the operations of the health system, including the digital health applications, point-of-service software applications, other software, devices, hardware, standards, governance and underlying information infrastructure (such as the digital health platform) functioning in a purposeful and unified manner. This guide distinguishes between four different types of digital health enterprise system architectures along a continuum of maturity: siloed, ball of mud, integrated and exchanged.

DIGITAL HEALTH STRATEGY. An overarching plan that describes high-level actions required to achieve national health system goals. These actions may describe how new digital health components will be delivered or how existing components will be repurposed or extended. The foundational building blocks of a digital health strategy include infrastructure, legislation, policies, leadership and governance, standards and interoperability, and financing. May also be known as an eHealth strategy.

ENTERPRISE ARCHITECTURE. A blueprint of business processes, data, systems and technologies used to help implementers design increasingly complex systems to support the workflow and roles of people in a large enterprise, such as a health system.

EXCHANGED SYSTEM ARCHITECTURE. A system architecture consisting of multiple applications connected through a health information exchange to address collective needs across the health sector, operating in a coordinated manner within a digital health enterprise.

INTEGRATION. Integration is the inter-connectivity requirements needed for two applications to securely communicate data to and receive data from another.

INTEROPERABILITY. Interoperability is the ability of different applications to access, exchange, integrate and cooperatively use data in a coordinated manner through the use of shared application interfaces and standards, within and across organizational, regional and national boundaries, to provide timely and seamless portability of information and optimize health outcomes.

MUD (MONOLITHIC UNARCHITECTED SOFTWARE DISTRIBUTION). Software characterized by an evolving agglomeration of functions, originating without a predetermined scope or design pattern, which accumulate technical debt.

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[1] Terms have been taken from the DIIG[iii].

STANDARD. In software, a standard is a specification used in digital application development that has been established, approved and published by an authoritative organization. These rules allow information to be shared and processed in a uniform, consistent manner independent of a particular application.

SILOED APPLICATION. A stand-alone digital health application consisting of one or more digital health interventions to address one or more health system challenges and fulfil the project goals.

TECHNICAL DEBT. Technical debt in software development and systems architecture describes the risk of taking shortcuts and making short-term fixes (which later require costly revisions and add-ons); rather than investing in carefully designed, robust solutions (which cost more upfront, but have lower maintenance and feature development costs over time).17

TOTAL COST OF OWNERSHIP. The resources required to support a digital health intervention throughout its life cycle.

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