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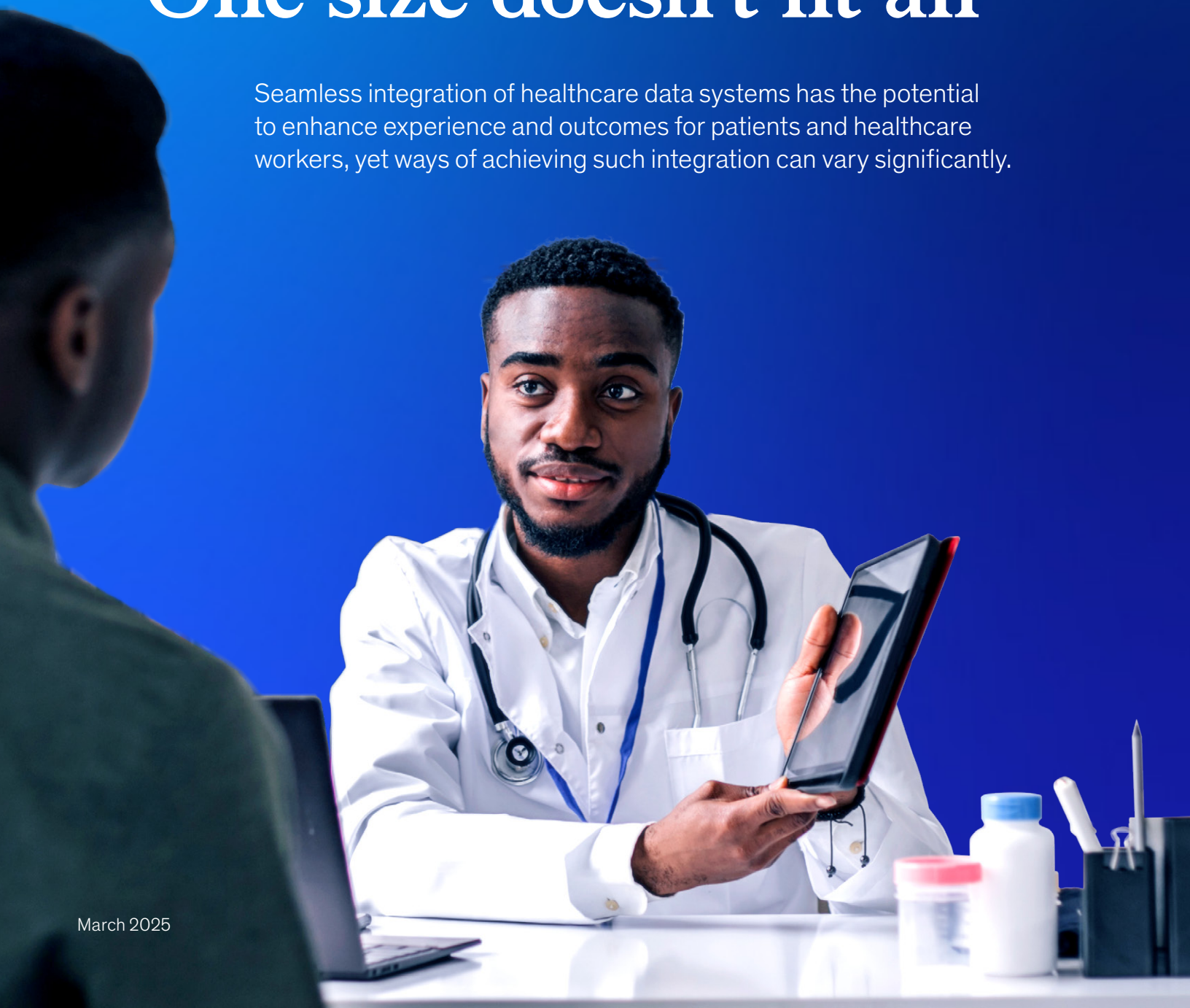
Building interoperable healthcare systems: One size doesn't fit all

Seamless integration of healthcare data systems has the potential to enhance experience and outcomes for patients and healthcare workers, yet ways of achieving such integration can vary significantly.



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Introduction

This report is a collaborative effort by Lars Hartenstein, Matt Wilson, Molly Bode, and Pooja Kumar, with Marilyn Kimeu, representing views from the McKinsey Health Institute.

The growing use of digital technologies in healthcare allows for a more comprehensive understanding of the health of individual patients and of populations and can improve the efficiency of providers. This in turn could enable more accurate diagnoses, timely treatments, and personalized care or interventions at a population level.

To achieve these positive outcomes requires a wide range of systems and tools—from electronic health records (EHRs) to varied management systems—to be "interoperable." That is, these systems need to be integrated and able to share or use the same data so that they can work together seamlessly. Our prior research, and research from others, suggests that such integration can lead to benefits: for example, accurate EHRs, along with tools such as e-prescriptions, could result in up to a 15 percent increase in efficiency within healthcare systems by 2030 (depending on implementation, digital tools and systems selected, existing scale, the spending base, and costs of system implementation).[1] Such gains would allow healthcare workers to concentrate more on high-value medical care and less on administrative tasks.

Achieving this data interoperability can be challenging, and there is no one-size-fits-all solution: country context is a critical factor, and many countries have accordingly adopted different approaches. In this report, the McKinsey Health Institute, as part of a consortium with Exemplars in Global Health and other partners, outlines a common set of options for how countries might build an interoperable system that fits their specific context and strategic aims, particularly the aim of increasing healthcare worker efficiency (see box, "About this report").

[1] This estimate builds on several prior McKinsey publications, including "How digital tools could boost efficiency in African health systems," March 10, 2023, which evaluated 24 digital health tools for 79 total use cases. The estimate of efficiency gains triangulates with several peer-reviewed sources, such as pilot findings in South Korea and a retrospective cross-sectional analysis from the United States. See Hayoung Park et al., "Can a health information exchange save healthcare costs? Evidence from a pilot program in South Korea," *International Journal of Medical Informatics*, September 2015, Volume 84, Number 9; and Abby Swanson Kazley et al., "Association of electronic health records with cost savings in a national sample," *American Journal of Managed Care*, June 2014, Volume 20, Number 6. However, more research on costs may be needed.

About this report

This report is part of the Digital Health Exemplars (DHE) consortium convened by Exemplars in Global Health. The DHE research project aims to generate practical insights into how exemplar countries use digital health technologies to improve primary healthcare systems and contribute to better health outcomes. The DHE project takes a threefold approach, with workstreams to develop case studies on exemplar countries, conduct deep dives into key digital health transformation themes, and support peer-to-peer learning to help translate evidence to practice.

Partner institutions include the Center for Global Digital Health Innovation at the Johns Hopkins Bloomberg School of Public Health, eHealthLab Ethiopia at the University of Gondar, the Indian Institute of Health Management Research, Instituto de Estudos para Políticas de Saúde in Brazil, the University of Ghana, and Africa Quantitative Sciences in Rwanda, which are leading the exemplar country case studies; McKinsey Health Institute, which is leading the preparation of select thematic deep dive analyses; and the World Bank Group, which is facilitating the peer-to-peer learning effort via the Joint Learning Network. The Gates Foundation is part of the consortium.

The report first focuses on key design dimensions grouped under strategic approach, architectural and technical design, and user engagement. It then examines the digital health experience in three countries that have a relatively high degree of maturity, according to the Global Digital Health Monitor (GDHM), but very different contexts and approaches: Canada, Estonia, and Tanzania.[2] These three examples underscore how the specific financing context, locally available resources, and governance models strongly influence the path toward interoperability.

Indeed, each of the focus countries exhibits unique relevant contextual factors:

— Canada has a large and decentralized public healthcare system in which provinces provide healthcare services, including the establishment of their own health interoperability architectures. This system is guided by Canada Health Infoway, a centralized, not-for-profit entity.

— Estonia has a centralized government-owned structure that uses the national digital infrastructure.

— Tanzania's system, which has included support from donors, has been developed with a focus on use cases integrated at various levels of care, with plans to eventually incorporate all use cases into the Health Information Mediator.[3]

These countries' varying experiences could provide lessons and options for others, particularly low- and middle-income countries currently looking to build and develop their own healthcare interoperability systems.

[2] Canada and Estonia both score 5 out of 5 for digital health, and Tanzania is rated 4 out of 5. See "State of digital health around the world today," Global Digital Health Monitor, accessed December 16, 2024.

[3] The Health Information Mediator is a "data exchange and translation system that can accept data from different systems, exchange the data so that the individual systems all have the same information, and enable health managers to readily analyze the data and use it in their decision-making." See "Tanzania deploys the most advanced health information exchange in sub-Saharan Africa," USAID, April 26, 2019.

CHAPTER ONE

Digital interoperability in healthcare

Simply put, interoperability allows different organizational and digital systems to interact—or digitally communicate—through the sharing of data.[4] The benefits of data interoperability play out in a variety of ways for different stakeholders that interact in the healthcare system:

— Patients and communities could benefit from more coordinated and integrated care and potential empowerment through access to their own digital health records.

— Clinicians might benefit from greater efficiency of data collection and better overall coordination with healthcare professionals and organizations.

— Healthcare organizations (public and private) may heighten efficiency by eliminating duplicative testing and repeat visits.

— Health authorities may find it easier to access high-quality aggregate data to formulate public policy and more cost-effective methods of ensuring compliance.

— Researchers might increase their access to big data and improve the identification and tracking of new treatments or interventions.[5]

In Canada, for example, early estimates from 2018 suggested that full adoption of interoperability could result in annual healthcare savings of approximately CA $4 billion (approximately US $3 billion),[6] or 1.6 percent of the country's total healthcare expenditure.[7] More recent data from a 2023 study suggests that improved adherence to interoperability guidelines could generate CA $1.35 billion[8] (approximately US $1.00 billion), representing 0.4 percent of overall spending.[9] These savings would stem primarily from reduced hospital admissions and a decrease in redundant laboratory and imaging tests.

In Estonia, research estimates that digital solutions powered by interoperability could lead to substantial process improvements such as reduced time in repeat prescriptions and reduced time in waiting for emergency services.[10] While Tanzania is still in the early stages, stakeholders express enthusiasm about the enhanced healthcare outcomes observed in the use cases implemented. For instance, an evaluation of one specialized hospital data-sharing case revealed substantial time

[4] The World Health Organization defines interoperability in healthcare as 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." See *Global strategy on digital health 2020–2025*, WHO, 2021.

[5] *ID4D Practitioner's Guide*, World Bank, June 1, 2019; *Strategic Interoperability Framework: Summary report*, Australian Digital Health Agency, November 2017; "Digital Health Standards," Digital Health Europe, accessed December 16, 2024; "Benefits of ISO standards," ISO, accessed December 16, 2024.

[6] *Connected health information in Canada: A benefits evaluation study*, Gartner, April 2018.

[7] The European Observatory on Health Systems and Policies estimated healthcare expenditure in 2018 at CA $255 billion. See "3.1 Health expenditure," Canada: Health Systems in Transition (HiT) profile, Health Systems and Policy Monitor, European Observatory on Health Systems and Policies, 2020.

[8] *Shared Pan-Canadian Interoperability Roadmap*, Canada Health Infoway, 2023.

[9] Healthcare expenditure in 2023 was estimated at CA $344 billion, according to the Canadian Institute for Health Information. See "National health expenditure trends, 2023 — Snapshot," CIHI, November 2, 2023.

[10] "Learning from the Estonian e-health system," Health Europa, January 11, 2019.

savings for clinicians when data was automatically processed rather than summarized manually. It also showed a reduction in data quality errors.[11]

Given such potential benefits, many countries have started taking steps toward building health information exchanges (HIEs) or similar digital health architectural frameworks that serve as the basis of interoperability. In 2023, 57 percent[12] of countries participating in the Global Digital Health Monitor—which tracks and evaluates the use of digital technology for healthcare in 67 countries, including 60 low- and middle-income economies—were building or beginning to implement high-level national digital health architectural frameworks.[13] Additionally, 55 percent[14] of countries have set and published data standards.

Building a basic interoperability platform is not enough: realizing the full benefits will require countries to adopt a robust approach to implementation. As of 2023, only 13 percent[15] of countries had a complex data architecture in place, while just 18 percent[16] broadly adhered to established data standards that are routinely updated.

[11] Alpha Nsaghurwe et al., "One country's journey to interoperability: Tanzania's experience developing and implementing a national health information exchange," *BMC Medical Informatics and Decision Making*, April 2021, Volume 21.
[12] *The State of Digital Health 2023: Global Digital Health Monitor*, HealthEnabled, 2023, Indicator 15, sum of phases 2 and 3.
[13] *The State of Digital Health 2023: Global Digital Health Monitor*, HealthEnabled, 2023, list of countries classified as low- and middle-income countries by the World Bank from the 67 participating countries.
[14] *The State of Digital Health 2023: Global Digital Health Monitor*, HealthEnabled, 2023, Indicator 16, sum of phases 2 and 3.
[15] *The State of Digital Health 2023: Global Digital Health Monitor*, HealthEnabled, 2023, Indicator 15, sum of phases 4 and 5.
[16] *The State of Digital Health 2023: Global Digital Health Monitor*, HealthEnabled, 2023, Indicator 16, sum of phases 4 and 5.

CHAPTER TWO

Design choices for building interoperability

Countries face a common set of choices when making decisions about the development of interoperable systems. To identify these choices, we selected three focus countries with varied characteristics, maturity, context, and experiences and gathered input from more than 50 digital health experts in these countries and beyond. We also incorporated findings from more than 60 publications. Here, we identify and describe seven key dimensions, categorized under strategic approach, architectural and technical design, and user engagement (Exhibit 1). Countries often choose hybrid approaches in their design strategies, and there might be additional dimensions relevant in other contexts.[17] The three focus countries have made varied choices.

Strategic approach

1. Governance and operating model

Governance structure. Key choices here include the degree of centralization, which may depend in part on the health system itself. A national structure led by a single entity may offer streamlined decision making across the system. Decentralized systems often have subnational governance with national guidance on key topics such as standards and suggestions for HIE architecture that can help guide decision making and investment. For example, Estonia's TEHIK (Health and Welfare Information Systems Centre) is a single centralized government-owned company that manages the Estonian Health Information System (EHIS), which supported the rapid uptake of interoperability.[18] Similarly, Canada Health Infoway offers general guidance on interoperability to provinces, such as suggested system architecture, while the specific design and implementation of interoperability systems remain under provincial jurisdiction.[19]

Leadership engagement. Engagement at the highest levels of government is crucial for driving decision making and aligning stakeholders, especially in the early stages of implementing interoperability systems. Ministerial-level engagement supports ongoing implementation efforts. Effective multistakeholder engagement involving government agencies, providers, payers, health tech service providers, digital and health lenders, donors, the medical sector, and others is essential but complex to orchestrate. Early engagement and frequent coordination are key to successful implementation and long-term sustainability of interoperability systems. Using each actor's strengths—such as political capital, funding access, and sector-specific knowledge—can help establish use cases and foundational interoperability layers.

Among the three focus countries, the Tanzanian government has coordinated closely with the Development Partners Group—a donors' group composed of 17 donor countries and five multilateral agencies that has been in operation since 1961—and with implementing partners to prioritize various

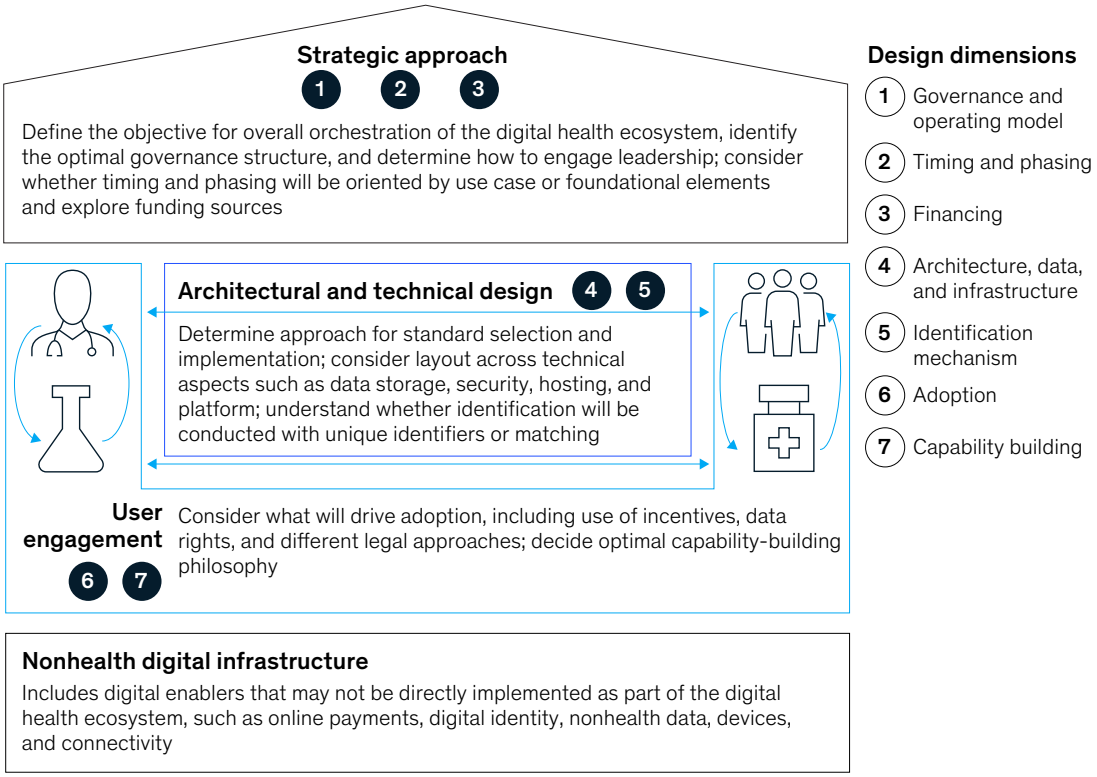
[17] Countries may consider additional dimensions based on their unique experience or needs, and outcomes that reflect a hybrid of choices are possible.

[18] Janek Metsallik et al., "Ten years of the e-health system in Estonia," 3rd International Workshop on (Meta)Modelling for Healthcare Systems, June 2018; "Developing an integrated e-health system in Estonia," IntegratedCare4People.org, June 2016; "Uue põlvkonna tervise infosüsteem (upTIS)" ("New Generation Health Information System"), TEHIK, accessed December 16, 2024; Michelle O'Brien, "Estonia leads the way in digital health reform," Health Services Daily, July 6, 2023.

[19] "Canada's Health Care System," Government of Canada, accessed December 16, 2024; Brian Hutchison, "Primary health care in Canada: Systems in motion," *Milbank Quarterly*, June 2011, Volume 89, Number 2.

Exhibit 1

Countries seeking to build interoperable health systems face key design choices.



Source: *ID4D Practitioner's Guide*, World Bank, June 1, 2019; *Strategic Interoperability Framework: Summary report,* Australian Digital Health Agency, November 2017; "Digital Health Standards," Digital Health Europe, accessed December 16, 2024; "Benefits of ISO standards," ISO, accessed December 16, 2024

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proposals and needs.[20] Canada's e-pharmacy program, PrescribeIT, gained momentum only after the pharmaceutical sector became involved and championed the program.

2. Timing and phasing and 3. Financing

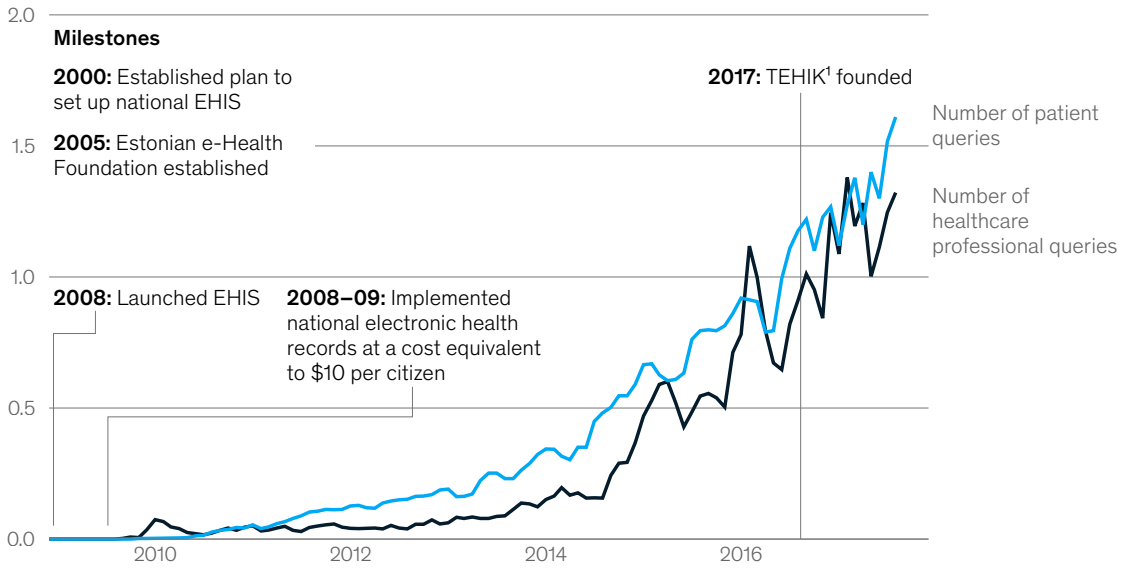
In countries with highly centralized decision-making power, more availability of financial resources, or both, countries may start their interoperability system journeys by building foundational elements such as the interoperability layer or spine.[21] Estonia's e-health system has evolved over time: planning to set up the national health information system began in 2000, and the system launched at the end of 2008 along with a first set of projects including electronic care summaries, digital imaging, and e-prescriptions.[22] The systems were subsequently connected to the preexisting digital government interoperability exchange platform. Adopting new systems can be time-consuming. In Estonia, for example, widespread use of the EHIS by patients and clinicians finally gained momentum in 2014, about five years after its go-live date and following substantial investments (Exhibit 2).

[20] "Towards an effective and inclusive dialogue for development in Tanzania," Development Partners Group Tanzania, accessed December 16, 2024.
[21] For simplicity, key design dimensions of interoperability related to timing and phasing (dimension 2) and financing (dimension 3) have been combined in this section of the report.
[22] Janek Metsallik et al., "Ten years of the e-health system in Estonia," 3rd International Workshop on (Meta)Modelling for Healthcare Systems, June 2018.

Exhibit 2

It took several years and heavy investment for Estonia's electronic health information system to gain traction.

Estonian Health Information System (EHIS) usage data, queries by millions



Note: As of June 15, 2024; approximate figures.
[1]Tervise ja Heaolu Infosüsteemide Keskus (Health and Welfare Information Systems Centre).
Source: "About," TEHIK, accessed January 10, 2025; Chip Means, "Estonia launches $10 EHR," Healthcare IT News, May 11, 2011; Janek Metsallik et al., "Ten years of the e-health system in Estonia," 3rd International Workshop on (Meta)Modelling for Healthcare Systems, June 2018; Artur Novek, *An overview of current Estonian Health Information System Architecture*, Health and Welfare Information Systems Center, October 13, 2017

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In countries with less centralized decision-making power, fewer available financial resources, or both, it may be necessary to build support for the system and secure funding by first building use cases with defined parameters and established standards. The interests of civil society and providers may influence the choice of use cases. In Tanzania, the health interoperability system was implemented in phases—for example, with certain use cases such as improving access to and use of data across specialized hospitals and children's vaccination data in the health information system and levels of care—and digital solutions have been gradually connected to the Health Information Mediator (HIM).[23]

In countries where there is a subnational, decentralized governance structure, jurisdictions could accelerate and shape their interoperability health systems according to their needs and available funding while national entities provide guidance on architecture and data standards. In Canada, for example, there are marked differences among interoperability systems based on province priorities, existing digital infrastructure, and access to funding and human capital. For example, some provinces, such as Alberta (MyHealth.Alberta.ca), and Quebec (Carnet santé Québec), have more-advanced patient portals than others.

[23] Alpha Nsaghurwe et al., "One country's journey to interoperability: Tanzania's experience developing and implementing a national health information exchange," *BMC Medical Informatics and Decision Making*, April 2021, Volume 21.

Architecture and technical design

4. Architecture, data, and infrastructure

Data standards and platform. Countries have the flexibility to implement either international or national data standards and can opt for open-source or proprietary platforms. A common approach is to adopt international data standards—which could be customized to meet specific national needs—alongside open-source platforms. Given the ease and flexibility in their use, these choices may be more cost-effective and encourage local capacity building and innovation over time. The best way to proceed may depend on the extent of legacy systems, local capacity to innovate, and stakeholder preferences.

Standards implementation. Often countries aim to adopt one standard, or a set of standards, to improve scalability. However, this can be difficult when legacy systems are in place. In such cases, the country might provide a time-capped allowance for providers and other organizations to adopt new standards and implement a central transformation system—a terminology server that transforms different data standards (often legacy standards) into unified standards to facilitate data exchange.

Data storage and security. In more centralized countries, central storage with a central authority that verifies identity may offer a streamlined approach for meeting data security expectations. Decentralized countries might still decide to have central storage at the jurisdiction level.

Hosting. Hosting on premises may better align with government data sovereignty priorities and data management protocols, while also operating independently of connectivity issues. Conversely, cloud hosting could offer potential cost advantages, depending on implementation.

For example, in Tanzania, the HIM used international standards, but they were customized for the country's needs. Most of the system (including HIM) has been built on open-source platforms, and hosting is done on premises to comply with legal mandates of data management. In Estonia, the EHIS stores data centrally on premises to streamline data management as part of its core functions.

5. Identification mechanism

Countries with more mature digital ecosystems might use existing national digital IDs to identify patients in healthcare systems, while other countries might use a combination of other existing IDs to build a robust health identification system. Countries might also migrate to a national digital ID over time. For example, Estonia provides citizens with a state-issued digital identity through e-ID, a comprehensive digital identity program for citizens. Tanzania aims to have a single ID number (Tanzania Universal Identity Number Jamii Namba) for its citizens by the end of 2025 (in the meantime, Tanzania uses multiple legacy identifiers to ID citizens).[24] For countries with substantial migrant populations, ensuring access to an identification mechanism compatible with the healthcare system could enhance access to integrated, quality healthcare for these groups.

User engagement

6. Adoption

A combination of mandates, where feasible, and both financial and nonfinancial incentives may drive adoption of the system across users including providers and vendors. In Tanzania, health facilities with sufficient connectivity in the public sector are mandated to capture data and share it with the system, depending on the level of care. For example, facilities at the district level with sufficient connectivity are mandated to share their captured data with the appropriate repository for district and primary care facilities.

A dual approach of providing data rights for patients while building trust and incorporating user feedback may support broad adoption. Estonia has a consent-based model under which patients can choose whether to disclose their data and monitor visits to their health information system.[25]

[24] "Work to develop the Tanzania Universal Identity Number Jamii Namba has started," The Chanzo Reporter, March 12, 2024.
[25] Artur Novek, *An overview of current Estonian Health Information System Architecture*, Health and Welfare Information Systems Center, October 13, 2017.

7. Capability building

Up-front investment in directly building capabilities within government and across providers may support initial adoption and provide a baseline of capabilities to better enable ongoing lighter-touch or train-the-trainer approaches. At Ontario Health in Canada, tech-savvy clinicians who are involved in crafting the implementation plan of digital solutions that rely on interoperability also support onboarding of their peers in clinical settings, according to experts we interviewed for this research. Estonia developed a train-the-trainer approach with introductory meetings and seminars for developers and vendors to help clinicians understand and implement e-health solutions.

Spotlight on three countries with three different contexts and experiences

The focus countries in this report—Canada, Estonia, and Tanzania—represent a range of income groups, geographies, and health system structures. Accordingly, they reflect different experiences in building digital health systems (Exhibit 3). Their contextual differences offer valuable lessons and adaptations that other countries can learn from.

Here we first note three independent and context-driven dimensions that affected the three countries, and we then delve in greater depth into the choices each has made.

Exhibit 3

Canada, Estonia, and Tanzania have differing contexts and approaches to digital health interoperability.

World Bank country income classification: High-income country; Low- or middle-income country

Canada	Estonia	Tanzania
Country: Canada	**Country:** Estonia	**Country:** Tanzania
Region: Americas	**Region:** Europe	**Region:** Africa
Healthcare system: Mostly public	**Healthcare system:** Mostly public	**Healthcare system:** Mixed
Data storage: Decentralized	**Data storage:** Centralized	**Data storage:** Centralized
Global Digital Health Monitor (GDHM) state of digital health score: 5 out of 5	**GDHM state of digital health score:** 5 out of 5	**GDHM state of digital health score:** 4 out of 5
Current health expenditure (CHE) per capita: US $6,4707.07	**CHE per capita:** US $2,094.50	**CHE per capita:** US $37.16
% adoption of electronic health records: 91%	**% providers updating patient information in central system:** 98%	**% primary care facilities connected to GoTHoMIS[1]:** 25%

[1]Government of Tanzania Health Operation Management Information System.
Source: Global Digital Health Monitor, 2023; "Current health expenditure (CHE) per capita in US$," World Health Organization; Digital Health Care Institute (2015); Sanna Rimpilainen, *Canadian journey to an electronic health record,* Digital Health & Care Institute, 2015

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Interdependent, context-driven dimensions affected design choices in the three focus countries

Three interdependent and context-driven dimensions—governance structure, financing, and existing digital infrastructure—affected design choices (Exhibit 4).

Canada's decentralized structure influences its digital health system, particularly its funding, system architecture, and user engagement, which are all specific to the country's provinces. Tanzania built its interoperability system with some donor funding and support, which has influenced the building of the system—with a greater focus on use cases, for example—and system architecture, including adherence to open-source and international-data standards. Estonia used its existing digital government infrastructure to guide the digital health system architecture, including security and identification mechanisms.

Exhibit 4

The three focus countries have made different choices according to their specific contexts.

Selected examples of critical context influencing overall interoperability system structure

1 Governance structure

Canada's decentralized governance structure has contributed to its federated digital health system and interoperability architecture

Canada's **decentralized structure** shapes its digital health system, particularly its **funding, system architecture, and user engagement.** Provinces and territories manage their own health interoperability, while the pan-Canadian system, partly represented by the not-for-profit Infoway, provides guidance to provinces and territories on standards, architecture, adoption mechanisms, and data rights

3 Financing

Tanzania's digital health system is funded by both government and donor partners, requiring coordination across partners in building the system

Tanzania has built its interoperability system with **donor funding support,** which has **influenced the evolution of the system** by ensuring a greater focus on use cases and by shaping the **system architecture** to adhere to open-source principles and international data standards

4 Architecture, data, and infrastructure

Estonia's system that enables digital health interoperability is built on its national interoperability layer and digital infrastructure

Estonia has leveraged its **existing digital government infrastructure** to guide the digital health **system architecture,** including **security** and **identification mechanism**—for example, authentication methods from X-Road (the existing interoperability layer) and the national e-ID (digital ID)

Note: As of June 15, 2024
Source: "Learning from the Estonian e-health system," Health Europa, January 11, 2019; "e-Health," e-Estonia, accessed December 16, 2024; Amy Lewin, "Inside Estonia's pioneering digital health service," *Sifted,* July 8, 2020; *Connected health information in Canada: A benefits evaluation study,* Gartner, April 2018; expert interviews conducted in April and May 2024

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Canada: A decentralized system funded with federal government support

Canada is a higher-income country with a decentralized system in which provinces have autonomy to design and fund their own interoperability systems. At a national level, EHRs are currently available for 91 percent of the population,[26] and 90 percent of community pharmacy stores in Canada have agreements with Infoway, a not-for-profit and pan-Canadian entity that acts as a source of guidance for provinces.[27]

Strategic approach. Canada has developed a decentralized approach aligned with its decentralized system of government. Provinces have autonomy over the provision of healthcare to citizens of the province, including the strategic approach (governance, timing, and financing) of health interoperability within their jurisdiction. The entity responsible for encouraging pan-Canadian interoperability is Canada Health Infoway. Founded in 2001, Infoway is a not-for-profit and pan-Canadian entity that acts as a source of guidance for provinces on HIE architecture and data standards, particularly regarding EHRs and data exchange.[28] It also sets the vision for standardized data governance and acts as a strategic investor for digital health and interoperability projects in the provinces. It promotes pan-Canadian harmonization without direct involvement of the federal government.

Provinces can levy their own taxes, receive funding from the federal government, or pursue individual implementation goals for interoperability systems and receive complementary funding from Infoway, which is funded through taxation. This method creates incentives for jurisdictions and private sector players to build a digital health interoperability system and participate in it. Infoway ties a portion of its disbursement of funds to the achievement of KPIs. Infoway's cost-sharing agreements with jurisdictions vary according to the financial resources of each province. In recent years, the federal government has funded provinces' interoperability projects directly, and Infoway's role has evolved to become a source of guidance on data standards and information exchange.

Architecture and technical design. Data is stored in a decentralized way, with each jurisdiction maintaining responsibility for its own data storage. Technical dimensions are also decided at the jurisdiction level, including levels of integration across different registries and systems. For example, Quebec's Dossier santé Québec platform grants authorized users (clinical workers, pharmacists, and laboratories) access to patients' information—including medication records, immunizations, and hospitalization information—across the province.[29] It is intended to have full interoperability with Epic, an electronic health records provider.[30] Infoway provides some pan-Canadian guidance on standards and architecture.[31]

User engagement. Overall, Canada's approach integrates financial incentives, regulatory frameworks, strategic guidance, and user-centric design to foster the digitalization of healthcare, ensuring both improved outcomes and the protection of patient rights.

The federal government and pan-Canadian institutes (including Infoway) provide guidance and suggestions; Infoway's *Shared Pan-Canadian Interoperability Roadmap*[32] is one of its most recent documents communicating the long-term vision for its digital health ecosystem. This road map outlines the strategic direction and goals for achieving a cohesive digital health infrastructure across the country. In addition to providing guidance, Infoway has implemented various financial incentives, such as subsidizing programs and compensating physicians for their technology costs, to broadly enable digitalization. Some experts suggest that adoption of PrescribeIT's e-pharmacy system increased to 90 percent from 20 percent after these financial incentives were introduced. Infoway also ties disbursement of resources to user adoption metrics as a key performance indicator. User engagement strategies fall within the purview of each province, allowing for diverse approaches

[26] Sanna Rimpilainen, *Canadian journey to a national electronic health record*, Digital Health & Care Institute, 2015.
[27] "2022 at a glance," PrescribeIT, accessed December 16, 2024.
[28] *Shared Pan-Canadian Interoperability Roadmap*, Canada Health Infoway, 2023.
[29] "Quebec Health Record: Available information," Gouvernement du Québec, accessed December 16, 2024.
[30] The Canadian Press, "Quebec chooses American firm Epic to create new digital health system," CityNews Montreal, August 25, 2023. Epic is a digital health software solution.
[31] "Standards," Canada Health Infoway, accessed on June 2023 and confirmed by expert interviews March–September 2023.
[32] *Shared Pan-Canadian Interoperability Roadmap*, Canada Health Infoway, 2023.

to ensure user participation. These strategies can range from positive incentives, such as positive recognition or training programs, to mandates and other measures, depending on the specific policies of each province.

In Canada, data rights belong to patients,[33] but the specific scope depends on provincial regulations.[34] Additionally, the Canadian Institute of Health Information, a pan-Canadian not-for-profit entity, holds rights to aggregated data. The system places a strong emphasis on safeguarding patients' rights to privacy.

Interviews with stakeholders highlight the potential of user-centric design principles to increase user adoption. In Ontario, for example, tech-savvy clinicians are involved in crafting implementation plans for digital solutions that rely on interoperability and support onboarding their peers.

Canada's interoperability challenges and solutions

Our research suggests that Canada faced three main challenges in its interoperability journey, addressing them through different mechanisms.

First, health leaders found that providers may be reluctant to adopt digital solutions, perceiving them as extra work without clear business gain.[35] Infoway has sought to address such reluctance by offering financial incentives, such as subsidizing pharmacies involved in PrescribeIT and compensating physicians for EHR technology costs, as noted above.[36]

Second, healthcare providers, vendors, and points of service were adhering to different messaging and terminology standards.[37] Rather than mandating a change in standards, Infoway has dealt with this issue by allowing interoperability layers to accommodate multiple messaging and terminology standards.[38]

Third, there are limitations on what the federal government can do. The Canada Health Act places health under the jurisdiction of provinces and territories rather than the federal government. The national government has worked within this construct through the creation of Infoway, which is both a provider of strategic guidance and an investor in digital health and interoperability to the provinces.[39]

Estonia: System built on advanced centralized digital infrastructure

Estonia is a higher-income country with one of Europe's leading digital government infrastructures. It has an advanced centralized government digital health infrastructure guided by a single entity. The majority of healthcare providers in Estonia—98 percent—update patient information in the central system, which creates a central record for each patient.[40]

Strategic approach. Estonia has a national governance structure with multiple entities: TEHIK[41] is a government-owned company that manages the EHIS (used by both private and public sectors), while the overall health system is overseen by the Ministry of Social Affairs. Estonia's e-health system has evolved over time: the first key projects, such as the EHR, digital images, and digital registrations, launched between 2006 and 2008, followed by the establishment of a national EHIS and other solutions, including e-prescriptions and e-ambulance services.[42] The evolution of the e-health system—including the addition of new solutions, functionalities, and services—responds to a need to consistently provide value to users and increase user trust and adoption.

[33] *Privacy as an enabler*, Canada Health Infoway, May 10, 2022, accessed June 2023 and confirmed by expert interviews March—September 2023.
[34] "Data protection laws of the world: Canada," DLA Piper, updated January 26, 2023.
[35] *Canadian national health interoperability standards*, TECHNATION, November 2021.
[36] Canada Health Infoway, accessed June 2023 and confirmed by expert interviews March–September 2023.
[37] *Canadian national health interoperability standards*, TECHNATION, November 2021.
[38] Canada Health Infoway, accessed June 2023 and confirmed by expert interviews March–September 2023.
[39] Canada Health Infoway, accessed June 2023 and confirmed by expert interviews March–September 2023.
[40] "Developing an integrated e-health system in Estonia," IntegratedCare4People.org, June 2016.
[41] Tervise ja Heaolu Infosüsteemide Keskus (Health and Welfare Information Systems Centre).
[42] Janek Metsallik et al., "Ten years of the e-health system in Estonia," 3rd International Workshop on (Meta)Modelling for Healthcare Systems, June 2018.

Architecture and technical design. Estonia's EHR platform is based on international standards,[43] which enables the exchange of digital health documents in a standardized way. The EHIS integrates with the state system, X-Road, which uses international standards whenever possible. Using widely accepted standards allows for the usage of data collected in different settings in a machine-understandable way and also facilitates cross-boundary exchange of data. X-Road secures data exchange with two-factor authentication and implements digital signing, encryption, and monitoring. The e-health system uses keyless signature infrastructure and blockchain technology to secure state-owned server resources against cyberattacks and mitigate internal threats to data. Estonia's data is centrally collected and connected to the national EHIS, and data is stored on premises.[44]

User engagement. EHIS is an example of successful digital health infrastructure driven by legal, financial, and operational frameworks. Since 2008, all doctors and hospitals have been mandated to digitize personal health data, with financial penalties for noncompliance. The government supports this with subsidies to cover IT system costs, ensuring interoperability and the use of EHR. TEHIK, the governing body, facilitates implementation through meetings, seminars, and guides for developers and vendors. Estonia follows a consent-based model, under which patients have the right to see their own data collected in the central database. Patients can choose not to disclose their data, although fewer than 1 percent of patients opted out in 2020.[45] They can also monitor visits to their health information system.

Estonia's train-the-trainer system, noted above, helps medical professionals understand data standards, increasing system adoption. This comprehensive approach has led to wide adoption of digital health tools and strong infrastructure in Estonia.

Estonia's interoperability challenges and solutions

Our research highlights two main challenges for Estonia on its health interoperability journey.

The first challenge is data quality and management. Variations in data quality—for example, in completeness, consistency, duplication, correctness, spatial stability, contextualization, and predictive value—can complicate the reuse of data for tasks including training AI, machine learning, and predictive analytics. This could lead to redundancies and necessitates ongoing oversight to screen the data. To address this, Estonia is transitioning to FHIR[46] data standards centrally[47] and plans to have all healthcare providers adopt these standards eventually. Additionally, the country is in the process of upgrading its mapping mechanism.

A second challenge is the slow adoption of new standards and new technology by providers. Estonia has supported the adoption process by carrying through testing events with developers. For example, the TEHIK team initiated capability-building initiatives including meetings to introduce the standards, seminars about new products, and implementation guides.

[43] Standards include HL7 clinical documentation architecture and fast healthcare interoperability resources, digital imaging and communications in medicine (DICOM), the systematized medical nomenclature for medicine-clinical terminology (SNOMED-CT), the national classification of surgical procedures (NCSP), the anatomical therapeutical chemical classification system (ATC), the international classification of diseases, 10th revision (ICD-10), and logical observation identifiers names and codes (LOINC). See Bharath Perugu et al., "Surmounting barriers to healthcare data and information: International case studies," *Telehealth and Medicine Today*, July 2023, Volume 8; "Ten years of the e-health system in Estonia," June 2018; Madis Tiik and Peeter Ross, "Patient opportunities in the Estonian Electronic Health Record System," *Studies in Health Technology and Informatics*, January 2010, Volume 156.

[44] *An overview of current Estonian Health Information System Architecture*, October 13, 2017; *Estonian cyber security innovation*, e-Estonia, February 12, 2016.

[45] "500 people out of Estonia's population of 1.3m choose to 'close' their entire records each year." See Amy Lewin, "Inside Estonia's pioneering digital health service," *Sifted*, July 8, 2020.

[46] Fast Healthcare Interoperability Resources.

[47] Ragne Õitspuu, "An analysis of the data composition of the Estonian National Health Information System and recommendations for the implementation of the HL7 FHIR standard," Tallinn University of Technology, 2024.

Tanzania: A system built on use cases and with some donor support

Tanzania is a lower-income country with an interoperability system built primarily by use cases and with some donor support. Tanzania laid out its digital strategy in 2013.[48] Today, about 25 percent of the country's primary care facilities are connected to the primary care interoperability layer GoTHoMIS, according to our research based on expert interviews. Tanzania has adapted to its context by making strategic design choices across the seven key design dimensions:

Strategic approach. Tanzania has a national governance structure led by multiple entities. The Ministry of Health (MOH) sets strategies and policies for digital health and implements the strategies on the regional level and above, while the President's Office, Regional Administration and Local Government Tanzania (PO-RALG) implements the strategies at the district level and below. This structure follows Tanzania's decentralized health systems structure[49]: districts are responsible for health provision at a district level and report to PO-RALG, while the Ministry oversees overall health implementation, including healthcare at a regional level and above. Tanzania's system was implemented in phases; digital solutions are slowly getting connected to the HIM. The phased approach responded to different donor-funded programs.

Architecture and technical design. Tanzania adapted the Current Procedural Terminology 4 (CPT4) international standard to the local context. This has facilitated data exchange between the HIM interoperability layer and legacy systems. The HIM can take data with varied standards received from legacy digital solutions and translate it to a centralized set of standards.[50]

Tanzania uses DHIS2 as the standardized repository system for the data from all of the systems connected to HIM. This gives health managers a universal view of available health data. Most of the Tanzanian system, including HIM, has been built on open-source platforms. This facilitates integration and interoperability with legacy digital solutions that might not have been compatible with proprietary systems.[51]

Tanzania uses a hybrid approach of unique identifiers and matching of identity. About 40 percent of residents have National Identification Authority (NIDA) numbers that can be used for identification.[52] Government employees have a "check number" that can be used instead of a NIDA. Individuals under 18 years old and those who don't have a NIDA or check number have to go through different identification mechanisms, such as first name, last name, and age. This method works because different people in Tanzania have access to different identification methods. The Tanzanian government aims to introduce a new universal identity number for all Tanzanians from birth by the end of 2025.[53]

User engagement. Tanzania combines legal mandates, financial and nonfinancial incentives, training, and technical support to support integration and use of interoperable digital health tools.

Tanzania mandates the use of EHR systems in facilities with adequate connectivity, ensuring integration with the HIM. Financial incentives, such as bonuses from the healthcare basket fund, are provided to encourage the adoption of EHR systems. Nonfinancial incentives include efforts to centralize EHR systems to reduce connectivity costs. Training programs have been established, with academic institutions offering degrees in health information systems and health informatics. The Maternal and Child Survival Program offered technical assistance by assigning a full-time advisor to work within the ICT unit of the MOH.[54] The strategy emphasizes a gradual connection of health facilities to the GoTHoMIS system, with trainers deployed as facilities come online.

[48] Alpha Nsaghurwe et al., "One country's journey to interoperability: Tanzania's experience developing and implementing a national health information exchange," *BMC Medical Informatics and Decision Making*, April 2021, Volume 21.
[49] *Digital Health Strategy July 2019–June 2024*, United Republic of Tanzania Ministry of Health, Community Development, Gender, Elderly and Children, July 2019.
[50] Alpha Nsaghurwe et al., "One country's journey to interoperability: Tanzania's experience developing and implementing a national health information exchange," *BMC Medical Informatics and Decision Making*, April 2021, Volume 21.
[51] "HISP Tanzania: Advancing digital innovations to empower information for action," HISP UiO, April 19, 2024.
[52] Patricia Boshe, "Tanzania: NIDA IDs for civic services, or not?" Research ICT Africa, July 2021.
[53] "Work to develop the Tanzania Universal Identity Number Jamii Namba has started," March 12, 2024.
[54] Alpha Nsaghurwe et al., "One country's journey to interoperability: Tanzania's experience developing and implementing a national health information exchange," *BMC Medical Informatics and Decision Making*, April 2021, Volume 21.

Tanzania's interoperability challenges and solutions

Our research suggests that Tanzania has faced four main challenges on its health interoperability journey, which the country has sought to address and is still addressing:

First, Tanzania's ability to develop and maintain high-quality digital health solutions is hampered by inadequate ICT staff. Tanzania has approached this challenge by bringing together technical personnel from across the government to share knowledge and expertise, collaborate on projects and problem solving, and provide guidance and assistance to colleagues.[55]

Second, Tanzania faces inconsistent coding standards in its legacy systems, including custom-made standards, which create hurdles for data comparison and exchange. To bridge the gap between custom codes and standardized formats, leaders took a three-pronged approach: creating a new standard list, building a translation system, and phasing in the switch.[56]

Third, the country has needed ongoing funding and technical support from partners to maintain and expand its healthcare systems. To address this sustainability risk, the MOH strengthened the sustainability of donor-supported efforts by owning the source codes of the full system (for example, the HIM, data repositories, and terminology services) and by aligning locally trained staff to maintain and manage the system.[57]

Fourth, the current ICT infrastructure is not adequate to support digital health solutions. To overcome this challenge, Tanzania's government aims to strengthen the ICT infrastructure by collaborating with foreign governments and securing financial help in the form of loans and implementation projects.[58]

Choosing a path forward

Establishing and maintaining a successful health data interoperability system can take various forms depending on a country's context and its specific digital health ecosystems. Context challenges include insufficient connectivity, shortages of skilled personnel, a reliance on donor funding, and challenging healthcare governance structures. Challenges for digital health ecosystems include low adoption by providers and vendors and insufficient adoption of standards. The most effective strategy to address challenges will vary according to each national context and capabilities and the availability of funding. While there is no single path forward for all, multiple paths can lead to positive outcomes from greater interoperability.

[55] *Digital Health Strategy July 2019–June 2024*, July 2019.
[56] Alpha Nsaghurwe et al., "One country's journey to interoperability: Tanzania's experience developing and implementing a national health information exchange," *BMC Medical Informatics and Decision Making*, April 2021, Volume 21.
[57] Alpha Nsaghurwe et al., "One country's journey to interoperability: Tanzania's experience developing and implementing a national health information exchange," *BMC Medical Informatics and Decision Making*, April 2021, Volume 21.
[58] Motolani Agbebi, Gong Xue, and Zheng Yu, *China-powered ICT infrastructure: Lessons from Tanzania and Cambodia*, South African Institute of International Affairs, Policy Briefing 252, November 2021.

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[59] For more information, see the Exemplars in Global Health website on digital health.

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