The costs of digital health interventions to improve immunization and data in low- and middle- income countries: a multi-country study

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Abstract

Background: Digital health interventions, such as electronic immunization registries (eIR) and electronic Logistic Management Information Systems (eLMIS), have the potential to significantly improve immunization data management and vaccine logistics in low- and middle-income countries (LMICs). Despite their growing adoption, there is limited evidence on the financial and economic costs associated with their implementation compared to traditional paper-based systems.

Objective: We aimed to measure the costs of implementing and maintaining eIR and eLMIS systems in LMICs, and to estimate the affordability of their implementation as compared to the previous paper-based registries.

Methods: The study was conducted across four countries: Guinea, Honduras, Rwanda, and Tanzania. A combination of primary and secondary data sources was used for the analysis. Expenditure information regarding the design, development and implementation of the tools was directly obtained from implementers and National Immunization Program offices in all countries. Primary survey data was collected to gauge the operational expenses of immunization information systems, both with and without electronic tools using an Activity Based Costing approach. The cost of immunization information system to the national level was then extrapolated and compared to national spending on immunization as a measure for affordability.

Results: The total costs of designing, developing and deploying eIR and/or eLMIS were I$ 1.7, 5.4, 4.7 and 33 million in Guinea, Honduras, Rwanda and Tanzania respectively. Design costs were greatly affected by the degree of customization of the tool, whereas roll out costs were mostly driven by the costs of purchasing hardware and training of health workers. Overall, the implementation of the electronic systems was associated with higher costs in Honduras (I$ 535 per facility, 95% CI 441; 702) and Rwanda (I$ 278, 95%CI 75; 482), a cost reduction in Tanzania (I$ -1,770, 95%CI -2,990; -550) and no significant cost difference in Guinea. The percentage weight of the cost of managing data with the electronic systems over the total national immunization budgets was estimated at 8.6%, 1.1%, 3.7% and 1.8% for Honduras, Rwanda, Tanzania and Guinea, respectively

Conclusions: Digital health interventions such as eIR and eLMIS can potentially reduce costs and improve the efficiency of immunization data management and vaccine logistics in LMICs. However, the extent of cost savings is contingent upon the degree to which these digital systems replace traditional paper-based methods. Our study suggests that the economic impact of digital health solutions greatly depends on factors such as infrastructure, implementation, and the extent to which these technologies are integrated into existing healthcare systems. Careful planning and investment are essential to realizing the full

economic potential of digital health in LMICs.

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Keywords: electronic immunization registries; electronic logistic management immunization registries; digital health interventions; immunization

Introduction

eHealth, short for "electronic health," refers to the use of information and communication technologies (ICT) in the health sector to enhance the delivery of healthcare services, improve patient outcomes, and facilitate the management and exchange of health-related information. It

encompasses a wide range of digital tools, systems, and applications that are designed to support and enhance healthcare delivery.[1] In recent years, the development of digital health technology solutions has attracted considerable interest from the medical and public health communities, particularly in low- and middle-income countries (LMICs), where digital health, including mobile health (mHealth) solutions, are seen as capable of overcoming existing infrastructural and geographical barriers to widespread and equitable access to health services. The 2005 WHO resolution on eHealth recognized the value of digital health interventions in achieving Universal Health Coverage (UHC) and meeting the Sustainable Development Goals (SDGs), urging ministries of health "to assess their use of digital technologies for health […] and to prioritize, as appropriate, the development, evaluation, implementation, scale-up and greater use of digital technologies...".[2] The strategic interest for digital health solutions was also confirmed in the WHO Global Strategy for Digital Health 2020-2025, that set 4 overall strategic goals to promote institutionalization of digital health in the national health systems.[3] In a joint document released in 2015, the World Bank Group and the United States Agency for International Development (USAID) acknowledged that countries could face challenges (time or skills) to produce quality health data and statistics and this constitutes a key barrier to building stronger health information systems, and called on governments, donors, and multilateral institutions to harness the power of digital health innovations to improve the availability, quality, and use of data for health decision-making.[4] This in turn has led to substantial investments in a wide range of digital health solutions by national and international funders in LMICs.

Within national immunization programs, several national and international initiatives have been launched aiming at implementing electronic immunization registries (eIR) and electronic Logistic Management Information Systems (eLMIS) in LMICs.[5-16] eIRs are eHealth interventions used to capture, store, access, and share individual-level, longitudinal immunization information in digitized records. Compared to traditional paper-based registries, eIR are expected to improve the capacity to identify spatiotemporal trends in vaccination coverage and dropout, inform resource allocation and program operations, and target quality improvement measures and statistics.[17,18] eLMIS are designed to manage and optimize the logistics and supply chain processes related to health commodities, including vaccines and other medical supplies. Their adoption is expected to improve end-to-end visibility and thereby change both how frontline workers place orders and how supervisors allocate stock across facilities, ultimately resulting in fewer stock-outs over time. [19]

Despite sustained interest in eHealth technologies for immunization programs and their implementation in several LMICs, robust evidence of the impact of these systems both in terms of programmatic outcomes [17,19-22] and costs [10,23,24] is still scarce and mostly focused on a small number of countries. This study aimed to provide additional evidence on the costs of implementing and maintaining eIR and eLMIS systems in four LMICs: Guinea, Honduras, Rwanda and Tanzania, and to estimate the affordability of their implementation as compared to the previous paper-based registries. More specifically, the following aspects have been investigated: (i) the upfront financial expenditures at national level for the design, development and implementation; (ii) the routine operating costs of data management with eIR and /or eLMIS; (iii) incremental operating costs for data management using the eIR and/or eLMIS compared to paper-based registries and reporting systems; and iv) the financial affordability and sustainability of maintaining the electronic systems based on each country's current expenditures on health. The presented results in this manuscript is integral part of a broader evaluation which uncovered both the programmatic and economic impact of implementing eHealth interventions in these four countries. The programmatic results of the study will be published separately.

Study setting

Guinea, Honduras, Rwanda and Tanzania have different data management systems in place, at

different scales of implementation and stages of maturity. Tanzania is the only country that has implemented both an eIR and eLMIS, whereas Guinea has implemented an eLMIS, and Honduras and Rwanda an eIR. Table 1 summarizes the main characteristics of the digital health solutions implemented in each country.

Table 1. Digital health solutions for immunization implemented in each country

	Guinea (eLMIS)	Honduras (eIR)	Rwanda (eIR)	Tanzania (eIR + eLMIS)
Known as	eSIGL	SINOVA	e-Tracker	TImR (eIR), VIMS (eLMIS)
Technical platform	OpenLMIS	Custom development	DHIS2 eTracker	OpenIZ/SanteSuite (eIR); OpenLMIS (eLMIS)
Implementation started	2018	2012	2019	2014 (eIR); 2015 (eLMIS)
Scale at the time of the evaluation	Implemented in 59/444 health facilities	Implemented nationwide	Implemented nationwide	Implemented in 15/26 regions
Implementation status	A dual paper-electronic reporting process is in place. Paper LMIS used nationwide at HFs, with LMIS data back-entered in eLMIS if HF introduced the system.	Data is back-entered by data clerks or HF staff either at mid-level primary care centres or at regional offices. No electronic tools exist at lower-level HFs	In varied use at HF level; alongside parallel paper process (being phased out). Data is back-entered by data clerks/managers; being transitioned to HWs. Not used/implemented at regional level.*	eLMIS implemented down to district level; eIR down to HF level providing interface for eLMIS.

eIR: electronic Immunzation Registry; eLMIS: electronic Logistic Management Information System; HF: heatlh facility; HW: health workers. * In Rwanda the system was subsequently scaled up and paper-based registries were phased out nationwide

Methods

Data sources

A mix of primary and secondary data sources were used for collecting the necessary data for the analysis. In all countries, expenditure data for the design, development and implementation of the tools was collected directly from the implementers and from the country offices of the National Immunization Program (NIP). Primary survey data was collected to estimate the operating costs of immunization information systems with and without the use of the electronic tools. Survey data was collected at different administrative levels including health facilities (HFs), district offices (DOs) and regional offices (ROs). In all countries, a purposive sampling of regions/provinces, districts and HFs was adopted to achieve a representative sample of health centers with relevant characteristics. Criteria for selection included implementation status of the digital solutions; time from first implementation; geographical distribution and type of health facilities. Table 2 reports the number of health facilities, district health offices and regional offices where primary data for the cost analysis was collected, whereas details of the criteria used in each country are reported in the Supplementary materials. Primary data were collected in October/November 2021 in Tanzania, in February/March 2022 in Rwanda, in April 2022 in Guinea and in September 2022 in Honduras. Questionnaires were

distributed using portable electronic devices with Open Data Kit (ODK) software and uploaded on central servers via the Kobo Collect application.

Table 2. Sample size for primary data collection in each country by administrative level

	Guinea	Honduras	Rwanda	Tanzania
Health Facility	43	80	24	61
District Health Office	7	-	12	30
Regional Health Office	-	8	-	10
Total	**50**	**88**	**36**	**101**

Data analysis

The methodology adopted for cost analysis varied across different dimensions investigated in our study. We outline below the methods used for each of the four economic aspects mentioned above.

National expenditures for design, development, and implementation

The perspective used for the analysis of financial expenditures was that of a "third-party payer," including the expenditures from external funders (e.g., international organizations and/or private funders) and domestic funders (e.g., national, or subnational authorities). A descriptive analysis was conducted classifying the financial expenditures into expenditures for the design and development of the tools and the expenditures for the roll-out in the country. Costs considered included those for purchases of goods and services, such as for equipment, internet bundles or the development of the digital health system, transport costs, training materials and other direct costs. In-kind contributions from local governments during the implementation of the tools, (i.e., in terms of government staff time spent for management, coordination and operational activities, as well as goods and infrastructure made available to the implementation team) were only partially available for Honduras and Rwanda and Guinea, and not available for Tanzania. For Honduras, despite the nationwide implementation, detailed expenditure data was available only for the two regions of the pilot implementation of their eIR between 2012 and 2013. Therefore, to estimate the implementation cost for the whole country, the cost of the pilot phase was used to extrapolate the cost of implementing the eIR to the other 18 health regions (Supplementary materials).

Routine operating costs of eIR and/or eLMIS

An activity-based costing approach (ABC) was employed for the calculation of routine operating costs based on primary data collected. The ABC approach consisted of identifying a series of activities performed by the staff of HFs, DOs and ROs and then tracing direct and indirect costs to these activities.[25] The activities considered were limited to those related to the management of immunization and vaccine stock data and were pre-defined based on a literature review and an iterative consultation process with experts of electronic immunization systems (table 3).

Table 3. Activities defined to estimate the routine operating costs of using the electronic tools

Activity[a]	Description
Child registration	Time spent on entering details and data regarding a new child

	registration (including service provision and data management, finding client folder and event recording).
Defaulter identification	Reviewing registry to identify children who missed appointments, establishing list of defaulters
Defaulter contacting	Contacting defaulters to remind caregivers of missed vaccinations
Organizing outreach sessions	Preparation for the delivery of immunizations in outreach settings
Identifying performance gaps	Reviewing data to find performance gaps (such as HFs not being on track for coverage goals)
Report generation	Time taken to search for and record data that will be included in the regular reports on immunization services and stock management.
Report transportation	Physical transport of weekly/monthly reports to higher administrative levels for submission
Vaccine quality control/ monitoring	Physical counting, recording, and checking of closed vaccine vials for expiry dates or temperature excursions; Physical counting, recording, and checking of any open vials
Cold Chain monitoring	Data entry of records of the refrigerator or freezer temperatures
Determining quantities of vaccine to order	Data mining and information extraction from dispensing/vaccine use and storage system and processing it to prepare the next order
Refresher trainings	Recurrent training provided to HF staff on recording and reporting of immunization data, whether on paper or electronically
Technical and/or administrative support visits	Recurring visits from higher health system levels for supportive supervision and technical assistance in immunization service delivery

[a]*in each country, based on discussions with the EPI offices and local research partners, the description of activities and their inclusion in the questionnaires was further refined to better fit the characteristics of the tools used, the country specificities and the administrative level at which the survey was distributed.*

In the questionnaires, respondents were asked to provide estimates of the number of staff and the amount of time spent on each of the defined activities, as well as other costs incurred for equipment, consumables and services that were directly attributable to that activity. To estimate annual costs, information was also collected on the average frequency at which each activity was performed. Additional information was collected on printing and IT maintenance costs which were shared across all the aforementioned activities. For each activity, mean costs were calculated together with 95% confidence intervals. Answers to the questionnaires were checked both within and between questions to ensure internal consistency in the answers given by each respondent and to identify outliers or implausible values by reviewing distributions of values for each answer. When possible, inconsistent/ implausible answers were corrected based on the qualitative comments given by respondents. Alternatively, a request for data validation was sent to the local research team who verified with the data collectors and either confirmed the original values or provided an adjusted value. Answers that were considered by the research team as inconsistent/implausible and that could not be validated with the approach described above were considered as missing values.

Cost analysis was done individually for each activity described in table 3 after disregarding missing values for which no imputation techniques were used. Staff time was converted to a monetary value using national reference salaries for health staff published in the Official Gazette or estimates on salary ranges directly reported by respondents during the interview (see Supplementary materials for details). The cost per minute of staff was then calculated considering a monthly practical capacity equal to 20 days per month and 8 hours a day, and assuming a 20% reduction in capacity to account for sick leave, training and breaks/leave. Unit costs for consumables and equipment were obtained from the NIP offices or local research partners. All IT equipment costs were then annuitized, assuming a useful life of 5 years. Indirect costs, such as utilities (electricity and internet), as well as maintenance and general costs of the health centres were available to different extents in the four countries (Supplementary materials for details). Both shared and indirect costs were apportioned to the different activities described in table 3 using as a cost driver the time spent for each activity over

the total time spent on all activities. The costs of performing immunization and vaccine stock management activities were reported as the total average annual cost per HF. The costs at district and regional levels were apportioned to each HF in the sample based on the total number of HFs delivering immunization services under the administration of the respective districts or regions.

Incremental costs of digital vs. paper-based systems

Given the different levels of digital tools' implementation in the four countries, different approaches were used to estimate the cost impact of using the electronic tools compared to paper-only systems. In Tanzania and Guinea, where implementation had not been achieved nationwide, the cost impact was estimated via an unadjusted cross-sectional comparison between HFs using and not using the electronic tools. In Honduras and Rwanda, where the electronic tools had been implemented nationwide at the time of the evaluation, a before-and-after analysis was conducted using survey responses on resource use (staff time, consumables, equipment, etc.) before and after the implementation of the electronic tools. All cost estimates were adjusted to 2021 real values using the World Bank GDP deflator index and converted to international dollars (I$) using the 2021 World Bank's Purchasing Power Parity conversion factor (1 I$ equal to 10.9 Honduran Lempiras, 330.5 Rwandan Francs, 890.6 Tanzanian Shillings, and 4,014.6 Guinean Francs). Analysis was done using Microsoft Excel and R Studio (ver. 4.2). The evaluation protocol and data collection instruments received ethical approval from the Bocconi University ethical review board and under the procedures set by the Tanzania Commission for Science and Technology (COSTECH) in Tanzania, Rwanda National Ethics Committee (RNEC) in Rwanda, National Health Research Ethics Committee in Guinea and the Pan American Health Organization (PAHO) Ethics Review Committee for Honduras.

Affordability of national scale-up

In all countries, the overall cost of immunization information system to the national level was extrapolated using the estimated cost per HF, the information on the utilization of the electronic tools, and the number of HFs providing immunization in each country (Supplementary materials). A measure of sustainability was then considered by calculating the percentage weight of the costs of using the electronic tools over the total immunization budget (including domestic and external sources). Immunization budgets were estimated at USD 7.4M, 35.7M, 11.6M, and 161M in Guinea, Honduras, Rwanda and Tanzania and respectively (Supplementaty materials).

Results

Financial expenditures of eIR/eLMIS

The upfront financial expenditures for the design, development and roll-out of the systems were mostly borne by external donors in all four countries (Table 4). Tanzania developed a highly customized eIR from an established open-source electronic medical records (EMR) platform, OpenIZ, (now known as SanteDB, SanteSuite) and an eLMIS, based on the OpenLMIS platform [17,19]. The design and development costs reported in table 4 also include learning costs for about I$ 1.2M relative to the development and pilot of a legacy eIR, the Tanzania Immunization Information System (TIIS)[23], which was since shelved and substituted by a new tool. Honduras developed a customized eIR by appointing an external national IT consultant for the task. However, the reported cost may not represent the full cost of developing the system, as interviews with members of the EPI revealed that the development process went through several iterations and changes that were not adequately planned for at the outset and were therefore carried out by the IT consultant without adequate compensation. Rwanda opted for an off-the-shelf eIR, the DHIS2 [26] with only minor customizations, which was rolled-out at national scale under the responsibility of the MoH. Finally, Guinea also developed its eLMIS based on OpenLMIS under the leadership of the Ministry of

Health and Public Hygiene, with technical assistance from external partners. The eLMIS was developed at the outset as a common tool across nine health programs, including the EPI. To calculate the share of development costs attributable to the EPI we used as a cost driver the proportion of vaccines managed through the eLMIS over the total number of items for the nine programs, equal to 6.5% based on data from the eLMIS itself. Roll out costs were mostly driven by the costs of purchasing hardware and training of health workers which accounted for 63%, 61%, 93% and 48% of the total implementation costs for Guinea, Honduras, Rwanda and Tanzania, respectively. Implementation involved all administrative levels until the HF, with the only exception of the Tanzanian eLMIS which was implemented down to the district level, and Honduras, where implementation of the eIR occurred only in selected urban mid-level primary care centres. The costs per HF relative to the design, development and roll-out are reported in Table 4.

Table 4. Development and roll-out costs of the electronic systems in each country (I$)

Country	System	Design & Development	Roll-out	Total	Total cost per HF
Guinea	eLMIS	639,105	1,067,563	1,706,667	3,843
Honduras	eIR	33,949	5,399,946	5,433,894	4,393
Rwanda	eIR	317,649	4,411,877	4,729,526	8,725
Tanzania	eIR	3,968,986	21,768,297	33,009,132	9,926
	eLMIS	3,826,829	3,445,021		

Operating costs and cost impact of implementing the electronic systems.

The routine operating costs of the electronic systems and the cost impact of using digital tools compared to performing data management activities using paper tools are summarized in Table 5. Labor costs accounted for the highest share of costs in all countries, comprising 49%, 72.1%, 85% and 59% of the operating costs in Guinea, Honduras, Rwanda and Tanzania, respectively. The costliest activities varied depending on the system used (i.e., eIR, eLMIS, or both) and implementation setting (Supplementary materials). Specifically, the organization of outreach immunization sessions in Tanzania, report generation and transportation in Guinea, and child registration in Honduras and Rwanda were identified as the costliest activities.

Overall, the implementation of the electronic systems was associated with higher costs in Rwanda and Honduras, a cost reduction in Tanzania and no significant cost difference in Guinea (Table 5). In all three countries where an eIR was implemented, the use of paper forms to record immunization data at the vaccination point was maintained in parallel with the electronic systems. This duplication of work was associated with an increase in costs for Honduras (+I$ 1084 per facility per year, 95%CrI 819; 1,255) and Rwanda (+I$234, 95%CrI 94; 373), but not for Tanzania, where the activity of registering children with eIR was associated with a reduction in costs of approximately I$310 USD (95% CrI: -767, 146) per year per HF. This reduction was linked to reduced staff costs, as less time was spent performing the activity by lower-paid workers. However, there was considerable variability across facilities, and the association between the cost reduction in Tanzania and the implementation of the tools, based on the qualitative comments by respondents, was not clearly identifiable. No other significant cost impacts were found for any other activity in Rwanda and Honduras, whereas in Tanzania the integrated implementation of the eIR and eLMIS was also associated with a reduction in the costs for report generation and transportation (I$ -367 and –258, respectively), vaccine ordering (I$ -45.6) and identification of performance gaps (I$ -314) and an increase in the costs for cold chain monitoring and supervision (I$ 278 and I$ 198, respectively) (Supplementary Materials).

Table 5. Annual operating costs of managing immunization and/or stock data management activities and cost impact compared to paper-only registries (International $)

Country	System	Annual operating cost[a] of users of electronic systems (95% CI)	Cost impact per HF compared to non-users of electronic systems
Guinea	eLMIS	679 (188; 1,170)[b]	-36 (-176; 102)
Honduras	eIR	5,342 (4,753; 5,930)	535 (441; 702)
Rwanda	eIR	1,211 (1,047; 1,376)	278 (75; 482)
Tanzania	eIR+eLMIS	4,002 (3,166; 4,835)	-1,770 (-2,990; -550)

[a] Cost of performing immunization and/or vaccine stock data management activities; [b] Note: the annual operating cost in Guinea considered only the LMIS/eLMIS process and excluded the national immunization programme legacy information flow, thus representing an incremental cost to the latter.

Affordability of national scale up

The extrapolated cost of managing immunization and vaccine logistics data using the electronic systems at the national level was equal to I$0.2M, 6.8M, 0.9M and 15.7M in Guinea, Honduras, Rwanda, and Tanzania, respectively. These costs reflect the situation at the time of the evaluation in Honduras and Rwanda, where parallel paper systems were in place, and a projection in case of a national scale-up in Tanzania and Guinea, where implementation was only partial. In the case of Tanzania, scaling-up the use of the eIR and eLMIS to national level was estimated to generate savings of I$11M per year compared to the current situation. The percentage weight of the cost of managing data with the electronic systems over the total national immunization budgets was estimated at 8.6%, 1.1%, 3.7% and 1.8% for Honduras, Rwanda, Tanzania and Guinea, respectively.

Discussion

To our knowledge, this is the first study that investigated the economic impact of digital health solutions in LMICs in a comprehensive way and across four different dimensions. We estimated the initial financial expenditures of implementing eIR and eLMIS and found that the upfront investment for the design, development and roll-out of the systems was mostly covered by external donors and was driven by hardware and training costs. In terms of their design and development, notably higher costs were observed for the bespoke or highly customized tools in Tanzania (International dollars - I$- 8 M combined), while considerably lower costs were observed for Rwanda and Guinea where off-the-shelf solutions were used. Overall, Guinea incurred the smallest upfront costs per HF for the implementation of the eLMIS, which was due to the implementation and use of the same eLMIS as for other health programs (e.g. malaria or tuberculosis control program etc.), allowing significant economies of scope to be achieved. The total annual operating costs of managing immunization data using eLMIS and eIR represent between 1.1% and 8.6% of the total immunization expenditure.

There was mixed evidence on the cost impact of introducing these systems. Compared to the use of paper registries alone, the cost of managing immunization and vaccine stock data with the electronic systems was found to be higher in Honduras and Rwanda, lower in Tanzania and negligible in Guinea. Notably, in three of the four countries, the implementation of a new process inclusive of electronic systems, was additional to the existing paper-based processes that remained in place with some adjustments. This duplication of processes resulted in higher costs for data recording compared to the paper registries with the only exception of Tanzania. In addition, the extent to which these higher costs were offset by savings in activities that would benefit from more readily available electronic immunization data (e.g., reporting and transport, planning routine activities at facility level, or performance management), was linked to whether the electronic systems were used for decision-making, particularly at the HF level, which, in fact, was rarely the case. For example, the cost benefits of generating and transporting reports using electronic data would be immediately

apparent. However, only in Tanzania did respondents clearly state that the introduction of the electronic systems had made this task easier, although implementation problems such as limited connectivity and an unstable electricity grid remained. The fact that paper registries were considered the primary source of information in almost all countries may have affected the overall quality and completeness of the electronic data and hampered the use of the systems to inform immunization activities, resulting in lower cost savings.

Overall, results in all four countries suggest that if the electronic systems were used as the primary source of information, managing immunization and vaccine stock data by electronic means would be cheaper than with paper-based systems, even if maintaining the latter exclusively as back-up. This finding is in line with a simulation by Dolan et al. in Kenya. [27] However, achieving such savings would be possible only if investments were dedicated to strengthening the ecosystem in which eIR and eLMIS are rolled out (i.e., infrastructure and local capacity), enabling their sustainability. In another survey-based micro-costing study in the Arusha region of Tanzania, Mvundura et al. [23] reported cost savings of US$ 10,236 per facility per year (95% CI US$ 7,606-14,123), much higher than the savings we estimated. As in our study, the savings were driven by reduced staff time for delivery of fixed and outreach immunization services, logistics and stock management, and data reporting. However, the authors did not clarify which activity contributed most to the reported cost savings, making a more detailed comparison difficult. In the same study, the authors estimated the savings associated with the introduction of an eIR in Zambia to be US$ 628.

This study has provided additional evidence on the costs of designing, implementing and operating eIR and eLMIS in 4 low- and middle-income countries. Together with evidence from the programmatic evaluation reported elsewhere (ref), the information gathered may be useful in understanding the likely impact of these eHealth interventions on immunization costs and outcomes, and in helping to prioritize national and international funding in this area.

This study has several limitations. The secondary data collected to estimate the design and development costs of the electronic systems were of variable quality and availability between countries, which may explain some of the variability observed. In addition, certain relevant costs, such as in-kind contributions from local governments, were not available in all countries. Also, this study was observational in nature, and therefore estimating the cost impact of implementing the electronic systems versus the previous paper-based systems may be subject to bias. Depending on the extent of implementation, the impact was estimated either by making a pre-post comparison at facility level or by making an unadjusted comparison between HFs that had implemented the systems and those that had not. Both approaches can be subject to several biases, including the effect of other fixed or time-varying missing variables or reporting/recall errors.

Conclusions

Digital health solutions have the potential to bring about significant benefits in LMICs by improving health access, enhancing productivity, streamlining data management, minimizing paperwork, and optimizing supply chain management. Furthermore, improved data collection and analysis through digital health systems can inform evidence-based health policies, leading to more efficient resource allocation. However, our study clearly shows that the economic impact of digital health solutions greatly depends on factors such as infrastructure, implementation, and the extent to which these technologies are integrated into existing healthcare systems. Careful planning and investment are essential to realizing the full economic potential of digital health in LMICs.

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Conflicts of Interest

All authors declare no conflict of interest

Abbreviations

ABC: Activity Based Costing; DH: Digital Health; DO : District Office; eIR: electronic immunization registries; eLMIS: electronic Logistic Management Information Systems ; EPI: Expanded Programme for Immunization; HF: Health Facility; HW: Health Worker; ICT: Information and Communication Technologies; LMICs: Low and Middle Income Countries; ODK: Open Data Kit; RO: Regional Office; SDGs: Sustainable Development Goals; UHC: Universal Health Coverage; USAID: United States Agency for International Development; WHO: World Health Organization

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Supplementary Files

Multimedia Appendixes

Additional details.
URL: http://asset.jmir.pub/assets/246174854b45dd4d44339f978e9369d7.docx