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Vital Wave℠

UNDERSTANDING TOTAL COST OF OWNERSHIP FOR DIGITAL HEALTH

A Budgetary Reference Document on Digital Supply Chain Systems for Investors, Implementers, and Governments

Vital Wave℠

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This reference document is part of a larger body of work conducted by Digital Square, Vital Wave, and a consortium of partners to understand market forces in digital health in low-resource settings. Through a series of analyses, the partners have identified current challenges to sustainability, outlined cost drivers for digital health software, and defined recommendations that would lead to a more sustainable digital health marketplace. To learn more, please visit: https://digitalsquare.org/market-analytics.

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Understanding Total Cost of Ownership for Digital Health

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Background and Introduction

The success of a digital health intervention (DHI) is enabled by a number of distinct yet interrelated ecosystem elements including alignment with national digital strategies, sustained political commitment and leadership, appropriateness for the context, active participation of stakeholders, and the adoption of a detailed implementation plan.

From a financial perspective, however, long-term success has one underlying requirement: the alignment of revenue and expenditures over the lifecycle of the intervention. This alignment can only be attained when *all* costs of an intervention are understood and documented. Too often, governments, donors, and implementers working in low-resource contexts have lacked visibility to this information, leading to underfunding, turnover, and low impact.

This **Total Cost of Ownership (TCO) Analysis** aims to fill that information gap as part of a broader set of activities conducted by Digital Square, PATH, and Vital Wave to shed light on digital health market dynamics in low-resource settings. This larger body of work is intended to inform the behavior of governments and donors and guide investment strategies for digital health by highlighting how to make markets more efficient and equitable. The lack of authoritative costing and cost outcomes research repeatedly emerged as root causes of market inefficiencies in initial analyses conducted by the partners.

Based on a comprehensive evaluation of costs for five, nationally scaled logistics management information systems (LMIS) used to manage stock and distribution of life-saving commodities, this reference document presents illustrative costs associated with the adaptation of an existing open-source global good for LMIS and its implementation and operation over a period of five years across a variety of different low-resource contexts. The document contains a comprehensive definition of cost categories as well as example costs and observed variances in cost for each category. It reveals key cost drivers and how costs may vary in different contexts. While these illustrative costs and variances are based on nationally scaled LMIS implementations, similar cost drivers and variances are expected for the implementation and operation of other types of DHIs deployed nationally at health facilities within the public health system. Understanding them will help inform the development of DHI proposals and budgets by implementers, the vetting of proposals and budgets by prospective investors, and the socialization and coordination of financing and partnership by government officials.

The analysis is grounded in secondary research, including foundational sources[1] on defining and estimating the costs of DHIs as well as in-depth interviews with key stakeholders, including investors, government officials, global and in-country implementing partners, and global LMIS experts. It also complements and informs a parallel Digital Square analysis aimed at modeling the health and cost outcomes associated with investments in LMIS for managing health commodities. Together, these analyses provide new tools and guidance for investors, government officials, and implementers looking to maximize the impact of their digital investments.

[1] Foundational secondary sources include: WHO's Digital Implementation Investment Guide and Classification of Digital Health Interventions v1.0, USAID's Software Global Goods Valuation Framework, and Global Health Cost Consortium's Reference Costs for Estimating the Costs of Global Health Service and Intervention.

How to Use This Information

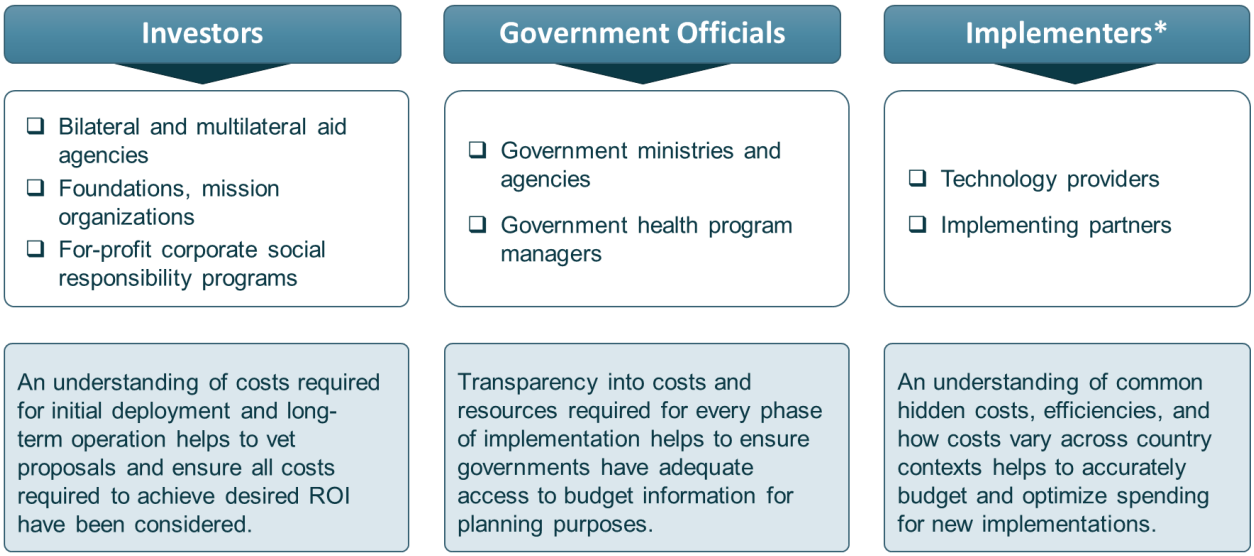
Value for Readers

Investors, government officials, and implementers can use this document to understand the totality of costs for a DHI over its first five years of implementation and operation and help estimate, validate, and socialize anticipated costs for their specific contexts.

The reader will find common hidden costs quantified and explained and will understand the cause and magnitude of common cost variances. Budgeting appropriately for every implementation context will substantially improve the odds of success and increase the potential impact for any DHI. Additionally, detailed descriptions of cost categories, the activities and resources they comprise, and illustrative cost data and included. When combined with additional budgeting and investment planning tools[2], this understanding provides the reader with the level of detail required to ensure their DHI budgets are comprehensive.

Lastly, the reader is given key questions for developing, vetting, and obtaining buy-in on budgets for all phases of a DHI implementation. These are questions that help investors, government officials, and implementing partners ensure their investments in time, capital, and human resources safeguard the success and long-term sustainability of the intervention. These intended user groups are defined and described in Figure 1, below.

Figure 1. Value of this reference document for investors, government officials, and implementers.



* Global, regional, or locally-based implementing partners typically provide project management, software development, deployment, training, support, and maintenance as a service to governments.

An **investor** is any actor in the market providing short or long-term funding for a digital health intervention. The investor offers project and innovation funding, strategic and technical expertise, and helps shape the digital health ecosystem. The investor may be a single actor funding an

[2] For additional budgeting and investment planning tools please visit: https://www.mcsprogram.org/resource/digital-health-investment-review-tool/ and https://confluence.dimagi.com/display/commcarepublic/Budgeting+for+a+Project.

entire DHI or funding a specific cost component (e.g., telecommunication costs only or initial deployment costs).

A **governmental official** is any government actor providing funding, human resources, or oversight of an implementation and ongoing operations at the national or subnational level. In low-resource contexts, funding often comes from international donors, yet the "customer" and ultimate owner of the system is the government health program owner.

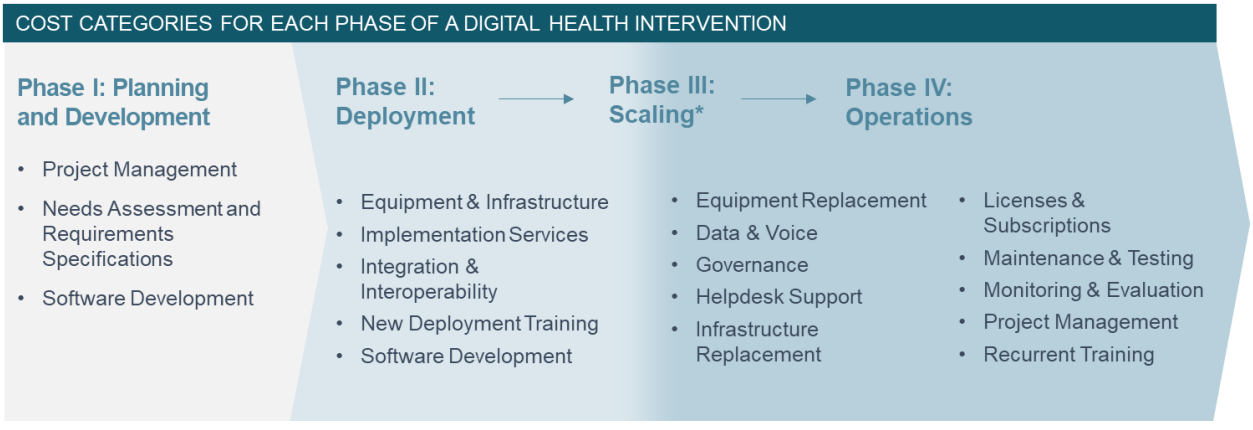
An **implementer** may manage the implementation, supply the core software, or adapt an existing software to meet program goals. Often the implementer is a consortium of partners engaged in several aspects of the implementation, including software development, training, partner management, technical support, system, and infrastructure upgrades.

Implementation Cost Categories by Phase

While every implementation is different, all DHIs entail the same types of activities and resources across their implementation lifecycle, from managers who develop and track implementation against project plans, to software developers and technical support staff who enhance and maintain the software, to the health facility infrastructure and equipment that allow health-facility staff to interact with the system.

Costs in this reference document are organized into phases of a DHI's lifecycle, from project planning and development, through deployment, scaling, and ongoing operations (see Figure 2, below). For a detailed definition of each cost category and a template spreadsheet for recording costs by category, please see Appendix A. Costs for each phase are presented in the sections below and split into cost categories, detailing the resources required for each phase (e.g., human resources, overhead, assets), example costs, key drivers of cost, and illustrations of variances seen across all implementations evaluated.

Figure 2. Cost categories by phase.

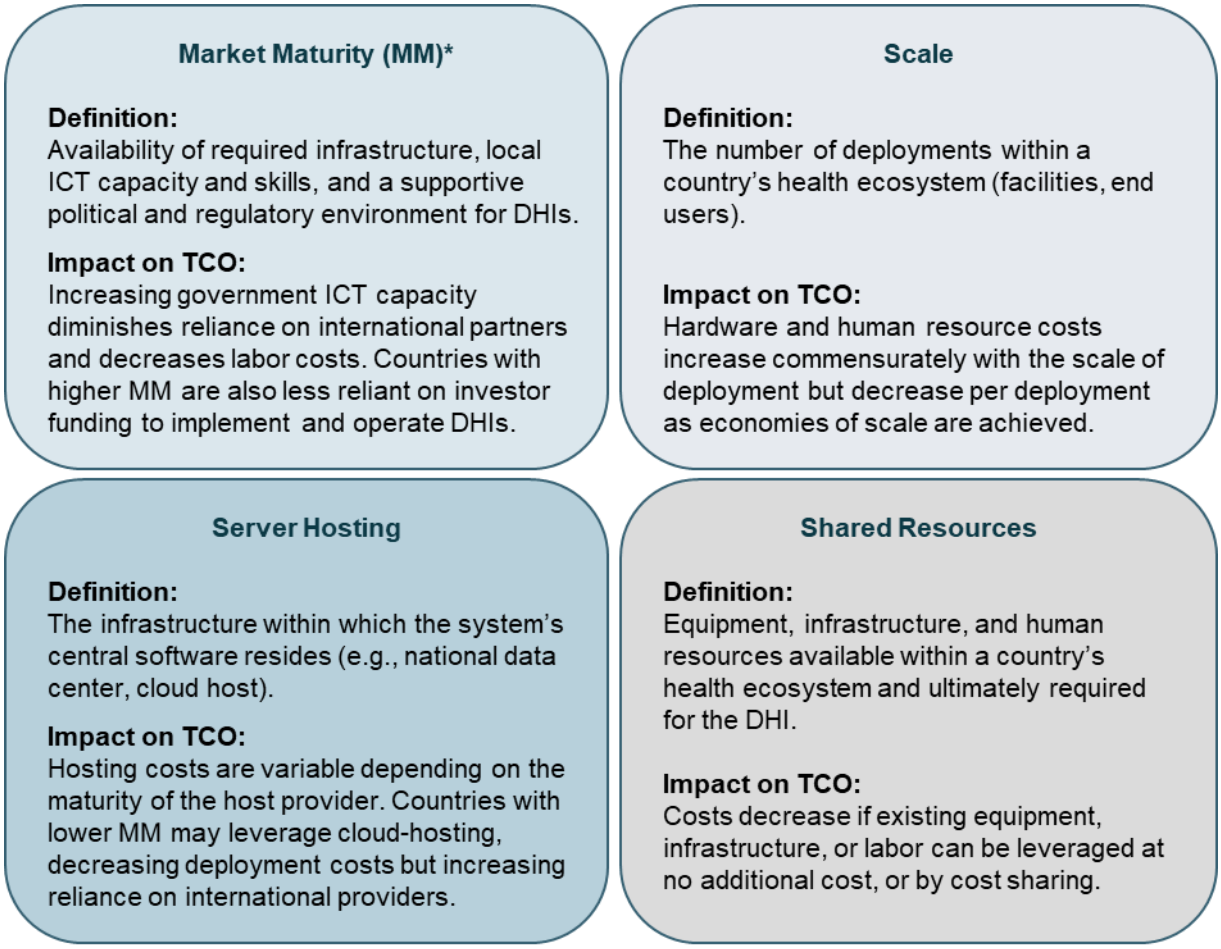


* Cost categories for scaling include a blend of deployment and operations cost categories.

Each phase can be broken down into three main summarizing factors: the total costs for a "model" implementation (a generic, example implementation based on actual data from country implementations evaluated for this research), its relative percentage of the five-year TCO, and primary drivers of cost. The variances in costs observed across all five implementations evaluated

are also presented to illustrate how costs might change depending on the specific context of implementation. Key drivers of variance include the digital health market maturity (MM)[3] of the country, the scale of the implementation, where and how the software and servers are hosted, and whether or not key resources such as health system staff and health facility infrastructure and equipment are shared across multiple DHIs. See Figure 3, below, for key drivers to cost variance observed in this analysis.

Figure 3. Key drivers of cost variance.



* Only implementations in LMICs with market maturities 1-3 were evaluated for this analysis. See Digital Square's Market Maturity Methodology here: https://wiki.digitalsquare.io/index.php/Market_Maturity_Methodology. Country market maturity is dynamic and typically rises alongside its GDP per capita.

In addition to illustrating key cost variances, each DHI implementation phase includes a detailed description of costs for the model implementation and key data points across all implementations, highlighting the significant variances in cost and why. Each phase concludes with a summary and key questions that investors, government officials, and implementers should consider when planning new DHI implementations.

[3] See Digital Square's Market Maturity Methodology here: https://wiki.digitalsquare.io/index.php/Market_Maturity_Methodology.

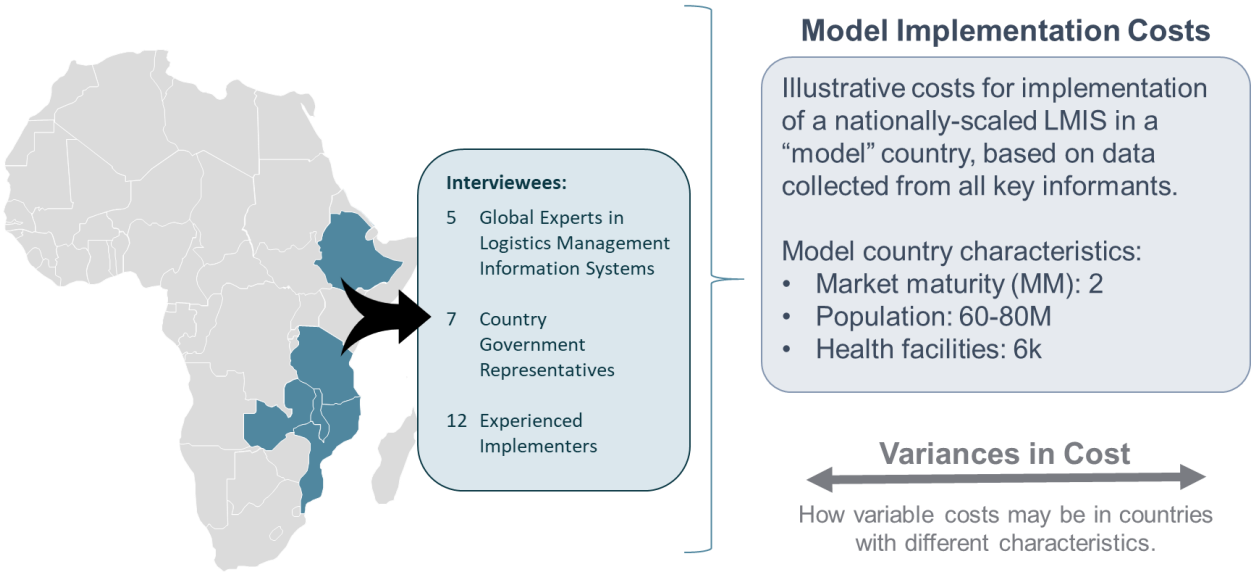
Total Cost of Ownership Analysis

Model Implementation

To present a generic analysis applicable across various low-resource contexts, stakeholders involved in LMIS implementations in five different countries were interviewed for this research. A "model implementation," based on cost data and experience from all implementations evaluated and supplemental interviews with global experts in LMIS, was established to present a generic example for the reader to use as a comparison. The model implementation presents the costs required to implement an LMIS at a national scale in a country with a level-two digital health market maturity (MM 2) across 6,000 health facilities, serving a population of approximately 60-80 million people. While the model implementation is based on actual implementation costs from national-scale implementations conducted between 2015 – 2020, the costs presented here have been rounded for readability and presented as costs for a generic country matching these high-level characteristics. This analysis is a generic reference upon which future implementations can be modeled (note: inflation and the time value of money should be taken into account for future implementations).

Model implementation costs and comparative variances are based on a combination of initial budgets, actual budgets, primary research interviews, and review of secondary documentation on LMIS implementations across several countries (see Figure 4, below). All costs are presented in USD.

Figure 4. Snapshot of the primary data sources used to develop the model implementation.



The model country has a national digital health strategy and limited but available ICT infrastructure and technical capacity. The nationally-scaled implementation of its supply chain system to manage the supply line for all essential medicines in approximately 6,000 primary public

health facilities (one facility per every 10,000 people) began over five years ago, providing retrospective costs.

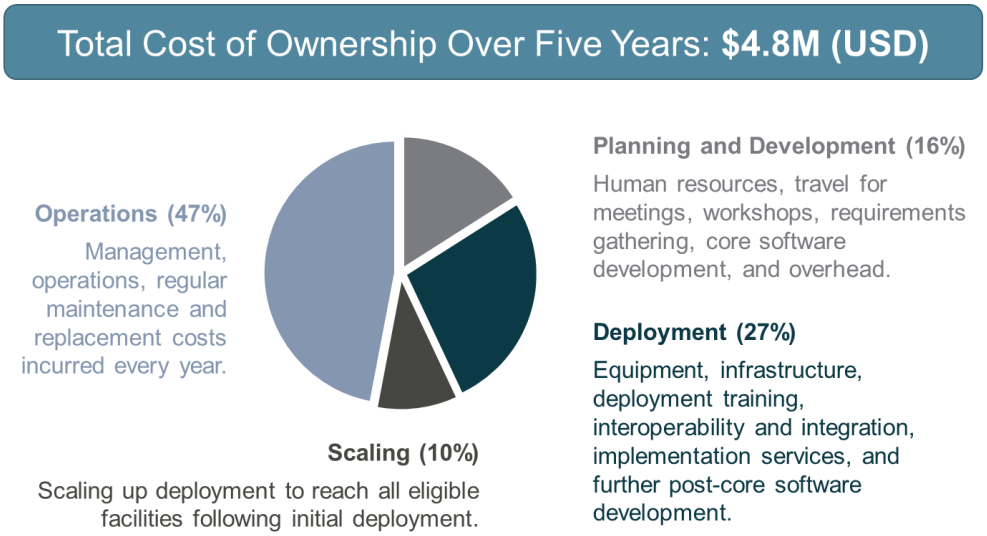
The system is a mature, fit-for-purpose platform based on an open-source global good[4], the Open Logistics Management Information System (OpenLMIS)[5], featuring inventory management, stock level notification, and distribution functionality and considered a supply chain management DHI to manage inventory and distribution of health commodities and stock level notification. System data is cloud-hosted, though eventual migration to servers within the national data center is planned.

The model country's government contributes shared human resources and equipment (hardware and infrastructure) to the implementation at existing health facilities as needed. Its primary implementing partner is an international vendor with in-country subsidiary offices dedicated to managing the supply chain system.

Total Cost of Ownership

The TCO over five years for our model implementation, including costs to deploy and scale an LMIS solution nationally across 6,000 health facilities, stood at $4.8M dollars. This five-year TCO can be broken into four key phases, as presented in Figure 5, below.

Figure 5. Total cost of ownership over five years for model implementation.



These phases and their costs are mostly sequential in time. For example, software development appears in each of the four phases, with differing objectives for each phase. However, some costs overlap in time. For example, maintenance and monitoring and evaluation (M&E) have been coded as strictly Operations phase costs but may start as early as Year 1, while the implementation is still being deployed. The following sections describe phase costs, and their observed variances, in detail.

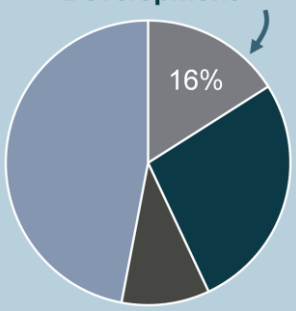
[4] Digital health global goods are defined as tools that are adaptable to different countries and contexts. This reference document focuses specifically on software global goods, defined as software tools that are free and open source (FOSS), and used to manage, analyze, or transmit health-related data, with proven utility in several settings. Please see more information here: https://digitalsquare.org/global-goods-guidebook

[5] Please see more information here: https://openlmis.org/

Phase I: Planning and Development

The costs associated with **Planning and Development** are incurred as initial, one-time-only, capital expenditures. These costs are related to human resources, travel for meetings, workshops, requirements gathering, project management and overhead, and other direct and indirect costs to carry out planning and development activities.

Model Implementation Costs



Phase I Costs:
$750k (16% of TCO)

Largest Cost Categories in Phase I:

- Software Development
- Project Management

Costs for Phase I activities include costs from multiple participating stakeholder organizations. However, limited budgetary transparency among key stakeholders is typical during this phase of the implementation.

In our model implementation, the highest Phase I cost category is **Software Development**, representing 77% of the Phase I costs or $580k. This cost is primarily attributed to human resources (software developers) dedicated to adapting the core, open-source software platform and localizing it for country-specific needs. While the international implementing partner kept **Project Management** costs for this phase relatively low (as a percentage of TCO compared to all implementations evaluated) by setting up an in-country office, staff in the office were dedicated solely to this implementation, meaning all direct and indirect overhead costs for the in-country office were attributed to the project implementation budget. In-country staff included project managers, solution advisors, program managers, M&E staff, a country director, a digital solutions director, software developers, software development managers, and administrative staff.

Variances observed for Phase I cost categories across all implementations evaluated are largely attributable to the market maturity of the country. In the lowest market maturity countries (MM 1), implementations relied more heavily on human resources from international partners, driving up TCO due to higher salary costs and international travel. Where multiple stakeholders participated in the implementation, TCO costs increased for the **Project Management** cost category.

Table 1 below presents the model implementation's total costs and the percentage of TCO for this phase. The range of variance across all implementations evaluated illustrates how each cost category, as a percentage of TCO, varied due to different country contexts. The primary cost drivers that pushed costs for that category up or down are also given. These cost categories are mutually exclusive and are listed from highest to lowest for our model implementation.

Table 1. Phase I costs and % of TCO by cost category.

Phase I: Planning and Development			
Cost Category	**Model Implementation Costs**	**% of TCO** (Model Implementation and Variance Across All Implementations Evaluated)	**Primary Cost Drivers**
Software Development, Customization, Localization	$580k	12% (0% – 25%)	Labor required to develop, adapt, customize, and localize the software for country-level project needs and functionality.
Project Management	$155k	3%	Labor (e.g., programmatic, technical, administrative), travel for meetings and workshops, and organizational overhead.
Needs Assessment, Requirements Specifications	$15k	0.3%	Labor required for landscaping, gaps analysis, requirements development, and documentation.

Key Drivers of Variances

Key drivers of variances related to **planning and development** costs across implementations can include the following. Details on specific cost categories and their cost drivers are described in the subsections below.

Low Market Maturity: Countries with low digital health market maturity (MM 1-3 countries) rely, to some extent, on international partners and vendors, if not entirely where government ICT capacity is low (MM 1 countries). As the number of stakeholder organizations involved in project planning and development increases, the number of human resources and associated organizational overhead can drive up costs.

Costs Per Category and Variance

Software development, customization, and localization costs include, for implementations evaluated, developing enhancements to the core software platform (an existing open-source global good) and adaptation of the core software to address country-specific project needs or desired functionality that may not yet be supported. Customization of the core software may also be necessary to enable interoperable integration with other health IT systems at the country level. This customization could be performed by the primary software vendor, the implementation vendor, or a combination of resources from the project team. Localization includes costs to adapt the software user interface for specific locations, such as language adaptations or specialized terminology.

In our model, implementation costs incurred for software development were $580k, representing the bulk of Phase I costs (12% of TCO). On average, software development costs were $310k across all implementations evaluated, representing a range of 7% to 12% of TCO. While all implementations evaluated were built on top of an existing global good, this early phase software development budget helped ensure the software was adequately fit for deployment and also resulted in core contributions back to the core software platform to the benefit of future implementations. (Note: the breakdown of core software enhancements to country-specific customizations was not assessed in this research.)

Project management includes costs incurred for project planning and scoping, day-to-day project management, change management, managing signoffs, and procurement. Project management costs are comprised primarily of human resources costs and are driven largely by the number of stakeholder organizations and requisite staff, travel, and organizational overhead involved. In addition to creating and managing detailed work plans and timelines, effective project management covers a broad range of activities in this phase, including the following.

- Project planning and scoping with key stakeholder organizations and staff to set the overall vision and strategy. Costs are directly related to the number of individuals participating.
- Change management, including identifying expected business process and staffing changes required to effectively implement new digital health technologies. Based on primary research interviews, change management tasks are not typically budgeted nor reported, introducing risks to uptake by health system staff and training budgets. While changes in staff roles and responsibilities are typically addressed in training and thus can be represented as a portion of training costs, these are truly “one-time” costs to support existing staff in adjusting to their new roles and, if budgeted separately, can help implementers budget initial and recurrent training costs more accurately.
- Final signoff for DHI project plans and budgets. These activities include finalizing the budget and obtaining stakeholder approval, which can require significant effort when many partners and stakeholders are involved, as costs include labor and travel costs for each participating stakeholder.
- Equipment and hardware procurement for the planned deployment including labor and time required for identifying and documenting requirements, creating requests for proposal (RFPs), evaluating RFPs, and contracting partners (e.g., software implementers and hardware vendors).

In our model implementation, several stakeholder organizations participated in the implementation, each with their own human resources and direct and indirect project overhead costs. Project management costs incurred were $155k, or 3% of TCO, which was closely in line with the percentage of TCO for this cost category for all implementations evaluated.

Some international implementing partners set up in-country subsidiary office(s) dedicated to the implementation. While this helps mitigate long-term sustainability issues by building specific system expertise for in-country ICT human resources, it is important to note that it may **increase** costs for this early phase as both internationally-based and in-country staff typically participate in project planning, scoping, and management activities. For example, in one implementation

evaluated where this was the case, project management costs were roughly two-thirds of all costs for Phase I activities.

Needs assessment and requirements specification costs include assessing the current state and enabling regulatory environment, assessing integration, migration, reporting requirements, conducting business process analysis, data modeling, and site and server assessment.

In our model implementation, costs incurred were only $15k or less than 1% of TCO. Other implementations evaluated incurred costs under $30k, representing an equally small portion of TCO. The use of an existing open-source, global good software platform as the basis for the country system helped keep requirements specification to a minimum.

Costs for this category will vary based on the complexity of the solution and resources required, scale (e.g., geographic breadth of implementation and variability of user needs), location of the resources involved in this activity, and associated travel costs. The number of stakeholder organizations and technology vendors drive up costs, especially when international travel is required.

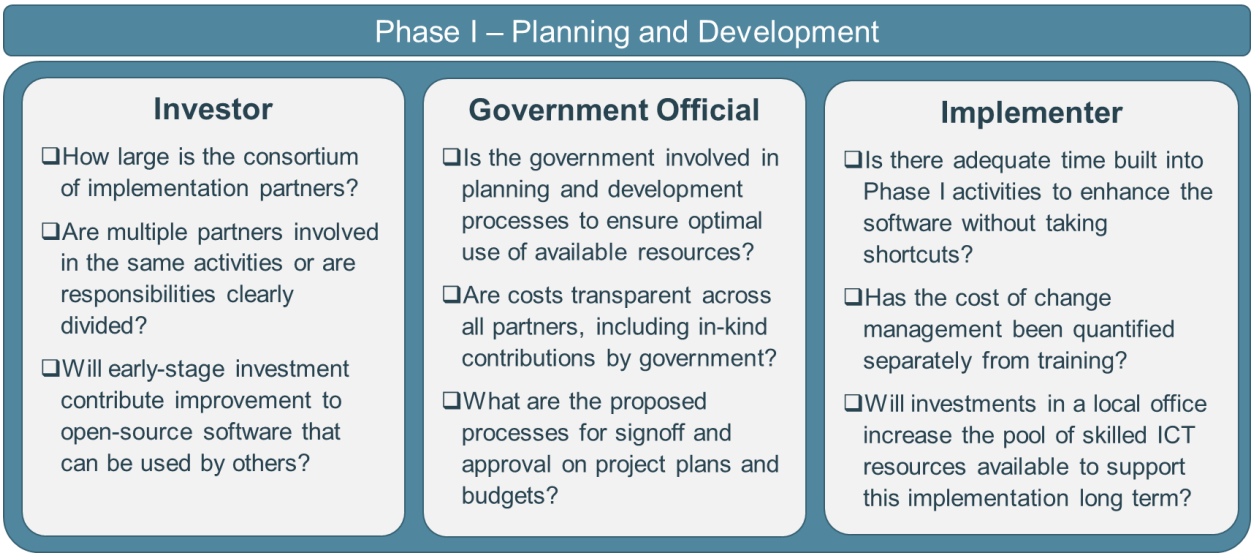
Key Takeaways

The early phases of any DHI implementation present an opportunity to invest directly in core enhancements to open-source global good software platforms, yielding new features and improvements that may benefit many future implementations to come. This early phase is the protected portion of a project, prior to deployment, where the foundations for a multi-year implementation are laid and present a safe space for in-country developers to hone system-specific skills and customize software to meet the needs of their users. This phase represents one of the greatest opportunities for investments in technological innovation and core product improvement.

However, early-phase costs for planning and development are not always transparently shared among partners, as they are driven heavily by human resource costs and organizational overhead, which are sensitive data to share. When cost data from multiple partners working together on an implementation was combined, total project management costs were higher than any individual partner expected. Multi-partner project management, travel, and organizational overhead increase directly with the number of partner organizations involved. If these costs are not made transparent, resources available for software development and technology skills development may be squeezed, resulting in compressed software development timelines, short cuts, and poor development practices, and increased effort required in later phases.

Figure 6, below, presents key questions to be asked by investors, government officials, and implementers when assessing, socializing, and budgeting planning and development costs.

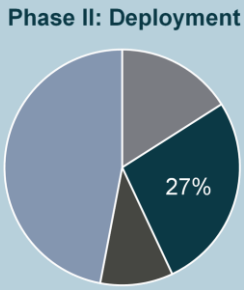
Figure 6. Key questions for stakeholders.



Phase II: Deployment

Deployment phase costs are characterized as capital expenditures associated with deploying the solution to a set number of locations. For implementations evaluated, this was typically defined in a three-year donor contract. During this phase, the DHI implementation is deployed or "goes live" to a specified number of health facilities and end-users. The target deployment number may be limited to a small pilot setting or a large percentage of all possible sites. There is typically some deployment target that is a subset of all possible locations either to allow initial deployment to be evaluated prior to subsequent funding rounds. The deployment scale varies based on the investor, donor, and government funding available and the maturity of the digital health solution. Mature, fit-for-purpose solutions are capable of more significant deployments based on the learning from other implementations.

Model Implementation Costs



Phase II Costs:
$1.3M (27% of TCO)

Largest Cost Categories in Phase II:

- Deployment Training
- Infrastructure
- Software Development

Deployment costs are typically characterized as "startup" costs, although the actual deployment activity occur over the entire initial contract term (three years for implementations evaluated). Cost categories include one-time costs for equipment (e.g., laptops, phones), infrastructure (e.g., backup generators, hosting, internet connectivity, power), new deployment training, implementation services, further interoperability updates and system integrations, and further software development to address issues and change requests encountered during the deployment time period.

In our model implementation, deployment costs were $1.3M, with the largest cost category by far consisting of $980k or 21% of TCO for **new deployment training**. Training costs included five days of fixed, classroom-based training costs for facility rentals, travel (both international and in-country trainers), per diem for trainees and trainers, and labor for a cadre of trainers. **Equipment** costs (e.g., laptops) were originally budgeted for the implementation at over $400k (assuming all new hardware would be required); however, implementers were able to decrease the equipment costs by 90% by working with government officials to leverage existing health facility equipment for the system. **Infrastructure** costs were subsequently the second highest cost for this phase.

Costs in implementations evaluated varied substantially based on the market maturity of the country and, importantly, the extent of **resource sharing** between the government and implementing partner organizations.

Table 2 below presents the model implementation's total costs and the percentage of TCO for this phase. The range of variance across all implementations evaluated illustrates how each cost category, as a percentage of TCO, varied due to different country contexts. The primary cost drivers that push costs for that category up or down are also given. These cost categories are mutually exclusive and are listed from highest to lowest for our model implementation.

Table 2. Phase II costs and % of TCO by cost category.

Phase II: Deployment			
Cost Category	**Model Implementation Costs**	**% of TCO (Model Implementation and Variance Across All Implementations Evaluated)**	**Primary Cost Drivers**
New Deployment Training	$980k	21% (0% – 25%)	Number of end users and type of training delivery (e.g., eLearning platform, classroom-based training, train-the-trainer or on-the-job training program).
Infrastructure	$145k	3%	Type of server hosting and number of health facilities requiring internet connectivity.
Software Development	$70k	1%	Development labor necessary for major modifications, scope expansion, ongoing product expansion.
Integration & Interoperability	$60k	1%	Labor necessary to set up communication and standards compliance between systems.
Equipment	$45k	1%	Type (e.g., desktop computers, tablets, phones) and number of devices required for end users.

Key Drivers of Variances

Key drivers of variances related to deployment costs across implementations can include those listed here. Details on specific cost categories and their cost drivers are described in the subsections below.

Low market maturity: Low digital health market maturity **increases** deployment costs as countries rely on an outside implementing partner for training and software development labor due to the low availability of in-country ICT capacity.

Shared resources: Where capital and human resources (e.g., shared hosting, shared human resources, shared equipment) support multiple digital health systems deployment costs attributed to any single specific DHI can **decrease** substantially.

Costs Per Category and Variance

New Deployment Training includes costs associated with developing and deploying a training program and associated training curricula and material. Costs are driven largely by the delivery approach (e.g., eLearning, classroom-based training, train-the-trainer, on-the-job training) and include labor, travel, facility rentals (e.g., for classroom-based training), and per diems for trainers and trainees.

Our model implementation trained health facility workers in a fixed classroom and onsite setting, incurring substantial costs for labor and travel for both international and in-country trainers, per diems, and facility rentals. At 21% of TCO, initial deployment training was the largest cost category

overall for the entire five-year period for our model implementation. This posed a substantial concern to the sustainability of long-term training that had to be addressed before subsequent rounds of funding could be obtained. (See **Phase IV: Operations** for more detail on the evolution of the model implementation's training approach.)

Comparing two implementations, on-the-job training for a mobile application cost ten times less (as a % of TCO) than classroom-based training for a different laptop-based application.

Variance in cost for new deployment training across all implementations evaluated depended largely on both the training approach and the type of device (computer vs. mobile phone) utilized for the DHI. In one implementation evaluated with a similar training approach to our model implementation (classroom and onsite training), new deployment training comprised more than half of all deployment phase costs. In another implementation, the type of device utilized, a mobile phone, was reported to have kept the cost of new deployment training substantially lower, given users familiarity with mobile applications for other work, at just a sixth of deployment phase costs, comprising just 2% of TCO.

Infrastructure costs include electricity, data center hosting, and connectivity (e.g., internet access, SMS costs, backup generator costs). Costs also include internet bandwidth or mobile data required for the system. Costs for this category were driven largely by whether new infrastructure procurement was required for the implementation or if existing health facility equipment was shared and used across multiple programs.

Although our model implementation leveraged shared equipment already available at health facilities, it invested substantially in internet and data costs required to operate the supply chain system on a day-to-day basis, spending ~$130k for network and communication costs and ~$15k for international, distributed cloud server hosting at a total of 3% of TCO.

Other implementations evaluated shared even more resources, incurring only server hosting costs from $5k to $40k at a cost of less than 1% of TCO. Where digital health market maturity is low or where limited infrastructure exists, costs to procure the required equipment may drive up initial capital expenditures. In these cases, generators may need to be procured to ensure that the system remains available during power outages. Solar chargers, car chargers, or spare batteries for reliable device charging may also need to be procured in low resource settings.

Software development in this phase covers significant modifications to address issues or changes requested during deployment and ongoing enhancement of the software. This category can incur additional, unexpected costs if initial software development work in Phase I is rushed or squeezed. Costs also include development labor for report generation and adding unplanned features to support new functionality, e.g., COVID vaccine rollout.

When comparing software development costs across all implementations evaluated, our model implementation incurred lower development costs on its laptop-based software as a percentage of TCO than another implementation that spent more time debugging and improving its custom mobile application. While the mobile application was easier and less costly in the training category, it required more software development (as a % of TCO) than the model implementation's more mature laptop application. Costs for software development of mature digital solutions require less development work, coupled with a compressed deployment schedule, driving down software development costs.

Integration and interoperability costs include the labor necessary to set up communication and standards compliance between the new solution and existing health systems, configuration, and required implementation work. Integration and interoperability activities and costs may also occur during initial software development or in the operational phase during product maintenance and testing.

Our model implementation's integration and interoperability costs were $60k, or just 1% of TCO, to complete an integration with a mature enterprise resource planning software during this phase. Had additional integrations been required, for example, with other systems hosted physically at each health facility (e.g., legacy desktop applications, laboratory equipment systems) or with immature systems that did not adhere to interoperable standards for data exchange, these costs would necessarily increase. Other implementations evaluated did not report costs when no integration or interoperability with other health systems was planned, or activity occurred during a different phase (e.g., initial software development or maintenance and testing).

One key factor of variance for this category is the maturity of a country's digital health ecosystem. Where mature digital health systems exist, there are more digital health systems with which to integrate, and investments in integration and interoperability to ensure data can be exchanged between different systems actually **increases** labor costs as a percentage of TCO for this category. However, this increase in cost to establish system integrations opens up important opportunities to reduce redundant data collection and siloed data, ultimately **decreasing** long-term operational costs and improving access to data for decision making.

Equipment includes centralized capital equipment (e.g., servers, storage devices, developer and program manager laptops, routers, switches), distributed equipment (e.g., desktops, tablets, mobile phones for frontline health workers), security equipment (e.g., secure boxes, locks, other equipment to secure devices), redundancy and disaster recovery (e.g., additional costs or backup equipment for failover redundancy or in the case of disasters).

The model implementation initially budgeted over $400k for desktop computers across facilities scheduled for deployment in this phase. However, implementers and government officials agreed that use of existing desktop computers available in health facilities scheduled for deployment would be feasible, reducing the overall equipment budget for this phase by 90%.

Most other implementations evaluated also utilized existing devices at health facilities at no cost. For example, one country utilized computers at health facilities that had been procured previously for the rollout of DHIS2 (a facility-based health management information system). In contrast, another implementation evaluated procured 900 new mobile devices at $270k, nearly two-thirds of all deployment phase costs. As noted in both training and development categories above, the use of mobile phones had a significant impact on other cost categories, with comparatively lower training costs but higher development costs (as a % of TCO).

In countries with higher market maturities (MM3+), the government may allocate health facility equipment costs in annual health system budgets. If implementations utilize existing health facility equipment in these environments, equipment costs may be omitted from DHI deployment budgets altogether. Alternatively, if the equipment is procured for a different program (e.g., desktop computers used in health facilities for DHIS2 monthly performance reporting in one implementation evaluated), that program may bear the entire cost of replacement ($60k over five years, for this example). In any shared resource environment, costs can be split or covered by

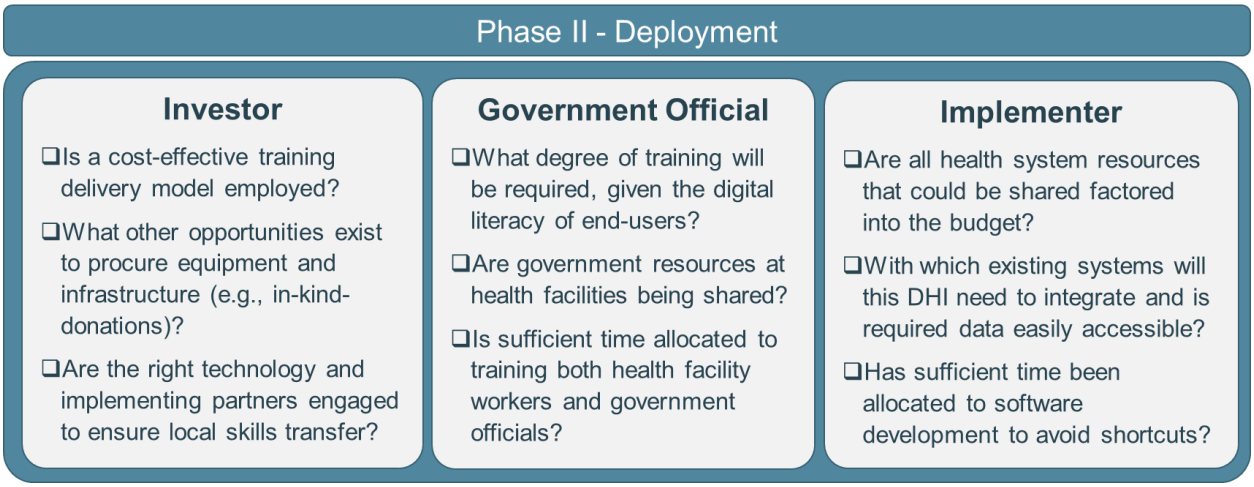
one or many different programs based on relative utilization, which may result in **higher** governance costs for coordination across programs but **lower** equipment costs overall for all programs.

Key Takeaways

Deployment phase activities present implementers with important choices on the training model, equipment, and infrastructure, which can substantially impact TCO through shared equipment resources at health facilities (e.g., hardware and telecommunications) and human resources where available for implementation services, integration, interoperability, and training as often similar human resources are engaged in these activities.

Figure 7, below, presents key questions to be asked by investors when determining when budgeting the size of deployment, by government officials to ensure long-term sustainability and the ability to coordinate across government and partner stakeholders for a successful DHI, and by implementers when developing their deployment budgets and resources.

Figure 7. Key questions for stakeholders.

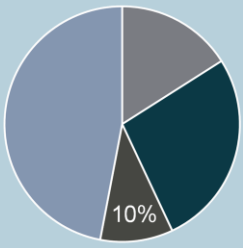


Phase III: Scaling

For this analysis, scaling a DHI implementation refers to expanding its deployment across a wider geographic area or number of facilities or end-users than originally scheduled for its initial deployment. While the activities conducted are similar to those conducted during the Deployment phase, the Scaling phase is typically distinguished by a subsequent round of funding and therefore, for budgeting purposes, occurs after initial deployment. Costs are driven by the number of facilities targeted for deployment and requisite costs to deploy to the solution per facility (e.g., equipment, infrastructure, training, and additional software development).

Model Implementation Costs

Phase III: Scaling



5-Year Scaling Cost:
$500k (10% of TCO)

Largest Cost Categories:
- Equipment

Scaling for our model implementation incurred a cost of $500k or 10% of TCO to achieve full scale at 6,000 health facilities, reaching all remaining facilities beyond the initial set of facilities covered during the deployment phase. In another implementation evaluated, scaling represented $700k or 22% of the 5-year TCO. The variance is attributed to the equipment costs required to scale the solution given its procurement of new mobile phones for end users, compared to use of existing desktop computers at facilities in the model implementation.

Table 3 below presents the model implementation's total costs and the percentage of TCO for this phase. The range of variance across all implementations evaluated illustrates how costs, as a percentage of TCO, varied due to different country contexts.

Table 3. Phase III costs and % of TCO by cost category.

Phase III: Scaling			
Cost Category	**Model Implementation Costs**	**% of TCO (Model Implementation and Variance Across All Implementations Evaluated)**	**Primary Cost Drivers**
Scaling	$500k	10% (0% – 25%)	Equipment and infrastructure required per facility or end user, beyond those procured for initial deployments.

Legend: Cost for model implementation; % of TCO for model implementation; Range of variance across all implementations

Key Drivers of Variances

Key drivers of variances in **scaling** costs across implementations can include those listed here. Details on specific cost categories and their cost drivers are described in the subsections below.

Low market maturity: Low digital health market maturity **increases** scaling costs as countries rely on an outside implementing partner for training, implementation services, and development labor due to low government ICT capacity scaling costs **increase**, driving up TCO.

Scale: Scaling costs for the implementation **increase** as the number of additional deployments required in this phase, and their geographic diversity, increases. This can be driven by the budget allocated in early funding rounds and subsequently, the target number of deployments scheduled in the deployment phase. Often, facilities that are easier to reach and support are targeted first, for early successes, and the facilities targeted during scaling are harder to reach and may face additional constraints including lower reliability connectivity and power, lower levels of education or exposure to digital tools and data by end users, additional languages and translation requirements, and additional variability in workflows the solution must support. These variables may increase the need for software development and adapation to meed the needs of new facilities and increase per facility deployment costs.

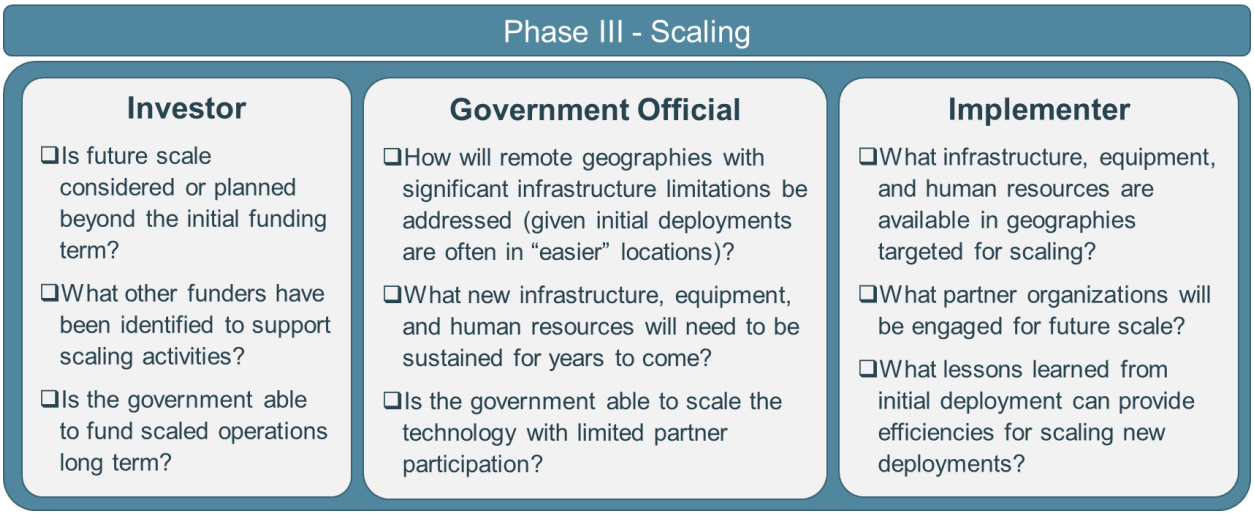
Shared resources: Where capital and human resources (e.g., shared hosting, shared human resources, shared equipment) support multiple digital health interventions scaling costs decrease, driving down TCO.

Key Takeaways

Digital health interventions often do not plan for or intend to reach the entire population during initial deployment due to a lack of sufficient funding commitments to achieve complete national scale during the span of one funding cycle. As a result, a subsequent scaling phase is often the solution to address country needs at national scale. The funding gap in initial deployment is often driven by misaligned investor incentives, political climate, short-term funding cycles, and limited government resources. Planning for scale requires a five-year TCO to identify funding gaps allowing the program owner or investor to identify alternate funding sources.

Figure 8, below, presents key questions to be asked by investors when determining whether to fund future scaling or provide feedback to improve potential return on investment by government officials to ensure resources are sufficiently allocated for long-term sustainability and the ability to coordinate across government and partner stakeholders for a successful DHI, and by implementers when developing their scaling budgets and resources.

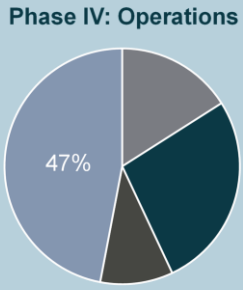
Figure 8. Key questions for stakeholders.



Phase IV: Operations

Operational expenditures are those associated with the ongoing operation of a DHI. Operational costs include the human resource costs to manage and operate a DHI, as well as regular maintenance and replacement costs incurred every year to keep a DHI running. These costs are separate from "startup" costs seen in Development and Deployment, as those costs are a one-time commitment of resources required to implement and deploy the solution. Fluctuations in operational costs are directly linked to the scale (e.g., the number of health facilities where a solution has been deployed) of the solution in subsequent years.

Model Implementation Costs



5-Year Operations Cost:
$2.3M (47% of TCO)

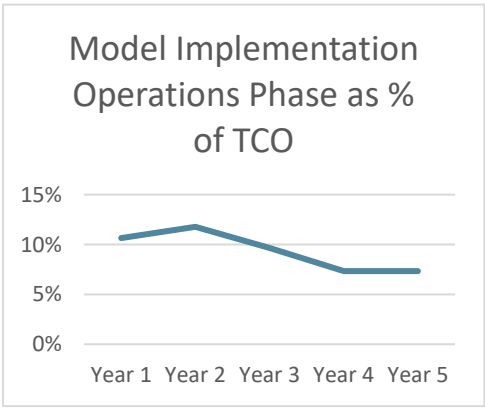
Largest Cost Categories:
- Recurrent Training
- Monitoring & Evaluation
- Governance

Operations cost categories include annual costs for hardware replacement, data and voice service, licenses and subscriptions, recurrent or refresher training, helpdesk support, maintenance and testing, project management, governance, and monitoring and evaluation.

Operational costs can vary substantially over five years based on the timeframe for scaling-up deployment, market maturity, and, importantly, the extent of shared government resources (human and capital) devoted to ongoing system maintenance and support.

In our model implementation, nationwide deployment to 6,000 health facilities was completed over the course of five years. Operational costs in Year 1 were relatively low while the number of live deployments was small but increased as new deployments came online and then flattened out once full scale had been achieved (see Figure 9, below). As an MM2 country, skilled ICT resources were available within the Ministry's ICT department, allowing our model implementation to receive technical support from ministry staff early on and to ramp up over time to support over 13,000 end-users.

Figure 9. Model implementation operations year on year.



Recurrent training, **monitoring and evaluation**, and **governance** made up the largest portion of our model implementation's annual operational costs at 8% of TCO each. Over time, the training model transitioned from classroom-based training to an on-the-job and train-the-trainer model, leading to decreases in annual recurrent training costs. This experience is consistent with other national-scale implementations involving a consortium of implementing partners and Ministry departments. The main driver of cost for these categories is the labor associated with them. In addition, interoperability and integration with other HIS, while critical to the effectiveness and sustainability of DHIs, requires additional labor for software development, maintenance, management, and governance and ultimately drives up costs in these categories over time.

Table 4, below, presents the model implementation's 5-year operations costs and the percentage of TCO for each. The range of costs across the four other implementations evaluated is presented to illustrate variances. The primary drivers of variance that could push costs for that category up or down are also given. These cost categories are mutually exclusive and are listed from highest to lowest for our model implementation.

Table 4. Phase IV costs and % of TCO by cost category.

Phase IV: Operations			
Cost Category	**Model Implementation Costs**	**% of TCO** (Model Implementation and Variance Across All Implementations Evaluated)	**Primary Cost Drivers**
Recurrent Training	$405k	8.4% (0% – 25%)	Type of training methodology (classroom-based, train-the-trainer, on-the-job), scale, and number of users to be trained.
Monitoring & Evaluation	$400k	8.4%	Number of Ministry and implementing partner staff and overhead required.
Governance	$395k	8.3%	Number of government and partner resources dedicated to coordinating the implementation according to health policies and strategies.
Project Management	$390k	8.1%	Number of implementing partner(s) staff and overhead costs.
Helpdesk Support	$365k	7.6%	Which organization provides level 1-3 support (i.e., government or outside vendor).
Maintenance & Testing	$135k	2.9%	Which organization performs software development and extent of integrations with other systems.
Infrastructure Replacement	$115k	2.4%	Type of server hosting, number of health facilities requiring internet connectivity, back-up devices, solar system, generator equipment.
Equipment Replacement	$35k	0.7%	Type and number of distributed equipment (e.g., computers, tablets, phones) for full deployment.
Data & Voice	$0k	0%	Use of existing internet connectivity and data requirements at health facilities required or the annual cost if procurement is required.
Licenses & Subscriptions	$0k	0%	Use of a solution or platform requiring licensing fees.

Key Drivers of Variances

Key drivers of variances in operational costs across implementations can include those listed here. Details on specific cost categories and their cost drivers are described in the subsections below.

Low market maturity: Low digital health market maturity **increases** operational costs as countries rely on an outside implementing partner for routine support, maintenance, and testing due to low government ICT capacity.

Scale: When internet connectivity or mobile data costs are required for consistent operation, data and voice costs, which scale more directly with deployments than labor costs, can become one of the highest drivers of operational costs when the solution is fully scaled to thousands of health facilities. Bulk discounts may be negotiated with mobile network operators at scale, especially with governmental support.

Server hosting: The chosen hosting solution drives both infrastructure and equipment costs. Cloud hosting (e.g., Amazon Web Services), a typical hosting option, drives infrastructure and equipment replacement costs down but **increases** data and connectivity costs; variances are based on the quantity of data and number of users.

Shared resources: Where capital and human resources (e.g., shared hosting, shared human resources, shared equipment) support multiple digital health systems, costs decrease, driving down TCO.

Costs Per Category and Variance

Recurrent Training includes all activities required to deliver refresher training and staff turnover training on an annual basis. Key subcategories include trainer time, train-the-trainer sessions, on-the-job training, training materials, and any required travel.

Shifting from a classroom-based training model to on-the-job training by superusers drove a near-tenfold reduction in training costs from initial deployment to annual recurrent training.

The training model utilized in our model implementation changed over the course of five years from fixed classroom-based training to training the most skilled government resources at the provincial and district level as “champions” and “superusers” to drive down recurring costs. To identify these users across health facilities, the Ministry conducted a computer literacy assessment. Reassessment and further training are incorporated into supervisory visits at each health facility, further driving down costs. Initial deployment training for our model implementation was $980k or 21% of TCO, and, with revisions to the training model, costs for recurrent training dropped to just over $100k on average annually and $405k total over five years at full scale, coming to 8% of TCO.

Across all implementations, refresher training represents one of the highest categories of cost in the operational budget. Higher training costs were incurred when training involved a fixed classroom setting, incurring travel and per diem costs for implementing partner resources; central, provincial, and district Ministry training resources; and health worker staff. For one implementation

evaluated, classroom-based training for 200 users involving Ministry and implementing partner resources and staff traveling to health facilities cost $450k across five years (24% of TCO). For this implementation and multiple others, classroom-based training models have shifted to more cost-effective training models over time (e.g., train-the-trainer, on-the-job training, eLearning) to decrease long-term operational costs.

In countries with the lowest recurrent training costs, district or provincial level staff provide periodic training as needed during supervisory visits to health facilities. In countries with low levels of market maturity, lower computer literacy skills require onsite training.

Monitoring and Evaluation costs are those associated with monitoring and evaluating program efficacy and impact. Activities include creating reporting plans with indicators, collecting data, writing reports, developing dashboards, gathering stakeholder requirements, and helping collaborate across stakeholders (e.g., investors, Ministry staff, implementing partners). Human resources involved in maintenance and testing in implementations evaluated were often involved in M&E development work.

Our model implementation incurred costs of $400k over five years or 8% of TCO. The costs represent the labor within the Ministry and implementing partner organizations necessary for monitoring and evaluation activities. In this instance, Ministry resources for M&E are shared across other DHIs, driving down operational costs.

Low market maturity countries lack the dedicated M&E resources found in higher market maturities. As a result, M&E activities are often integrated into the responsibilities of project management staff and are represented in the project management cost category, described below. In low market maturity contexts, where project management may be provided by implementing partners (international or in-country) with higher wages, the cost of M&E activities will be higher than if they were performed directly by dedicated Ministry M&E resources. Obtaining access to dedicated M&E resources in this or earlier phases can both decrease operations costs as well as improve the continuity of performance monitoring over the lifetime of the DHI, making impact easier to measure over time.

Governance costs are associated with the labor necessary to govern the DHI, including developing and communicating a vision, creating national guidelines, writing strategic plans, and coordinating implementation across ministries and other stakeholders (e.g., a consortium of partners).

Our model implementation incurred costs of $395k, or 8% of TCO. For implementations evaluated in low market maturity countries, a limited number of government resources and a consequently limited number of counterparts within implementing partner organizations were involved in DHI governance, decreasing overall governance costs. This leaves the DHI with a limited ability to coordinate with other programs resulting in siloed operation and makes it vulnerable to failure due to turnover of political leadership.

Project Management costs are driven by the labor costs needed for day-to-day project management activities across all stakeholder organizations (e.g., scheduling future deployments, deploying software updates, recurrent training).

In our model, implementation costs are $390k, or 8% of TCO. In other implementations evaluated, the percentage of TCO ranges from 3% to 9%. Variances are attributable to the number of

organizations involved in project management activities and the number of resources from each organization exclusively involved in project management for the DHI.

Additionally, costs associated with **transportation, communication, and procurement (**e.g., contracting, equipment purchase) were not reported as direct costs for any of the DHI implementation evaluated. These costs were assumed to be overhead costs for the implementing partner or government for these implementations. However, these may be appropriate costs to include in operational budgets.

Helpdesk Support costs are primarily associated with labor for supporting the use of the system by end-users, including level one (L1 – basic troubleshooting), level two (L2 – complex troubleshooting), and level three support staff (L3 – last line of support, usually comprising development team members who can develop solutions for bugs and other issues). Other cost drivers include any software utilized to respond and track support incidents, where support is provided (e.g., onsite, remote), whether qualified and trained support staff are available in-country, and what training is required.

A mixture of Ministry ICT staff and implementing partner staff provides helpdesk support in our model implementation. ICT staff now provides all L1 and limited L2 support, with the implementing partner providing L3 support. Helpdesk support cost is $365k over five years (8% of TCO).

Cost variances identified in other implementations were driven by the number of end-users, relative average computer literacy of end-users, the system's usability, and training required for in-country support staff. Additionally, cost efficiencies can be obtained by utilizing a shared helpdesk across multiple DHIs. For one implementation, a formal helpdesk was created and staffed during regular business hours, with a toll-free number for end-users to dial in, allocating only a percentage of labor costs to the DHI for a total cost of only $270k over five years.

In lower market maturities (MM1), L2 - L3 is usually provided by an implementing partner long-term, increasing operational costs and reliance on donor funding. At the highest end of implementations evaluated, helpdesk support cost upwards of $455k over five years (24% of TCO), even with a more informal L1 support model where WhatsApp was used for end-users to report issues.

Maintenance and Testing costs are primarily labor by software development resources, system administrators, database analysts, and business analysts and were covered by implementing partners for all implementations evaluated. These same resources also provided L3 support. Testing includes discrete scheduled activities including load, security, disaster recovery, and redundancy testing, as well as testing done as routine steps in regular software development and maintenance, including unit, integration, QA, UAT, and smoke testing. Our model implementation is $135k over five years (3% of TCO).

Maintenance and testing costs were substantially higher for an implementation with large-scale integration work underway by an implementing partner, driving costs up to 16% of TCO.

Costs vary based on the number of staff required and annual planned development activities (e.g., version upgrades, feature enhancements, planned interoperability, integration with other HIS). In one of the implementations evaluated, significant work was underway to upgrade the DHI solution and integrate it with another DHI solution, resulting in a total cost of $300k over five years, representing 16% of TCO.

Equipment (e.g., computers, tablets, mobile phones, power cords) and **Infrastructure** (e.g., servers, internet connectivity equipment, backup generators) must be maintained and replaced over time based on expected useful life and environmental factors, including security measures at health facilities (e.g., securing equipment in locking rooms or storage units), degree of equipment use (daily or less), and quality of equipment at a rate between 10-25% of the total procured equipment costs (see Deployment costs above) per year.

90% of budgeted equipment replacement costs for the model implementation were eliminated by using existing health facility hardware.

In our model implementation, a 20% replacement rate is applied to the value of procured equipment and infrastructure. Initially, $425k of equipment was budgeted; however, the actual cost of equipment procured during deployment decreased by 90% by utilizing shared equipment at health facilities, reducing the replacement rate by the same percentage amount. Our model implementation also hosted its solution at its government-run national data center. Other implementations evaluated incurred annual cloud-hosting fees between $12k - $15k per year on average, with one implementation incurring up to $60k per year using AWS.

In countries with lower market maturities where infrastructure is not readily available or reliable, additional investments in infrastructure may be required, also increasing replacement costs. In countries with higher market maturities (MM3+), the government may allocate health facility equipment costs in annual health system budgets. In these environments, if DHIs utilize existing health facility equipment, replacement costs may be omitted from DHI operational budgets altogether. Alternatively, if the equipment is procured for a different DHI (e.g., desktop computers used in health facilities for DHIS2 monthly performance reporting in one implementation evaluated), that DHI may bear the entire cost of replacement ($60k over five years, for this example). In any shared resource environment, equipment replacement costs may be split or covered by one or many different programs based on relative utilization, which may result in higher governance costs for coordination across programs but **lower equipment costs overall** for all programs.

Data and Voice services are the recurring data and voice services required for the DHI. These costs function like equipment and infrastructure replaced costs in a shared resource environment if existing health facility connectivity exists. In health facilities requiring data plans for the DHI, the costs may be a significant portion of the annual operations budget based on the scale of deployment.

Like equipment and infrastructure replacement, data services for our model implementation are shared across multiple programs at health facilities, and therefore, no direct data and voice costs were attributed to the DHI. In another implementation evaluated, where 900 mobile phones were used as end-user equipment, costs for mobile data incurred totaled $215k over five years, representing 7% of TCO for the implementation. In a different implementation where data plan costs were found to be unsustainably high, the Ministry (payor of data costs) managed to reduce

overall data costs by purchasing smaller data bundles for periodic data uploads (once per month instead of continuously), decreasing their data costs to 1% of TCO.

Licenses are budgeted based on the type of software implemented. No annual licensing costs were incurred for our model implementation or other implementations evaluated. However, commercial-off-the-shelf solutions and open-source or custom-developed solutions may require annual licensing fees for use or support services. When licensing costs are present, one can expect variances in costs due to the scale of deployment (e.g., number of licenses required per user, device, or facility). While license costs are additional, licenses typically provide the purchaser with some level of technical support and/or provision of future software updates thus reducing the ongoing cost of maintenance and testing resulting, making commercial and open-source products equally viable options. The best solution (commercial or open-source) for each situation will depend on specific context, including how fit-for-purpose the solution is, how mature and rigorously tested it is, how adaptable it is, and whether skilled technical resources and software developers are available to maintain it in-country over time.

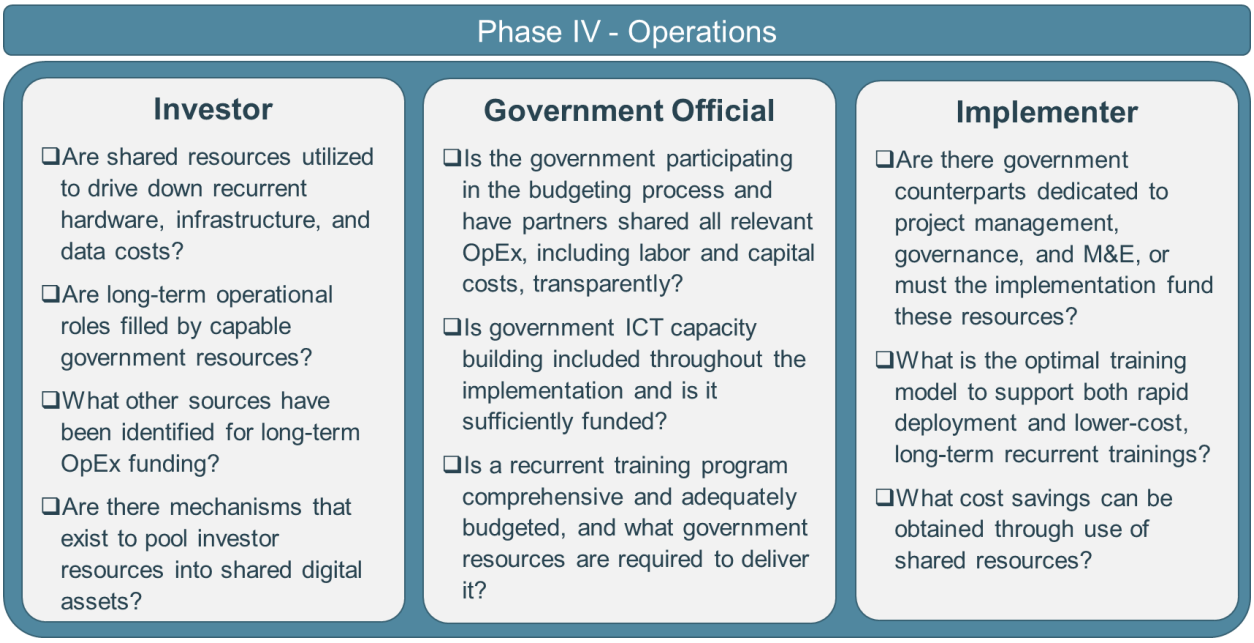
Subscriptions are generally related to software applications used to support the development environment, for example, database licenses (e.g., MongoDB), and software development, operations management, and data analytics products (e.g., Jira, Jenkins, Scalyr). The costs incurred for the implementations evaluated are less than 1% of their annual operations.

Key Takeaways

Digital health implementations often fail because investors do not understand and do not plan for the long-term costs of ongoing operations. This gap is driven by donor funding cycles, which are typically three years, and a lack of transparency of budgeted costs and expenditures across partners. Building a comprehensive 5-year operational budget shared with all stakeholders provides a common understanding of the actual human and capital resources required by cost categories. It identifies gaps in long-term funding and human resources and allows governments to discuss and plan for ownership of the digital health intervention. The exercise requires a significant investment in time but will ensure adequate resources are identified and built into a 5-year operational budget.

Figure 10, below, presents key questions to be asked by investors when determining whether to fund implementation projects or provide feedback to improve potential return on investment, and by government officials to ensure long-term sustainability and the ability to coordinate across government and partner stakeholders for a successful DHI, and by implementers when developing their operational budgets.

Figure 10. Key questions for stakeholders.



Implications for Planning

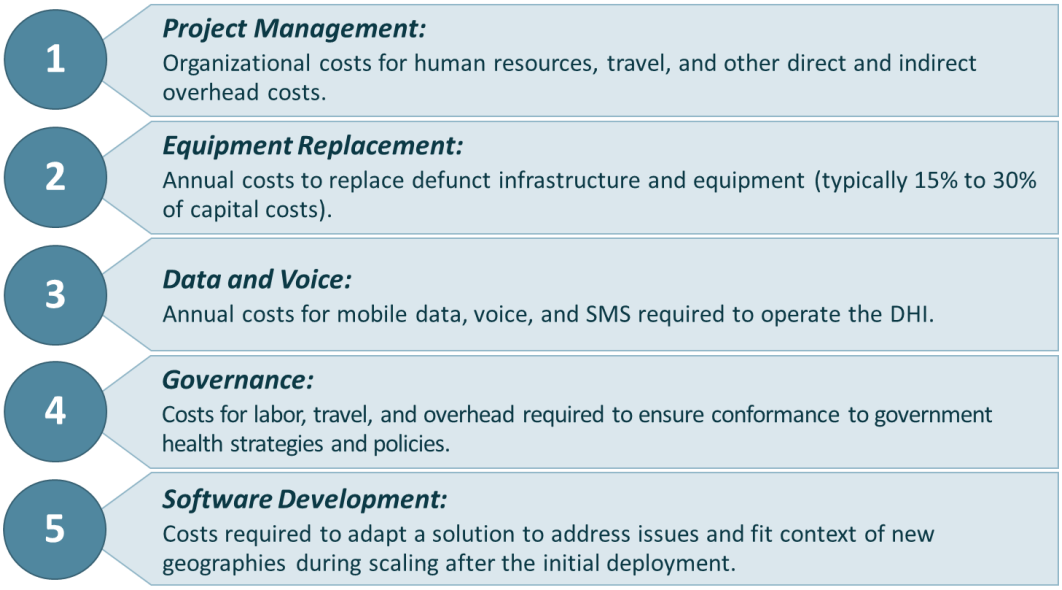
This reference document presents the TCO over five years for the implementation of a digital health intervention across several different contexts and scenarios. While every specific implementation may be unique, commonalities in drivers of cost and variance begin to appear when costs are analyzed and compared across all interventions evaluated for this research.

In addition to presenting a reference for TCO and potential variance to inform planning for, investment in, and implementation of future DHIs, this analysis also highlights key areas of cost that are commonly omitted or inaccurately estimated. Understanding and addressing these key hidden costs and variances can help implementers develop more accurate budgets and ensure costs and required investments are understood more transparently by governments and investors alike.

Five Common Hidden Costs

Detailed below are five cost categories that were identified across all implementations to be commonly omitted or inaccurately budgeted. Implementers, government officials, and investors would do well to ensure that these costs are discussed and rigorously documented to ensure they are well understood, transparent, and not omitted from project budgets.

Figure 11. Five hidden costs of digital health interventions.



Project management costs include the activities of the global partners (international and in-country subsidiary offices) engaged in the digital health intervention and **increases** TCO as the number of partner organizations increase. Each partner's project budget consists of the human resources (e.g., technical, programmatic, administrative staff), travel, and direct and indirect overhead costs for the duration of the project's contract. Project management costs for all implementations evaluated for this research ranged between $150k - $550k across all phases, or between 7% - 11% of the TCO.

Equipment and infrastructure replacement costs, the annual cost to replace damaged or obsolete equipment and infrastructure, are often omitted from proposal budgets and lead to facilities or end users to stop using the system. For budgeting purposes, an annual equipment replacement rate is applied to the value of the total equipment purchased and typically ranges between 15% to 30%, depending on the type of equipment. Implementing the system by leveraging shared resources helps **decrease** these long-term operational costs and divide them up among different programs, which can constitute variances as large as 15% of TCO. Transparent communication on required infrastructure and equipment across DHIs is critical to achieving cost efficiencies.

Data and voice services (e.g., data, voice, SMS) costs may or may not require budgeting as these services exist within the health system environments and may be shared. Where costs are incurred, they typically **increase** as the DHI scales, depending on per user costs from telecommunications providers. The maximum total cost for these services in implementations evaluated was just over $200k, or 7% of TCO.

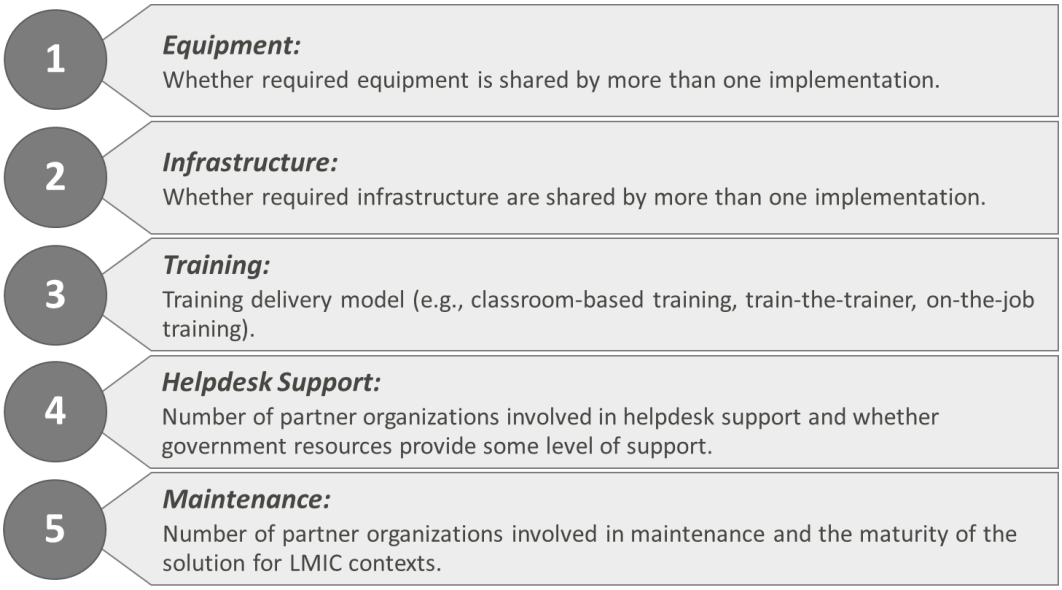
Governance costs typically include the human resources required to ensure the implemented technology conforms to government health strategies and policies across the ecosystem. These costs include integration and interoperability requirements, which may **increase** as the system matures in the health ecosystem. Governance costs comprise time and effort on the project by key government officials and project management staff within government and implementing partner organizations. Effective governance can consume as much as 8% of TCO, or ~$400k for one of the implementations evaluated and is critical to ensure long term operations.

Software development costs that are often underestimated or omitted in initial project budgets include the costs to adapt the solution when scaling to new geographies or address issues encountered during the initial deployment phase. Scaling an implementation can entail conducting subsequent rounds of planning, scoping, and software development to meet the needs of new and different users. Scaling a solution often means adding users with lower levels of education or exposure to digital tools, adding support and translations for new languages, and building support for variability in workflows. For implementations performing more custom software development on mobile applications, scaling costs can be significantly higher than implementations that rely on more mature software deployed to facility laptop or desktop computers that have a longer typical shelf life. At 22% of TCO for one implementation evaluated using custom mobile applications, scaling costs were more than double the costs of another implementation that used a more mature desktop solution due to the level of additional custom software development required to achieve scaled deployment.

Five Common Cost Variances

Additionally, this analysis identified five categories for which costs vary most widely, depending on the implementation context. Similar to hidden costs, these categories also require thoughtful discussion to ensure the specific country context and its impact of TCO is well understood by implementers, investors, and government officials. It is important to note that while three of the categories with high variance are encountered in the deployment phase, all five are encountered in the operations phase of a DHI. This indicates that an understanding of operational cost drivers may be of the greatest value to understanding and controlling TCO.

Figure 12. Five largest cost variances for digital health interventions.



Equipment and infrastructure costs are **highest** when a DHI requires new hardware equipment (e.g., computers, laptops, tablets, phones, power cords) and infrastructure (e.g., electricity, data center hosting, and connectivity) to be procured to support the technology or when implementers do not design the implementation to leverage existing resources. These costs are **lowest** when existing equipment and infrastructure at health facilities are utilized. Even when doing so may require upgrading existing equipment and infrastructure, the cost savings are substantial, depending on the number of end-users, size of the targeted geographic area, and the number of health facilities. When factoring in replacement costs required for ongoing operations, these costs varied between 7% of TCO, for an implementation that leveraged substantial shared resources, to over 30% of TCO (equaling nearly $1M), for an implementation requiring new equipment for every end user.

Training costs, whether for new deployment or recurrent training, depend on delivery model, scale, trainer type, and the length of training required for the end-users. Where an implementation requires trainers to travel to health or other facilities to train end-users, costs are **highest**, as travel, per diems, and facility fees increase costs. In low-resource settings where implementations are reliant on international partners to train end-users, costs also **increase**. However, where superusers or system champions train end-users at health facilities, costs **decrease**, and they may decrease even further when training is integrated into other job performance-related activities. This allows government supervisors to play a more prominent role in recurrent training

activities and ultimately decrease operational costs. In implementations evaluated, training costs between these two ends of the spectrum varied by a factor of ten, from 20% of TCO to 2%, respectively.

Helpdesk support costs are **highest** when implementing partners provide all levels of support rather than in-country, government ICT resources. This scenario resulted in costs as high as 24% of TCO (~$450k) for one implementation that was heavily reliant on international partners for this activity. In low market maturity countries, assessing government potential to provide basic end-user support early on in the implementation can **decrease** helpdesk support costs considerably. Over time, as government ICT capacity increases through experience supporting the DHI, these resources can provide higher levels of support, relying on partner organizations such as technology vendors only when complex system upgrades or enhancements are required, which helped bring costs down to only 3% of TCO on the lowest end for implementations evaluated.

Maintenance costs are similar to helpdesk support, as costs are dependent on the type of organization providing system maintenance and testing. Costs are **highest** where a solution is not fit-for-purpose in low-resource contexts requiring increased system maintenance. Costs also vary depending on the timing of implementation: major software releases and requirements to upgrade to new versions of the technology to obtain new features can require substantial training for end-users and helpdesk support staff alike, further **increasing** costs to upwards of 15% of TCO, compared to costs of less than 3% of TCO for implementations that saw no major upgrades.

When taken together, the comprehensive set of cost categories, illustrative costs, variances across country contexts, and an understanding of common hidden costs and cost variances equip implementers, government officials, and investors with a reference for practical discussion and planning. Furthermore, this understanding of TCO is key to understanding the potential return on investment for DHIs. As exemplified by the implementations evaluated for this research, greater transparency and communication of actual cost information can help the entire digital health field to identify efficiencies and make the best use of every investment to improve health outcomes.

Appendix A: TCO Framework

The total cost of ownership (TCO) framework below provides a comprehensive list of cost categories, definitions, and a table where costs can be tabulated for planning or retrospective analysis. Several, more granular categories (e.g., “Landscaping”) from those presented in the reference document are included here to ensure costs considered are comprehensive. The costs for these granular categories were combined with others in the reference document where the relative cost reported was too small to warrant detailed analysis.

Project Phase	Cost Category	Description	One Time Costs + Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs per Category
I. Planning and Development								
	High-level Scoping	Project scoping with key stakeholders to set the overall vision and strategy.						
	Project Planning	Create detailed project workplan and timeline.						
	Landscaping	Assessing the current state and enabling regulatory environment.						
	Context Assessment	Conduct business process analysis, data modeling, site and server assessment.						
	Requirement Specifications	Assess integration, migration, and reporting requirements.						
	Final Signoff	Finalize budget and obtain stakeholder approval.						

Project Phase	Cost Category	Description	One Time Costs + Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs per Category
	Initial Deployment Procurement	Costs associated with contracting, including identifying requirements, creating RFP, evaluation RFP, and contract negotiation with software implementers and hardware vendors.						
	Software Development and Customization	Software development and adaptation of the core software to enable country-level project needs or functionality that may not yet be supported. Customization may be necessary to allow integration or interoperability with other health IT systems at the country level. This customization could be performed by the primary global goods platform, implementation vendor, or project team.						
	Localization	Customization for specific location, such as language adaptations or specialized terminology.						
		Phase Subtotal						
II. Deployment Phase								
	Equipment	Centralized capital equipment as well as distributed equipment. Equipment budgets should also account for failover redundancy and disaster recovery.						

Project Phase	Cost Category	Description	One Time Costs + Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs per Category
	Infrastructure	Infrastructure costs includes electricity, data center hosting, and connectivity (e.g., internet access, SMS costs, backup generator costs).						
	Implementation Services	Includes initial configuration of settings and user accounts, plus data configuration such as migration of data and setup of custom schemes and/or data types.						
	Integration and Interoperability	Labor necessary to set up communication and standards compliance between system and existing systems. This category covers configuration and implementation work. If the software is not capable of communicating with existing software, adaptation is covered under software the customization bucket.						
	New Deployment Training	Costs associated with the development of a training framework, Standard Operating Procedure (SOP), training curriculum and material, eLearning platform, and a train-the-trainers program for all facilities that still require training.						

Project Phase	Cost Category	Description	One Time Costs + Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs per Category
	Change Management	Identify expected business process and staffing changes.						
	Software Development	Development costs for major modifications or scope expansion, includes software development costs post initial deployment and ongoing product expansion.						
		Phase Subtotal						
III. Scaling Phase								
	Scoping	Defining the scope of expansion and deployment activities.						
	Deployment	Identify expected business process and required staffing changes.						
		Phase Subtotal						
IV. Operations Phase								
	Equipment Replacement	Computer hardware is often replaced once it becomes obsolete. This cost can be estimated for most equipment based on expected useful life.						
	Infrastructure Replacement	Infrastructure costs includes electricity, data center hosting, and connectivity (e.g., internet access, SMS costs, backup generator costs.).						

Project Phase	Cost Category	Description	One Time Costs + Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs per Category
	Software Licensing and Subscriptions	Includes recurring software licensing costs. If the system is a global good, costs are typically open source with zero licensing fees, supporting software (e.g. databases, operating systems) may require licensing fees.						
	Data and Voice	Recurring voice and data services fees.						
	Recurrent Training	Includes all elements to deliver refresher training and staff turnover training at set intervals. Key activities including trainer time, train-the-trainer sessions, training materials, and any required travel.						
	Helpdesk Support	Costs associated with labor for operating the system; includes system administrators, database administrators, business analysts, as well as a support team that provides ongoing end user support.						
	Maintenance	Costs associated with maintaining the IT system (e.g., patches, downtime, scheduled + unscheduled). Final SLAs and maintenance contract(s).						

Project Phase	Cost Category	Description	One Time Costs + Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs per Category
	Testing	Covers testing which can be conducted as discrete scheduled activities for the central system environment including load, security, disaster recovery, and redundancy testing. Testing done as a routine step in regular software development and maintenance including unit, integration, QA, UAT, and smoke testing is included in the software development and maintenance sub-categories.						
	Transfer of Ownership	Costs associated with transferring ownership from the implementation vendor(s) to the government.						
	Project Management	Costs associated with managing the project, typically the costs of project manager role.						
	Transportation and Communication	Costs associated with ad hoc and routine transportation and communications between core staff for project management and execution.						
	Governance	Resource or time costs associated with overall digital health governance in the Ministry, including developing visions, national guidelines, strategic plans, and implementation.						

Project Phase	Cost Category	Description	One Time Costs + Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs per Category
	Monitoring & Evaluation	Costs associated with monitoring and evaluating program efficacy and impact. Includes creating reporting plan, metrics collection, writing reports, liaising with donors / funders.						
	Procurement	Costs associated with contracting, including identifying requirements, creating RFP, evaluating RFP, and contract negotiation with software implementers and hardware vendors.						
		Phase Subtotal						
		Five Year Total Cost of Ownership (TCO)						

Appendix B: Key Questions for Stakeholders

Phase I – Planning and Development

Investor

- ❑How large is the consortium of implementation partners?
- ❑Are multiple partners involved in the same activities or are responsibilities clearly divided?
- ❑Will early-stage investment contribute improvement to open-source software that can be used by others?

Government Official

- ❑Is the government involved in planning and development processes to ensure optimal use of available resources?
- ❑Are costs transparent across all partners, including in-kind contributions by government?
- ❑What are the proposed processes for signoff and approval on project plans and budgets?

Implementer

- ❑Is there adequate time built into Phase I activities to enhance the software without taking shortcuts?
- ❑Has the cost of change management been quantified separately from training?
- ❑Will investments in a local office increase the pool of skilled ICT resources available to support this implementation long term?

Phase II - Deployment

Investor

- ❑Is a cost-effective training delivery model employed?
- ❑What other opportunities exist to procure equipment and infrastructure (e.g., in-kind-donations)?
- ❑Are the right technology and implementing partners engaged to ensure local skills transfer?

Government Official

- ❑What degree of training will be required, given the digital literacy of end-users?
- ❑Are government resources at health facilities being shared?
- ❑Is sufficient time allocated to training both health facility workers and government officials?

Implementer

- ❑Are all health system resources that could be shared factored into the budget?
- ❑With which existing systems will this DHI need to integrate and is required data easily accessible?
- ❑Has sufficient time been allocated to software development to avoid shortcuts?

Phase III - Scaling

Investor

- ❑Is future scale considered or planned beyond the initial funding term?
- ❑What other funders have been identified to support scaling activities?
- ❑Is the government able to fund scaled operations long term?

Government Official

- ❑How will remote geographies with significant infrastructure limitations be addressed (given initial deployments are often in “easier” locations)?
- ❑What new infrastructure, equipment, and human resources will need to be sustained for years to come?
- ❑Is the government able to scale the technology with limited partner participation?

Implementer

- ❑What infrastructure, equipment, and human resources are available in geographies targeted for scaling?
- ❑What partner organizations will be engaged for future scale?
- ❑What lessons learned from initial deployment can provide efficiencies for scaling new deployments?

Phase IV - Operations

Investor

- ❑Are shared resources utilized to drive down recurrent hardware, infrastructure, and data costs?
- ❑Are long-term operational roles filled by capable government resources?
- ❑What other sources have been identified for long-term OpEx funding?
- ❑Are there mechanisms that exist to pool investor resources into shared digital assets?

Government Official

- ❑Is the government participating in the budgeting process and have partners shared all relevant OpEx, including labor and capital costs, transparently?
- ❑Is government ICT capacity building included throughout the implementation and is it sufficiently funded?
- ❑Is a recurrent training program comprehensive and adequately budgeted, and what government resources are required to deliver it?

Implementer

- ❑Are there government counterparts dedicated to project management, governance, and M&E, or must the implementation fund these resources?
- ❑What is the optimal training model to support both rapid deployment and lower-cost, long-term recurrent trainings?
- ❑What cost savings can be obtained through use of shared resources?