Evaluating the impact of electronic Immunization Registries (eIR) in low- and middle-income countries: RWANDA

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LIST OF ABBREVIATIONS

AEFI:	Adverse Events Following Immunization
BMGF:	Bill and Melinda Gates Foundation
CERGAS:	Centre for Research on Health and Social Care Management
CHW:	Community Health Worker
CIIC-HIN:	Center for Impact, Innovation and Capacity building for Health Information Systems and Nutrition
CRVS:	Civil Registration and Vital Statistics
DH:	District Hospital
DHIS2:	District Health Information System version 2
eIR:	Electronic Immunization Registry
eLMIS:	Electronic Logistics Management System
EPI:	Expanded Program for Immunization
ESAVI:	Event supposedly attributable to vaccination or immunization
GDP:	Gross Domestic Product
HC:	Health Center
HISP:	Health Information Systems Program
HMIS:	Health Management Information System
HW:	Health Worker
IMF:	International Monetary Fund
IS:	Information Systems
IT:	Information Technology
LMICs:	Low-and middle-income countries
MINALOC:	Ministry of Local Government
MoH:	Ministry of Health
MRS:	Medical Record System
NCD:	National Data Center
NIDA:	National Identification Agency
NIN:	National Identification Number
NISR:	National Institute of Statistics of Rwanda
PBF:	performance-based financing
RBC:	Rwanda Biomedical Centre
RISA	Rwanda Information Society Authority
RNEC:	Rwanda National Ethics Committee
SEM:	Standard Error of the Mean
SMS:	Short Messaging Service
SRMP:	Smart Rwanda Master Plan
TOC:	Theory of Change
UNICEF:	United Nations International Children's Fund
VPDP:	Vaccine Preventable Disease Program
WHO:	World Health Organization
WUENIC:	WHO/UNICEF Estimates of National Immunization Coverage

EXECUTIVE SUMMARY

INTRODUCTION

Led by the Centre for Research on Health and Social Care Management (CERGAS) at SDA Bocconi School of Management, Bocconi University, a partnership was formed with MMGH Consulting GmbH (MMGH) to perform a comprehensive evaluation of electronic immunization registries (eIR) and electronic logistics management information systems (eLMIS) in four low-and middle-income countries (LMICs): Guinea, Honduras, Rwanda and Tanzania. The Bill and Melinda Gates Foundation (BMGF), together with the World Health Organization (WHO) and Gavi, the Vaccine Alliance, have provided support to this work with the overall aim of generating robust actionable evidence to enable future decisions on the introduction and scale-up of these digital technologies.

In Rwanda, this evaluation was conducted in collaboration with the Center for Impact, Innovation and Capacity Building for Health Information Systems and Nutrition (CIIC-HIN) which oversaw the planning, conducting, and managing of the fieldwork. Participatory meetings on the data analysis and report writing guided the development of and the finalization of the current report.

BACKGROUND

In 2019, the Vaccine Preventable Disease Program (VPDP) in Rwanda made the decision to implement the District Health Information Software Version 2.0 (DHIS2) EIR Tracker package (e-Tracker) for routine immunization. Although Rwanda had achieved high national coverage rates in the years before the introduction of e-Tracker, some children were still being continuously left behind. The e-Tracker was introduced as part of a digital solution to improve the efficiency and effectiveness of the national immunization system and to support achievement of the national goal of substantially reducing "zero dose" children through linkages with the national civil registration and vital statistics system (CRVS) and the real-time monitoring of immunization coverage and drop-out rates. The e-Tracker was designed to capture basic information related to demographic characteristics and vaccine history across all health centers delivering immunization services in Rwanda.

Importantly, the COVID-19 pandemic strongly influenced the implementation of e-Tracker in Rwanda, interrupting training on data management and information analysis, delaying interoperability with the CRVS and a Rapid Short Messaging Service (RapidSMS) feature for client notifications and slowing down the Ministry of Health's one-year transition plan to move from a paper system to a fully electronic system. Accordingly, at the time of this evaluation, Rwanda operated a dual registration system for routine immunization with a paper registry maintained at each health center, as well as a hard copy of the child vaccination card kept by caregivers. On 1 October 2022, the country initiated its transition to a fully electronic system with paper-based registries to be made no longer available. The operational impact of this ongoing transition is yet to be evaluated.

OBJECTIVE

The objective of this evaluation in Rwanda was to assess the interoperability, programmatic impact, costs, affordability and sustainability of the e-Tracker in its early use and to generate actionable evidence to support future decisions on the management of e-Tracker and other digital technologies, in the context of the government's strong commitment to digitalization. The evaluation aimed to also generate new evidence on tools and technologies, modalities, and governance of the e-Tracker to inform further investments in Rwanda and other countries from domestic sources, health financing institutions and technical partners.

As Rwanda implemented its eIR nationally over only a few months, it was also foreseen that the evaluation would provide insights on the potential advantages or challenges conferred by rapid implementation at scale, including its effect on immunization coverage, timeliness and dropout rates. However, as the implementation coincided with the beginning of the COVID-19 pandemic, its impact on these immunization indicators was difficult to dissociate from the effects of the repeated COVID-19 lockdowns in 2020 and 2021 on immunization service delivery. It was, nevertheless, envisaged that the evaluation's findings could still provide insights on the contribution of the e-Tracker to potentially mitigate the decrease in routine immunization coverage during the pandemic and to confer resilience to the primary health care system. It was also anticipated that important learnings could be gathered on how to effectively support the forthcoming transition process to a fully electronic system.

METHODS

A purposive sampling strategy was used to identify a representative sample of districts hospitals (DHs) and health centers (HCs) for inclusion in the evaluation. The final sample contained 12 DHs and 24 HCs (13 rural and 11 urban). The field work for data collection was coordinated by CIIC-HIN and executed over a period of 3 weeks in February and March 2022.

The evaluation adopted a mixed methods approach to respond to the complexity of rolling out the e-Tracker at national scale during the COVID-19 pandemic, exploring both the programmatic and economic dimensions of its development and implementation. Quantitative and qualitative methods were used to evaluate the programmatic impact of the early use of the electronic system. The evaluation included two specific comparisons: before and after the introduction of the e-Tracker and between those health facilities which used the tools ("frequent users") and those who did so to a lesser degree ("non-frequent users"). The impact was assessed in terms of service delivery processes including data quality and data use for decision-making, as well as an interrupted time series (ITS) analysis to understand the effect of the e-Tracker on the uptake of vaccines. The economic impact evaluation aimed to provide an estimate of the upfront financial expenditures at national level of implementing the e-Tracker; the routine operating costs of managing immunization data using the e-Tracker; and the difference in operating costs with the e-Tracker compared to only using the paper-based registry.

FINDINGS

The data yielded findings categorized into four domains: ecosystem; tool design and functionality; implementation experience and costs; and impact and sustainability. A summary of the findings is described below.

The Government of Rwanda has long been recognized for its progressive adoption of digital solutions, and the country has demonstrated strong political commitment and experience in implementing successful IT solutions. However, this evaluation highlighted several barriers related to the overall ecosystem for the successful deployment of the e-Tracker, including: limited internet connectivity; somewhat limited availability to hardware; limited interoperability, specifically with the CRVS; perceived insufficient capacity building and training; parallel work (i.e., due to use of the dual-system of paper and electronic records); and the impact of the COVID-19 pandemic. Specifically, findings revealed that limited access to the internet remains a challenge with 64% of the HCs and 85% of the districts reporting sufficient internet availability.

While the design of the e-Tracker seemingly satisfied many of the functional requirements on an "ideal" eIR, because of the continued use of the dual system, the e-Tracker has not yet measurably improved efficiencies, particularly at the HC level. With only approximately 30% of national health management information system (HMIS) data presently being entered through use of the e-Tracker, there has been limited benefit to the HWs as the tool does not provide sufficiently complete information to inform decision making. The evaluation showed that data are largely entered into the e-Tracker by data managers at some time after the immunization sessions, and the tool is rarely used, as intended, for real-time data entry at the point of vaccine administration.

The evaluation also highlighted specific concerns that the limited interoperability of e-Tracker has been a bottleneck to effective use of the tool. Importantly, at the time of the evaluation, e-Tracker was not yet interoperable with the CRVS, though this has subsequently changed. Similarly, interoperability with the RapidSMS feature has been introduced as part of the transition to a fully electronic system as of 1 October 2022. It is also expected that future interoperability with the vaccine logistics management module would further enhance the utility of the e-Tracker.

While the transition to a fully electronic system and the interoperability of the e-Tracker with both the CRVS and RapidSMS should favor a more consistent and efficient use of the tool and reduce the workload of both HWs and data managers, findings from this evaluation suggest that HC and DH staff felt that prior to the transition, implementation of the e-Tracker had actually increased their workloads resulting in requests for additional staff and the need for reorganization of human resources. Despite reports of adequate computer literacy and timely access to IT support, limited IT capacity-building may have inhibited the impact of e-Tracker use, as only 25% of HC and DH staff felt they were adequately trained. This evaluation supports the call for more tailored training and supportive supervision to meet the practical needs of HC and DH staff.

Due to the limited period of implementation and the effect of the COVID-19 pandemic on immunization delivery and the roll-out of the e-Tracker, use of the tool was not expected to have had a measurable impact on immunization outcome indicators (e.g., coverage, timeliness, or drop-out rates). Results from an ITS analysis for DPT3 coverage data showed that for the two years following e-Tracker introduction (October 2019 - September 2021), there was a decrease of administered doses compared to before e-Tracker use**.** These findings corroborate WUENIC data that reported a decrease in routine vaccination coverage during this time. Given that the introduction of e-Tracker in Rwanda coincided with the COVID-19 outbreak, uptake and coverage of routine vaccines were heavily influenced by subsequent lockdowns and relocation of health staff and materials, severely confounding the potential impact of e-Tracker on these outcome measures. The pandemic shifted government priorities and influenced and delayed the country's e-Tracker scale-up plan. It also impacted routine immunization service delivery and reduced the demand for routine vaccinations as a result of COVID-19 related accessibility factors. Together these factors made it difficult to demonstrate the anticipated impact of the use of the tool on primary immunization outcomes.

The assessment of impact in this evaluation, thus, focused on several process and output measures (e.g., data quality, data use for decision-making and user and client satisfaction) which were assumed to result in changes of the above outcome measures in the absence of confounders. Given the incomplete use of the e-Tracker for immunization data recording at the HC level, data quality improvements were reported by only two thirds of DH and half of the HC staff, with frequent users of the tool reporting more positive views. However, the e-Tracker reportedly enabled improved data use for decision-making with notable variability for three activities: defaulter identification and tracking, outreach services and supportive supervision. While almost all HCs had a defaulter tracking mechanism for the identification of un-or under-immunized children in place, less than a third of HCs and DHs regularly used the e-Tracker to generate a list of defaulters. At the same time, slightly more than half of HCs and more than two third of DH staff used data from the e-Tracker to guide supervision activities.

In addition to these programmatic findings, the evaluation provided critical data about the economic impact of the e-Tracker. The full initial investment of adapting and deploying the e-Tracker at national scale was approximately USD 1.6 million, which represented around 13.8% of the country's average annual expenditures for immunization in the years 2017-2019, though the financing of the implementation of the e-Tracker was almost entirely borne by external donors, notably WHO and Gavi. Most implementation-related expenditures were attributed to hardware (e.g., computers, tablets and modems), with training as the second highest cost item accounting for 16% of the total cost. The cost of system development and customization to the Rwanda setting was limited, at approximately USD 100k, 7% of the total implementation costs. Overall, the cost of developing and deploying the e-Tracker in each of the 505 HCs delivering vaccination and in the 37 district hospitals in Rwanda was estimated to be USD 2,917 per site.

The implementation of the e-Tracker has led to an almost doubling of costs compared to only using paper registries reflecting a duplication in carrying out child registrations with both paper and electronic registries. This has resulted in an additional financial burden of approximately USD 0.04 per dose. It had been anticipated that the use of the e-Tracker would reduce the cost of all activities that require retrieving immunization data (e.g., generating immunization reports, identifying defaulters, etc.) due to the greater ease of retrieving electronic data as compared to data on paper. However, the findings suggest that the e-Tracker was limitedly used to perform these activities, with the paper registry still considered the most trustworthy source of information. This may explain why no significant difference in costs compared to the paper registry was seen with the only exception of the cost of registering children. The greater trust and reliance in the paper-based registry will need to be carefully taken into consideration in the ongoing transition to a fully electronic registry.

Given the higher costs of the e-Tracker and the limited impact on immunization outcomes, it was highly unlikely that the system in its mode if use before October 2022 (i.e., dual system with minimal impact on decision making) would be cost-effective. Transitioning to a fully electronic system may eliminate any duplication of effort and may result in process efficiencies and cost reductions. Findings from an economic scenario review simulating the experience following the switch to a fully electronic system demonstrate that a fully electronic system is more likely to generate cost savings, if proper equipment (e.g., tablets) and infrastructure (e.g., internet connectivity) are available at the HCs and adequate training and supervision are provided.

These findings suggest that further investments should be aimed at ensuring that the e-Tracker is effectively used as a data management and decision-making tool at all levels of the health system. Targeted investments in strengthening the digital infrastructure and improving data quality will likely generate a positive impact on immunization service delivery by creating a favorable environment for sharable, high-quality immunization data which, in turn, may constitute a first step towards real-time, evidence-based decision-making processes.

The main findings summarized above have been mapped to the guiding research questions of this evaluation, providing a snapshot of the key learnings from early implementation of the e-Tracker in Rwanda.

Has the implementation of the e-Tracker improved immunization service delivery? [Impact]

- Due to the limited period of implementation and the effect of the COVID-19 pandemic on both immunization delivery and the roll-out of the e-Tracker, use of the e-Tracker was not expected to have yet had a measurable impact on immunization outcome indicators (e.g., coverage, timeliness, or drop-out rates). In fact, the ITS analysis for DPT3 coverage data showed that for the two years following e-Tracker introduction there was actually a slight decrease of administered doses compared to before e-Tracker use.
- Impact in this evaluation, therefore, focused on process and output indicators, specifically on data quality and data use for decision-making, which are expected to result in improvements of the outcome measures.
- Improvements in these proxy measures were largely experienced by the more frequent users of the tool at HC level and by supervisors at the DHs. This included better access to information needed, improved data analysis and interpretation, better accuracy and completeness of data and easier reporting of immunization data, including from static clinics and outreach services.
- At the same time, the e-Tracker was deemed beneficial for the conduct of supervisory activities and was ultimately considered by its users to have improved the quality of their decisions related to immunization delivery.

What is the short- and medium-term economic and financial impact of rapidly implementing and scaling-up the e-Tracker in the whole country? How affordable and sustainable is it? [Impact, Affordability and Sustainability]

- The full initial investment of adapting and deploying the e-Tracker at national scale was approximately USD 1.6 million. Most implementation-related expenditures were attributed to hardware. Training was the second highest cost item accounting for 16% of the total cost.
- The use of the e-Tracker has led to an increase of costs for immunization data management activities by 30% compared to only using paper registries. The average cost per HC for performing these activities after the implementation of the e-Tracker is USD 405.2 or USD 0.09 per dose. The majority (85%) of this cost was accounted for by personnel costs and was related mainly to the activity of data entry for each child registered.
- The additional financial burden to the country for the e-Tracker was estimated at approximately USD 128,735 per year, representing approximately 1.1% of the average budget allocated to routine immunization activities in 2017-2019 (or 9% of the domestic expenditure for running the VPDP).
- Given the higher costs of the e-Tracker and the limited impact on immunization outcomes to date, it is highly unlikely that the system in its mode of use before October 2022 (i.e., in combination with the paper registries) would be cost-effective.
- Findings from a simulation exercise suggest that transitioning to a fully electronic system, based on eliminating the duplication of HW time, may result in process efficiencies and substantial cost reductions. This transition is more likely to generate a substantial cost saving as compared to a fully paper-based registry if proper equipment and infrastructure are available at the HCs, as well as provided that adequate training and supervision is performed.
- The macroeconomic context in Rwanda appears to be favorable. However, as the country relies heavily upon external funding, especially for the immunization budget, with only 16% of the budget covered by domestic sources, this may imply that the continuous operation of the e-Tracker could be difficult to maintain should external resources decrease in the future.

How interoperable is the e-Tracker with other RHMIS modules and the civil registration system? [Ecosystem, Tool]

- Despite displaying ideal features of an eIR, the limited interoperability of the e-Tracker at the time of the evaluation was perceived as a significant bottleneck to its effective use. This has subsequently changed with the implementation of new technical features, which now include interoperability with both the CRVS and RapidSMS.
- The additional interoperability with the vaccine logistics management module would further enhance the utility of e-Tracker.
- Sufficient stress-testing for full scale-up of additional features will need to be factored into any future implementation plans given the experience from other countries with similar systems 'collapsing' once fully scaled.

How can new evidence on tools and technologies, modalities, and governance of the e-Tracker inform further investments in other countries from domestic sources, health financing institutions and technical partners for its sustained operation? [Ecosystem, Impact, Affordability and Sustainability]

- A decision to further invest in the e-Tracker should be aimed at ensuring that it is effectively used as a data management and decision-making tool at all levels of the health system. Investments in strengthening digital infrastructure, enabling greater interoperability and improving data quality may create a favorable environment for sharable, high-quality immunization data which, in turn, may constitute a first step towards real-time, data-driven decision-making processes.
- Given the identification of specific barriers and enabling factors, it is recommended that an evaluation framework be developed to monitor the uptake and use of the e-Tracker, as well as to document the process changes as Rwanda transitions to a fully digital system. This evaluation should serve as a baseline assessment with a re-assessment of the situation within 1-2 years of the transition.
- The experience of Rwanda in this transition will be an important learning opportunity for other countries presently exploring implementing similar changes.

RECOMMENDATIONS

The further use and expansion of the e-Tracker to inform data collection, analysis and decision making on immunization should be enabled so that the full potential of the system can be realized which in turn may assist with reaching improved immunization outcomes. It is only when the e-Tracker is used in this way that the system will be cost-effective and that the investments made in its development and implementation will have positive returns. This will require strengthening the overall ecosystem, with specific attention to the IT infrastructure, in addition to maintaining the recently introduced interoperability features, such that the tool can be fully functional. Ensuring that refresher training and ongoing supervision adequately enable both use of the e-Tracker and the use of data will also be paramount.

Finally, as Rwanda continues its digital journey in transitioning to a fully electronic system, it is recommended that a monitoring and evaluation framework be developed to monitor the further use of the e-Tracker, as well as any associated process changes. This evaluation should serve as a baseline assessment with a re-assessment of the situation within 1-2 years of the transition. The learning from Rwanda's experience will be an important contribution to global knowledge exchange in this area.

I. INTRODUCTION

With the increasing digitalization of health systems in low- and middle-income countries (LMICs), there is growing interest from governments, donors and implementing partners to introduce and scale-up electronic immunization registries (eIR). While current evidence suggests that eIR may contribute to improved data quality and use, many are never rolled out nationally, nor rigorously evaluated. Where innovation around digitalization has failed, it was often because the country context, user requirement specificity and/or issues related to interoperability with existing systems were ignored. Importantly, no impact has been observed from technological interventions alone. Multicomponent interventions, including related capacity building and change management, are critical.

This report builds upon recent literature which documents experiences with eIR and other health and medical registries in LMICs (Danovaro-Holliday et al., 2014; Nguyen et al., 2017; Dumit et al., 2018; Dolan et al., 2019), and answers the call for more evidence to estimate the effectiveness, affordability and sustainability of these interventions, particularly in LMICs. It is part of a multicounty evaluation of the impact of both eIR and electronic logistics management information systems (eLMIS) across Guinea, Honduras, Rwanda and Tanzania. Four country reports exploring the challenges and opportunities around developing and implementing eIR, the associated costs and the programmatic and economic impact are being drafted. A final report will synthetize cross-country learnings to support future decisions on the introduction and management of eIR and eLMIS in LMICs.

The primary audiences for this report are decision-makers and technical staff, such as government officials, program managers, donors and implementing partners. Other stakeholders including those from academia and private sector may also benefit from the findings in this report.

II. BACKGROUND

A. E-TRACKER IN RWANDA

The Rwanda Health Management and Information System (R-HMIS), overseen by the Ministry of Health (MoH), became digital in 2012 with the deployment of the District Health Information Software Version 2.0 (DHIS2). This web-based platform is used nationally in both public and private health facilities and supports the management of data across several programs, including the Vaccine Preventable Disease Program (VPDP), a division of the Rwanda Biomedical Center (RBC) formerly known as the Expanded Program on Immunization (EPI).

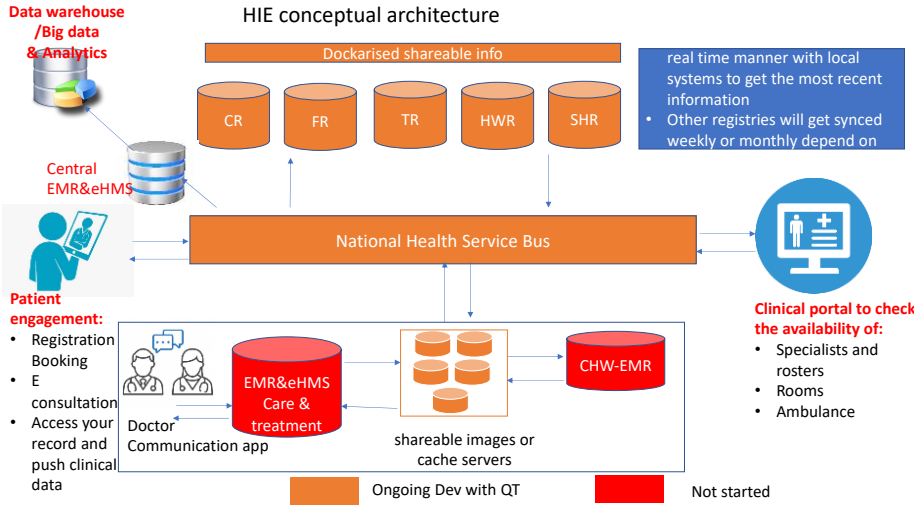
In 2009, the VPDP made the decision to implement the DHIS2 EIR Tracker package (e-Tracker) for routine immunization supported by the national Health Information Systems Programme (HISP), UNICEF, CDC, USAID/Intrahealth, University of Oslo and the World Health Organization (WHO). The system was introduced under the responsibility of the MoH, with support provided by the Ministry of Local Government (MINALOC), National Institute of Statistics of Rwanda (NISR) and Rwanda Information Society Authority (RISA). Although Rwanda had achieved high national coverage rates in the years before the introduction of e-Tracker with coverage of the third dose of Pentavalent vaccine (Penta3) estimated at 97% in 2018 and of the first dose of measles and rubella vaccine (MR1) at 99% in 2018 (WHO, 2021), some children were still being left behind continuously across years. The e-Tracker was introduced as part of a digital solution to improve the efficiency and effectiveness of the national immunization system and to support achievement of the national goal of substantially reducing “zero dose” children through linkages with the national civil registration and vital statistics system (CRVS) and the real-time monitoring of immunization coverage and drop-out rates.

Before the introduction of the e-Tracker, childhood vaccination status had been exclusively tracked through vaccination cards and paper registries. Health facility data managers compiled data from these registries and aggregated it into RHMIS. Data analysis was performed manually using existing reports (i.e., tally sheets) and aggregated RHMIS reports. Notably, the vision for e-Tracker was part of a broader health technology approach in Rwanda that predated its actual introduction. The MoH wished to capitalize on growing investments in digital health and made a commitment to using real-time data for decision making. Strong political will drove this agenda, as evidenced by several national plans articulating the goals, strategies, and policies for eHealth in

Rwanda. The Health Sector Strategic Plan IV (2018–2024) lays out a strategic direction for eHealth and research to "ensure the availability of interoperable, responsive and functional information systems providing high quality data in a timely manner to inform planning and decision-making." Similarly, Rwanda's National Digital Health Strategic Plan (2018–2023) articulates the government's vision for digital health and complements the Service-Oriented, Modern, Accountable, and Real-Time (SMART) Rwanda Master Plan (SRMP) 2015–2020 which very early articulated the overall aim of the digital transformation in Rwanda toward a "knowledge-based society." The SRMP specifically sought to improve the service delivery environment for health workers (HWs) to increase their productivity and experience, reduce the direct and indirect costs of healthcare per patient, per encounter, and improve patient experience.

It was against this landscape that the e-Tracker was introduced at national scale. The MoH had identified opportunities to leverage the existing digital health infrastructure, including available internet coverage and penetration, as well as the longstanding experience implementing other digital health system solutions such as an electronic logistics management information system (eLMIS), Rapid Short Messaging Service (Rapid SMS) and an electronic Open Medical Record System (OpenMRS), for example. A vision of interoperability fueled this "digital revolution," as embodied by the "One Citizen Health Record" and the architecture of the Rwanda Health Information Exchange System (RHIES). A mapping of the RHIES and its implementation status is captured below in *Figure 1*. Complete interoperability is under development, with functional interoperability of the e-Tracker and CRVS now implemented. In addition, one component of the HIV integrated system is being tested currently in half of the district hospitals (DHs) in Rwanda.

Figure 1: RHIES Architecture *(figure from MoH, 2022)*



Implementation of the e-Tracker commenced in May 2019 with customization and training sessions, followed by a national roll-out in health facilities delivering routine immunization services from September 2019 to January 2020. While the software platform was designed to have several key features such as scheduling of appointments, sending of digital reminders to both parents and community health workers (CHWs), staff management and the monitoring of adverse events following immunization (AEFI), the operationalization of many of these features was delayed, reportedly as a consequence of the COVID-19 pandemic.

The e-Tracker is currently deployed nationwide in all 505 health centers that deliver immunization services, inclusive of public, non-profit and faith-based organizations. Overall, the e-Tracker aims to provide clinical guidance and support to HWs. The e-Tracker captures basic information related to demographic characteristics and vaccine history. At the HC level, data managers maintain and update the e-Tracker while clinical staff are filling the paper registry, for primary data collection. HCs are expected to enter information of nominal records and transmit to the central level (RBC), as well as analyze and use data locally for decision making. District level staff follow-up on facility reports and identify gaps in information transmitted. At the central level, RBC oversees documentation, notification and registration of immunization related data at all levels of the health system, collates, analyzes and feeds back on data obtained from the lower levels, provides guidance, and capacity building and finally disseminates data and summary reports.

The e-Tracker links to the infant's National Identification Number (NIN) as the unique identifier to register and record individual vaccine doses delivered. As more than 93% of births in Rwanda are facility-based, birth registration and the issuance of a NIN are performed at the health facility through the R-HMIS. Mother and infant are not discharged unless the birth dose of BCG is administered in line with Rwanda's vaccination schedule. Interoperability with the Civil Registry and Vital Statistics (CRVS) System had been designed from the outset, though implementation was delayed because of the COVID-19 pandemic. This interoperability has been tested and validated by VPDP supervisors at health facilities, and end users have completed training on how to retrieve data from birth registrations in DHIS2 and now use it to enroll children in immunization programs (DHIS, 2022). This will result in a more simplified process whereby a custom script pushes data on all registered newborns from the CRVS system to the DHIS2 e-Tracker in the national HMIS system.

Importantly, the COVID-19 pandemic strongly influenced the implementation of e-Tracker, interrupting training on data management and information analysis, delaying the interoperability of the CRVS, as well as the RapidSMS feature, and slowing down the MoH's one-year transition plan to move from a paper system to a fully digital system. As such, Rwanda operated a dual registration system for routine immunization until October 2022. A paper registry was maintained at each health center, and a hard copy of the child vaccination card was kept by caregivers. In parallel, the e-Tracker was used for data entry of vaccine doses administered across different antigens as well as for a range of analytical tasks (e.g., monthly reporting, generating defaulter lists, generating new immunization records, including for children with lost vaccination cards or resident in other health center catchment areas, etc.). To enhance the completeness of the e-Tracker database, a performance-based financing (PBF) scheme was rolled out with BCG vaccination data as the indicator variable on which payments were made. Early findings demonstrate more complete reporting for BCG vaccination; however, the scheme has not influenced the reporting of other antigens. As of 1 October 2022, paper-based registries are being abandoned, and the e-Tracker is to be used as the sole source of immunization data. The transition process is still ongoing.

Although Rwanda has had steadily high immunization coverage over the past few years, it experienced long periods of lockdown during the COVID-19 pandemic which led to a decrease in routine vaccination with Penta3 vaccination coverage decreasing from 98% in 2019 to 91% in 2020 and 88% in 2021, and MR1 vaccination coverage decreasing from 96% in 2019 to 94% in 2020 and 87% in 2021 (WUENIC), the period in which the e-Tracker was rolled out nationally. The impact of easing the restrictive measures in 2022 on routine immunization coverage is not yet known.

B. EVALUATION RATIONALE

OBJECTIVE OF THE EVALUATION

The objective of this evaluation was to assess the interoperability, programmatic impact, costs, affordability and sustainability of the early implementation of the e-Tracker and to generate actionable evidence for the Government of Rwanda to support future decisions on the management of e-Tracker and other digital technologies, in the context of its strong commitment to digitalization. The evaluation also aimed to generate new evidence on tools and technologies, modalities, and governance of the e-Tracker to inform further investments in other countries from domestic sources, health financing institutions and technical partners.

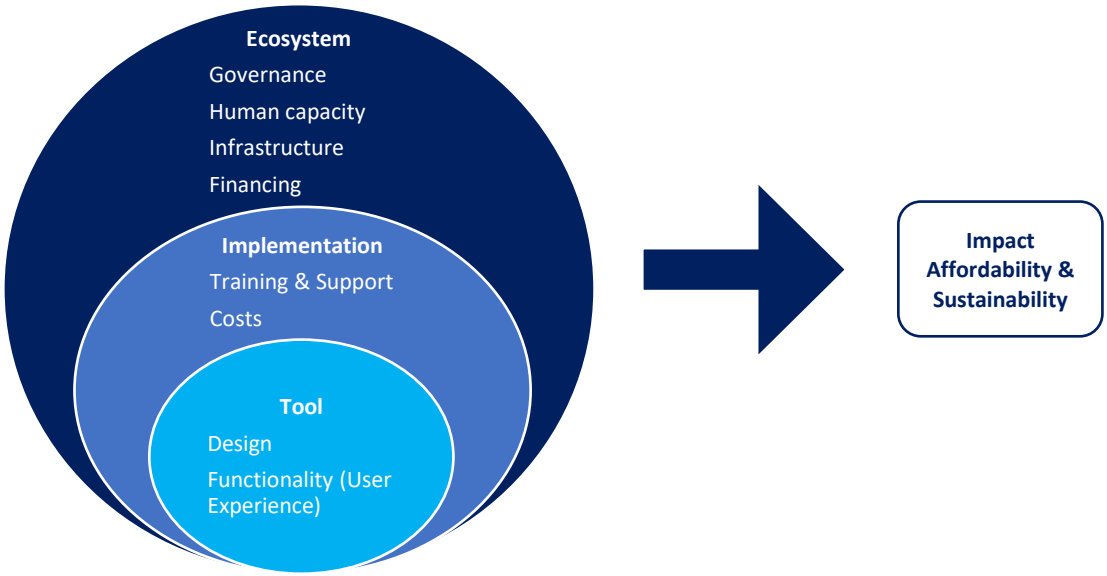
As Rwanda implemented its eIR nationally over only a few months, it was foreseen that the evaluation would provide insights on the potential advantages or challenges conferred by rapid implementation at scale, including its effect on immunization coverage, timeliness and dropout rates. However, as the implementation coincided with the beginning of the COVID-19 pandemic, its impact on these immunization indicators could not be dissociated from the effects of the repeated COVID-19 lockdowns in 2020 and 2021 on immunization service delivery. It was nevertheless envisaged that evaluation findings could provide insights on the contribution of the e-Tracker to potentially mitigate the decrease in routine immunization coverage during the pandemic and to confer resilience to the primary health care system. Additionally, it was determined that important learning could be gathered on more proximal indicators such as data quality and use or HW and client satisfaction and on how to effectively support the transition process to a fully electronic system.

THEORY OF CHANGE

This evaluation is consistent with the wider evaluation design of the multi-country evaluation. It is based on an overarching evaluation framework supported by a Theory of Change (ToC) which is presented in **Annex 1**. Implementation and sustained use of an eIR at scale is envisaged to contribute to improved immunization program performance by ensuring more equitable coverage and system efficiency. Implementation and sustained use of an eIR at scale is also envisaged to be a good investment in the medium to long-term, with the assumption in the ToC that it is both well-embedded into the country's processes and data architecture, and that it is affordable and financially sustainable, providing value for money.

The ToC serves as the foundation for an evaluation framework used to guide the interpretation of the key findings from this evaluation. The framework focuses on four domains: ecosystem; tool design and function; implementation; and impact and sustainability. This is illustrated below in *Figure 2*.

Figure 2: Evaluation Framework



RESEARCH QUESTIONS

The following outline reflects the principal research questions for this evaluation in Rwanda. The research questions have been mapped against the domains of the evaluation framework above to ensure clear reporting of the findings and their implications.

- Has the implementation of the e-Tracker improved immunization service delivery? [*Impact]*
  - To what extent does the system comply with established norms and standards? *[Tool]*
  - What were/are the barriers and opportunities for implementing it in the country? *[Ecosystem, Implementation, Tool]*
  - What is the impact of the e-Tracker on the national immunization program (e.g., cost saving, efficiencies, timeliness, coverage)? *[Impact]*
- What is the short- and medium-term economic (i.e., costs) and financial (i.e., expenditure) impact of rapidly implementing and scaling-up the systems in the whole country? How affordable and sustainable is it? *[Impact, Affordability and Sustainability]*
- How interoperable is the e-Tracker with other RHMIS modules and the civil registration system? *[Ecosystem, Tool]*
- How can new evidence on tools and technologies, modalities, and governance of the e-Tracker inform further investments in other countries from domestic sources, health financing institutions and technical partners for its sustained operation? *[Ecosystem, Impact, Affordability and Sustainability]*

III. METHODOLOGY

A. PROGRAMMATIC AND ECONOMIC IMPACT EVALUATION

PROGRAMMATIC IMPACT EVALUATION

A mixed methods approach involving both quantitative and qualitative methods was used to evaluate the programmatic impact of the e-Tracker. This impact was assessed in terms of service delivery processes potentially enhanced by the sustained use of the tool. These included the functioning of the e-Tracker as part of a broader health information system, immunization data quality and accuracy, data use for decision-making, and HW and client satisfaction. A number of programmatic input, process and output indicators were assessed and compared a) before and after the introduction of the electronic tool and b) between those health facilities which used the tools frequently and those that did not. In this context 'use of the tool' was defined on the basis of a subset of six criteria contained in the 'User Acceptability Survey' of the Modular Data Quality Assessment Protocol (PAHO 2017) - see further details under Data Collection and Data Analysis below. Overall, the programmatic evaluation aimed to identify and explore discrete factors critical for the successful implementation and scale-up of the e-Tracker.

ECONOMIC IMPACT EVALUATION

The economic impact evaluation aimed to provide an estimate of: (i) the upfront financial expenditures at national level of implementing the e-Tracker; (ii) the routine operating costs of managing immunization data using the e-Tracker; and (iii) the difference in operating costs with the e-Tracker as compared to the paper-based registry. An activity-based costing approach (ABC) was used for the analysis of routine operating costs with and without using the e-Tracker. This approach consisted of identifying a series of activities performed by the health facilities (i.e., HCs and DHs), tracing direct and indirect costs to these activities and then using cost-drivers to calculate a cost per unit of product or service (Udpa, 1996). The activities considered were limited to those related to the management of immunization data (i.e., data entry and analysis, including the maintaining of records of children vaccinated, completing reports and performing analyses, and monitoring and evaluating immunization program data). When estimating the difference in operating costs with and without the e-Tracker, the analysis considered two further activities whose costs, while not directly attributable to the management of immunization data, might be affected by the way immunization data is managed and used. These activities refer to the cost of delivering outreach sessions and the cost of emergency vaccine replacement. A rationale for the inclusion of these activities is provided in **Annex 6**.

Additional insights for decision-makers on the financial sustainability of maintaining the e-Tracker in the long-run are provided based on the Rwanda's economic outlook, current expenditures on health and exposure to external funders. Specifically, a series of indicators across three levels are presented: (i) macro-sustainability; (ii) activity-specific sustainability; and (iii) sustainability from the perspective of funders. For the first level, an overview of the macroeconomic trends for Rwanda is provided, based on macro-economic indicators such as GDP, GDP per capita, share of public debt over the GDP and other indicators on health care expenditure. The activity-specific sustainability is expressed as the percentage weight of the costs of using the e-Tracker over the total budget for immunization in Rwanda. Lastly, the sustainability of the e-Tracker for domestic funders is expressed as the share of costs covered by external payers over the total costs of the e-Tracker.

Finally, as Rwanda initiated the transition to a fully electronic system on 1 October 2022, a scenario analysis, simulating the costs of a fully electronic system, now implemented, was conducted based on the data collected from the current dual system, where the e-Tracker co-exists with the paper registry.

B. DATA COLLECTION INSTRUMENTS

The data collection strategy was generated from an overarching evaluation framework based on the ToC which defined the principal research questions associated with the main objectives. T*able 1* includes the data collection instruments, summarizing the purpose of each instrument and the number of respondents. The programmatic data collection instruments were adapted from pre-existing and validated tools including: the Modular Data Quality Assessment Protocol with Electronic Immunization Registry Component (PAHO, 2017); a range of data

instruments used in the Evaluation of the Better Immunization Data Initiative (Mott MacDonald, 2019); and the eIR Readiness Assessment.

Table 1: Data collection instruments

Level	Data collection instrument	Purpose of the data collection instrument	Number of respondents
Health Center	Programmatic: Interview guide	To explore the use of e-Tracker including infrastructure and workforce requirements and impact on data quality and data use (e.g., impact on drop-out rates; defaulter tracking; outreach activities; reporting; and supervision). *(Note: Interviews sometimes took place in the form of focus group discussions.)*	24
	Economic: Interview guide	To elicit information to quantify the costs of managing immunization services with and without using the e-Tracker	24
	Programmatic: Competency assessment	To assess the competency of staff using the e-Tracker	49
	Programmatic: On-site accuracy check	To assess the accuracy between different data sources	24
	Programmatic: HW survey	A self-administered survey designed to gather insights on infrastructure, computer literacy, IT services, information quality and HW user satisfaction	44
	Programmatic: Caregiver interview guide	To explore if caregivers of vaccinated children had noticed any change in service delivery since the introduction of the e-Tracker	95
District Hospital*	Programmatic: Interview guide	Adapted from the programmatic interview guide used at HC level	12
	Economic: Interview guide	Adapted from the economic interview guide used at HC level	12
	Programmatic: Survey	Adapted from the survey used at HC level	13
	Programmatic: Competency assessment	Adapted from the competency assessment used at HC level	16

**Official notation for the district level in Rwanda is "District Hospital." It is important to highlight that the District Hospital takes on the function of a district health office including those of an immunization supervisory role for the associated HCs. Reference to "District Hospital (DH)" in this report is therefore synonymous with the district level.*

The evaluation protocol and data collection instruments all received research and ethical clearance in December 2021 under the procedures set by Rwanda National Ethics Committee (RNEC). The data collection instruments are available in **Annex 2**.

The field work for data collection was coordinated by CIIC-HIN and executed over a period of 3 weeks in February and March 2022, following training of data collectors and piloting of data collection tools. Four teams of 4-5 members visited between 2-4 districts each. In each district, the selected health facilities were visited, and all interviews and observations conducted. Teams were composed of an experienced CIIC-HIN team lead, two trained and competent data collectors, a supervisor and a driver. Data collectors were fully trained on all aspects of the protocol and the administration of the questionnaires and data collection forms and equipped with the necessary technical evaluation tools and skills. A pilot testing of the data collection process and tools was done as part of the training process. Data were collected using portable electronic devices (i.e., tablets) by each of the data collection teams and synchronized on a central server via the ODK Central application.

Daily reports of collected data were sent to the CIIC-HIN headquarters in Kigali where a senior data analyst reviewed data quality and completeness and provided immediate feedback and suggestions for improvements in case of missing or unclear data. Data were cleaned, compiled, and analyzed by senior CIIC-HIN team members

with remote assistance by the Bocconi/MMGH research team in March and April 2022. Additional telephone district and regional interviews were conducted following the initial data collection period to clarify specific issues and to obtain additional information and insights over and above those collected during the initial data collection period.

Further, secondary data were collected during the ensuing period, specifically related to the costs of implementation, as well as on immunization-related indicators from government sources such as coverage, drop-out, vaccine stock-out and wastage rates for the years before and after implementation of the tools.

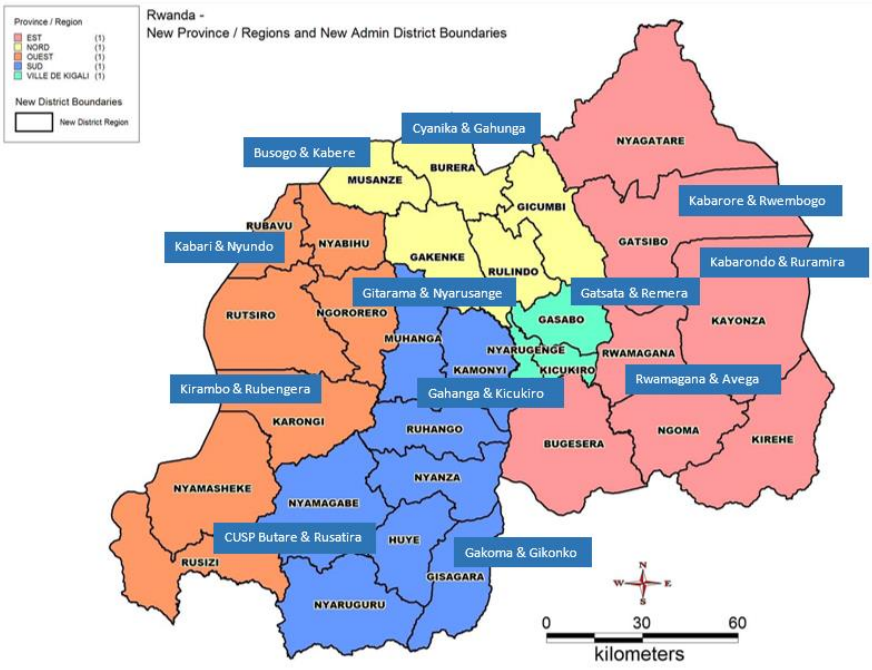
C. SAMPLING STRATEGY

A purposive sampling strategy was used to identify a representative sample of district hospitals (DHs) and health centers (HCs) for inclusion in this evaluation. All provinces and the City of Kigali were included in the sampling frame. The selection of HCs for inclusion in the sample was based on the following criteria, as summarized in **Annex 3**.

- HC type (public and faith-based health)
- Size of catchment population of the HC (infants <1 year of age)
- Vaccine dropout rates between Penta1 and Penta3 and Penta 3 and MR1 for the years 2018-2020
- Urban or rural location of HC
- In addition, e-Tracker performance (i.e., categorization of districts as high, medium and low performers in terms of e-Tracker use[1]) was used to review the distribution of selected HCs across these categories. To reduce an initial skewness in this distribution, the sample of HCs was increased from 18 to 24.

Pragmatically, HCs could only be included if vaccination services took place during the two-week period of data collection to allow for observations. The final sample contained 12 DHs and 24 HCs (13 rural and 11 urban), as shown in *Figure 3*. A list of sites visited is presented in **Annex 4**.

Figure 3: Mapping of health facilities inhe final sample



[1] Use of e-Tracker for reporting Penta1, Penta3 and MR1 coverage data to the HMIS between January-June 2021

In a final review, the sample of 24 HCs was found to be representative of the distribution of the above criteria across all 505 HCs in the country offering vaccination with the following deviations observed, all of which were found to be statistically non-significant:

- The sample had slightly more faith-based HCs, however these are nevertheless considered public health institutions
- There were slightly more HCs with larger infant catchment populations in the sample
- The sample contained slightly more HCs with higher vaccine Penta3-Penta1 dropout rates while Penta3-MR1 dropout rates were identical
- The sample contained a deliberate oversampling of urban sites to allow for the evaluation of urban-rural influences as a potential confounding factor.
- Finally, while 29.5% of overall immunization data in the HIMIS was reported through the e-Tracker, the respective proportion in the sample was 28.1%

D. DATA ANALYSIS

PROGRAMMATIC ANALYSIS

The multi-country study protocol includes two specific comparisons of inputs, process and output parameters: before and after the introduction of the electronic tools; and a comparison between those health facilities who use the tools and those who do not. In the case of Rwanda, given the rollout of the e-Tracker over a short period of time in the whole country, a comparison between "frequent" and "non-frequent" users was used.

The programmatic data analysis adopted a mixed methods approach. A descriptive analysis of primary data collected during the field work was performed by generating uni- and bivariate frequency distributions and summary measures. A qualitative review of open-ended questions contained in the data collection instruments was done which focused particularly on the challenges and enabling factors of the use of the tool. An additional analysis by urban/rural strata was performed. Simple statistical tests were performed which included z-tests and t-tests for the comparison of continuous variables, Chi-square tests and Fisher's exact tests to assess associations between independent categorical variables. Given the non-random sampling strategy used, any associations from these tests should not be viewed as establishing statistically significant associations but rather as allowing the generation of hypotheses to be further investigated.

The categorization of "frequent" and "non-frequent" users was done by using results of the health center survey. This survey, based on the *'User Acceptability Survey'* of the Modular Data Quality Assessment Protocol was divided into six domains: computer literacy, infrastructure, information quality, IT services, use of the tool, and user satisfaction/perceived benefit. A score for each domain was calculated by dividing the total number of 'yes' responses by the number of questions per domain. Half-scores were assigned for responses where a 'partial yes' was provided. If a health center had more than one survey response, the mean of the scores was taken. Categorization of "frequent" and "non-frequent" users was based on the average score of the domain 'Use' of the e-Tracker derived from responses to six standard questions. HCs described as "non-frequent" users are those that scored less than 25% on this domain. The cut-off at 25% was set based on a natural shift in the distribution of the use scores across HCs. A comparison of the post-hoc classification of HCs by frequency of use and the a-priori classification as low, medium and high performing districts, as per the sampling strategy, confirmed that the majority of "non-frequent" users (56%) were also classified as belonging to a low-performing district in terms of e-Tracker use. As no district hospital scored below the 25% threshold, a comparison between "frequent" and "non-frequent" DHs could not be made.

To further understand the effect of e-Tracker use on uptake of specific vaccines, an interrupted time series (ITS) analysis of Penta3 vaccine coverage for children aged 3.5 months and for MR2 vaccine coverage for children aged 15 months was conducted. The data was derived from monthly reports and HMIS records for a period of 45 months between January 2018 and September 2021. This period includes 21 months before e-Tracker implementation (pre-intervention) from January 2018 to September 2019, and 24 months after e-Tracker implementation (post-intervention) from October 2019 to September 2021. The aggregated HMIS data for these two time periods across all HCs were used to construct longitudinal models to predict the expected vaccine uptake. The trend of the uptake of these selected vaccines 21 months before the implementation (baseline) of the e-Tracker was assessed and the possible change in trend after the implementation of the tool evaluated.

ECONOMIC ANALYSIS

The economic analysis used a mix of primary and secondary sources of data and different methodological approaches for data analysis, as summarized in *Table 2* and explained in more detail below.

Table 2: Summary of economic analysis

	Financial expenditures of implementing the e-Tracker	**Routine operating costs of using e-Tracker**	**Cost impact of using e-Tracker**	**Financial sustainability of e-Tracker**	**Scenario analysis of a fully electronic registry**
Scope of the analysis	Design & development and roll-out expenditure of e-Tracker	Routine operating costs related to the management of immunization data using the e-Tracker	Difference in the operating costs of managing immunization data with e-Tracker as compared to the paper-based system	Financial sustainability of maintaining the continuous operations of the systems, using domestic resources	Simulating the impact on costs of a complete paperless registry
Type of analysis	Descriptive analysis	Activity Based Costing analysis – subgroup analysis by frequent vs non-frequent users and rural vs urban users	Activity Based Costing analysis using a before and after comparison of avoided cost from e-Tracker	Descriptive and comparative analysis. Analysis of the total cost of the system based on the Activity Based Costing analysis	Simulation
Output of analysis	Total expenditure of implementation and roll-out of the system	Cost per Health Center	Net cost of e-Tracker, including any avoided cost to the immunization program	Macroeconomic and health care sustainability indicators. Percentage of financial resources required for e-Tracker / Total EPI costs. Percentage of costs covered by domestic payers	Net cost of e-Tracker in the absence of the additional cost of maintaining the paper registry
Source of data	HISP data, RBC	Questionnaires, RHMIS data	Questionnaires, RHMIS data	International Monetary Fund (IMF), WHO and country report indicators, e-Tracker data extract	Base-case analysis + simulation
Cost inputs		Personnel, durable goods, consumable goods, services, indirect and shared costs			

FINANCIAL EXPENDITURES OF IMPLEMENTING E-TRACKER

The perspective used for the analysis of financial expenditures was that of a "third-party payer." This perspective includes the expenditures from both external funders (e.g., international organizations and/or private funders) and domestic funders (e.g., national or subnational authorities). Expenditure data were obtained from the Health Information Systems Programme (HISP) Rwanda and RBC. A descriptive analysis was performed categorizing expenditures into financial expenditures for: (i) system design and development (i.e., customization of the DHIS2 e-Tracker to the country needs and context, as well as testing activities performed by HISP Rwanda) and (ii) implementation (i.e., purchasing of hardware, such as tablets, desktops and modems; and trainings), as aligned with the evaluation framework in line with a an approach followed by Mvundura et al. (2019).

ROUTINE OPERATING COSTS OF USING E-TRACKER

The analysis of the routine operating costs of using the e-Tracker was based on data extractions from the e-Tracker data base and the primary data collected on costing information for a set of activities related to the management of immunization data. These activities were pre-defined by the research team based on a literature review and an iterative consultation process with experts in electronic immunization systems, as summarized in *Table 3*.

Table 3: Description of activities related to the management of immunization data

Activity	Description
Vaccination session execution: Child registration	Entering details and data regarding a new child registration (including services provided and data management, finding client folder and event recording).
Defaulter identification	Reviewing registry to identify children who missed appointments, establishing list of defaulters
Defaulter tracing	Contacting defaulters to remind caregivers of the need to get their children vaccinated
Organizing outreach sessions	Preparation for the delivery of immunizations in outreach settings
Identifying performance gaps	Reviewing data to find performance gaps (such as not being on track for reaching coverage goals)
Report generation	Searching for and recording the data that will be included in the regular reports for immunization and stock management.
Report transportation	Transporting of weekly/monthly reports to higher administrative levels
Vaccine quality control/ monitoring	Physical counting, recording, and checking of closed vials for surpassing expiry dates or for temperature excursion; Physical counting, recording, and checking of open vials

In the questionnaires, respondents were asked to provide estimates of the number and profile of staff and the amount of time spent by staff on each of the defined activities, as well as other costs incurred on average for equipment, consumables and services that were directly attributable to that activity. Information was also collected on the average frequency at which each activity was performed at monthly or annual intervals, and on other costs that were directly attributable to the management of immunization data (e.g., printing costs of reports and maintenance of IT equipment). In addition, to allow for a comparison with the paper-based registry, respondents were also asked to report on the same information before and after the implementation of the e-Tracker. In addition to the activities in *Table 3*, respondents also reported on the costs of printing and maintenance related to immunization data management. The costs for these activities were attributed to all the other activities as direct shared costs which are indirectly associated with the execution of the data management activities of Table 3, as data is not directly managed during printing and maintenance.

Staff time was converted to a monetary value using national reference salaries for healthcare staff (Official Gazette, 2020). Annex 6.1 provides further details on the approach used to map the staff profile reported in the primary data collection to the staff titles and salary list published in the official Gazette. The cost per minute of staff was then calculated considering a 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, trainings and breaks.

In addition to the primary data collected, indirect and shared costs were obtained from secondary data sources. Specifically, expenditure data from 2018 and 2021 for the 24 HCs in the sample were obtained from the RHMIS. Cost data for the following categories were available: (i) communication, telephone, and internet; (ii) purchase of non-medical equipment; (iii) maintenance and repair of infrastructure; and (iv) office supplies, printed materials, medical records. All indirect costs were apportioned to the activities in scope using staff time per activity as the cost driver (i.e., by allocating a percentage of these costs equal to the overall time dedicated to each activity over the total available time of all the personnel of the HCs). The latter was calculated using data on the number of employed staff per facility published in the official Gazette, and assuming the same practical capacity of each staff member, as described above.

The costs of using the e-Tracker were then reported as the total average annual cost per HC, and the cost per dose delivered. In both estimates, the costs of using the e-Tracker at the district level were apportioned equally to each HC in the district by dividing the estimated district cost by the number of facilities under its administration. The cost of immunization data management per dose was based on the 393,445 surviving infants in Rwanda in 2021 (UNPOP, 2021) and on the national immunization coverage rates estimates by the WHO and UNICEF for the first dose of BCG, the third dose of Pentavalent vaccine, the third dose of oral Polio vaccine and at least one of Measles containing vaccine, which are required for a child to be considered fully immunized. Coverage rates were taken from 2019 to avoid incorporating the effect of COVID-19 on coverage. The average annual cost of immunization data management per health center was then divided by the total number of doses for the above antigens delivered to surviving infants.

All cost estimates were adjusted to 2021 real values using the World Bank Gross Domestic Product (GDP) deflator index (World Bank, 2022) and converted to USD using the World Bank's average exchange rate in 2021 (1 USD = 988.6 RWF). Given the limited sample size, outlier values for each variable (i.e., greater or smaller than 1.5 times the interquartile range) were excluded from the analysis. The average costs in the economic analysis are reported along with the 95% confidence intervals.

COST IMPACT OF USING E-TRACKER

As the e-Tracker was rapidly implemented at national scale, a pre-/post approach was used to estimate the difference in costs for immunization data management with and without e-Tracker use. The broader impact on the immunization program was investigated through costing of delivery of outreach sessions and emergency vaccine replenishments, on which the e-Tracker might have had an indirect impact. The mean difference in costs was calculated using both before and after data from the health center questionnaires and secondary data from the HMIS. For the latter, the costs reported in 2018 were used as proxy of the indirect costs in each facility before the implementation of the e-Tracker. No differences were assumed in the frequency with which activities were performed before and after the implementation of the e-Tracker.

To account for potential costs avoided as a result of the implementation of the system the cost impact analysis explored whether implementing the e-Tracker would affect the costs of delivering outreach sessions and the costs of emergency vaccine replenishment due to unplanned stock-outs. For these two additional activities, it was explored whether the implementation of the system was associated with any difference in costs, for example, through a reduction in stock-out events or through an improvement in the efficiency of outreach sessions (e.g., if the number of children vaccinated per session was increased or if the number of outreach sessions in a year was reduced because of better planning).

Subgroup analyses were performed by comparing the costs of using the e-Tracker between frequent and non-frequent users and between rural and urban HCs.

FINANCIAL SUSTAINABILITY OF E-TRACKER

Time series data for the sustainability analysis were derived from the International Monetary Fund (IMF), for macro-economic indicators such as GDP, GDP per capita and share of public debt over the GDP, and from WHO for the total health expenditures data. The current expenditure for routine immunization was derived from WHO Joint Reporting Form (JRF) data. The expenditure for routine immunization in 2020 and 2021 for Rwanda were respectively 8.3 and 2 million USD (i.e., 72% and 18% of the reported expenditure for 2019). The apparent vast difference in expenditures could be due to either direct (e.g., reallocation of funds, poor budget execution) or indirect (e.g., poor accounting and reporting) consequences of the COVID-19 emergency. Therefore, to calculate the indicator for sector-specific affordability we considered as immunization budget the average total expenditure on health in 2017, 2018 and 2019, as reported by JRF data, and equal to 11.6 million USD.

ECONOMIC IMPACT OF A FULLY ELECTRONIC REGISTRY: SCENARIO ANALYSIS

Finally, to simulate the impact on costs of fully switching to a paperless process from the current dual system, the data collected on costs and resources spent for running the e-Tracker or the previous paper-based registries were used to define assumptions on how the newly implemented paperless process would affect the costs of managing immunization data. Specific assumptions based on the findings of the data collected at the HCs were made on how service design would change and affect the total time used by staff to perform data-management related activities and other costs such as printing.

IV. FINDINGS

This evaluation provides data on the status of the implementation, use and programmatic impact of the e-Tracker in Rwanda, as of March 2022 and as reported by both the district and health center levels, coupled with financial data on the implementation and routine operating costs of the tool. Programmatic findings are reported based on the analysis of primary data from questionnaires triangulated with information from a desk review. Economic findings are reported as derived from the activity-based costing analysis and include a sustainability and affordability analysis. Additional details on the programmatic and economic findings are provided in **Annex 5** and **Annex 6**, respectively.

A. E-TRACKER USE

Despite its national rollout, use of the e-Tracker varied across DHs and HCs. At the time of the data collection, Rwanda ran a dual process whereby the planning and delivery of immunization services, as well as the associated data-capturing and reporting processes, were performed by HWs first on paper and later back-entered in the e-Tracker by use of a desktop computer by a data manager. In this evaluation, HCs were categorized as either frequent (15) or non-frequent (9) users of the e-Tracker.

A review of questionnaire data obtained from the district level and from all HCs provides an initial description of frequent users. Frequent users were HWs who were more likely to be adequately trained than non-frequent users, to better understand their roles and responsibilities, and to more often report good access to infrastructure and IT support. Frequent users perceived an improvement in the quality of their data and reported increased user satisfaction. Frequent users were more often located in rural areas, in HCs with larger catchment populations and low Penta3 vaccine drop-out rates. They reported slightly less frequent supervision activities. District hospital staff supervising frequent users were more likely to use the e-Tracker to inform these supervision activities. Importantly, amongst frequent users, respondents more often had data management, rather than clinical roles. The characteristics of frequent e-Tracker users are further summarized in *Table 4.*

Table 4: Characteristics of health facilities by frequency of e-Tracker use (n=24)

Characteristics		Frequent	Non-frequent
Location	Rural	60%	44%
	Urban	40%	56%
Type of HC	NGO/FBO	13%	11%
	Public	87%	89%
<1yr population catchment area	Large	73%	89%
	Small	27%	11%
Penta3 drop-out rates	High	27%	11%
	Low	67%	67%
Role within immunization services	Data manager	73%	56%
	Clinical services	27%	44%
Frequency of immunization supervision activities	At least once a year	13%	11%
	Once a month	33%	56%
	Once a quarter	53%	33%
Use of the e-Tracker by DH to inform supervision		79%	56%
Access to support from the DH or elsewhere		80%	89%
Adequately trained		27%	22%
Clear understanding of roles & responsibilities in use of e-Tracker		93%	67%
Access to infrastructure^		81%	67%
Computer literacy^		94%	90%
Perceived quality of IT support^		86%	58%
Perception of information quality^		71%	33%
User satisfaction^		67%	38%

^ refers to domains of Modular DQA with eIR component used in the Health Centre survey.

B. PROGRAMMATIC FINDINGS

ECOSYSTEM (INFRASTRUCTURE)

Access to appropriate IT, hardware, and electricity was good throughout the country and did not appear to negatively affect the implementation and use of the e-Tracker. Approximately **77% of the HCs and 92% of the DH reported that they could access hardware (e.g., computers, tablets and smartphones) when they needed it. However, 79% of HCs and 33% of DHs reported they did not have sufficient hardware for their immunization program**, while 89% of the HCs and 92% of the DHs reported sufficient access to electricity. Better access to hardware at the workplace was associated with more frequent use of the e-Tracker (p=0.01). Access to the internet was, however, a concern raised in about one third of HCs (36%).

TOOL IMPLEMENTATION (TRAINING AND SUPPORT)

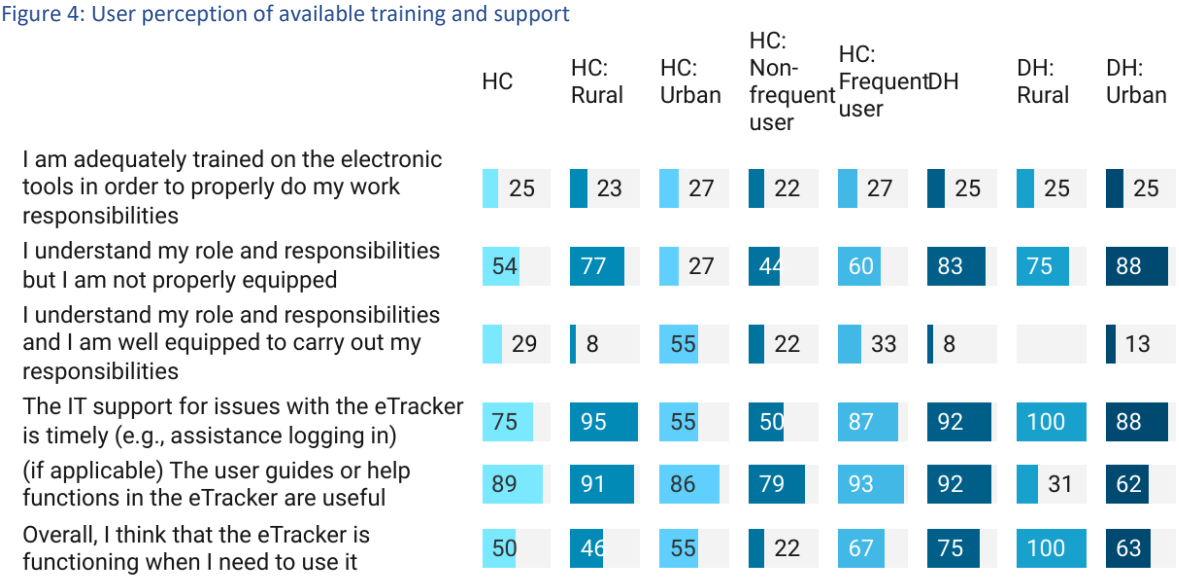
Only 25% of HC and DH staff reported that they felt adequately trained on using the tool. Almost all (96%) of HC immunization staff voiced additional training needs. Training requests included: general use of the e-Tracker (15), data analysis and report generation (4), how to make appointments in the system (1), and how to use the tool for defaulter tracking (1). Similarly, 71% of HC and 92% of DH staff did not fully understand their roles and responsibilities in using the e-Tracker or felt inadequately equipped to carry out their responsibilities. In this context, urban users were more likely to understand their roles and responsibilities than rural users (p=0.03).

The available user guides and help functions were found useful by 89% of HC and 92% of DH staff, although there was an acknowledgement that training materials for the e-Tracker needed to be updated.

IT service support, including support from DH supervisors, IT staff, and user-guides was felt by HC staff to make the e-Tracker more dependable, with functioning hardware. Respondents from both HC (83%) and DH (92%) levels agreed that they had timely access to IT support. However, only half (50%) of HC and 75% of DH respondents felt that the e-Tracker was fully functioning when required.

Frequent users were more satisfied with the timeliness of IT support than non-frequent users (p=0.02). Rural users were more satisfied with the overall software support (p=0.02) and with its timeliness (p=0.005) than those working in the urban areas. In the urban settings, frequent users were more satisfied with the software support than those using the tool less often (p=0.08). This is summarized below in *Figure 4*.

Figure 4: User perception of available training and support



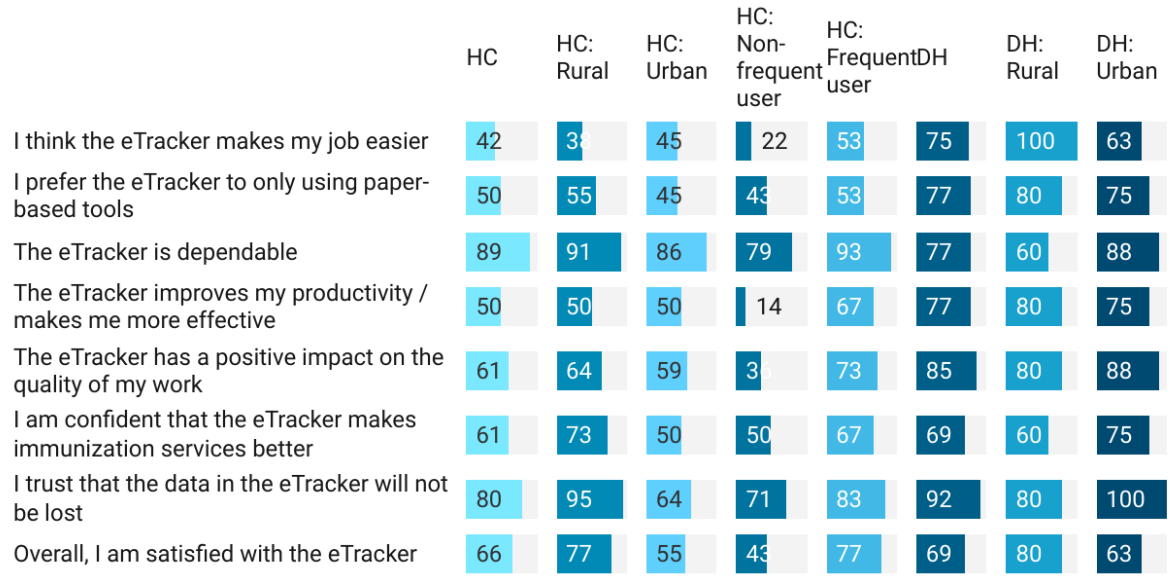
TOOL FUNCTIONALITY (USER EXPERIENCE)

In terms of functionality, at the HC level, the e-Tracker was most often used for **forecasting vaccine requirements**, followed by determining needs for immunization and outreach sessions and planning for staff needs. At the district level, DVPD supervisors used the e-Tracker mainly for **program monitoring** and evaluation, monthly reporting, and adjusting supervisory visits to target HCs with poor performance. VPDP supervisors compared local HC data with HMIS aggregated data to identify ways to improve immunization service delivery.

The tool was largely considered to be user-friendly by frequent users at the HC (67%) and DH staff (83%). Rural users (62%) were more likely than urban users (45%) to think the tool was user friendly. The majority (92% DH; 80% HCF) of respondents trusted that the data in the e-Tracker would not be lost; with rural users more likely to trust the system than urban users (p=0.02). While 45% of HC and 62% of DH staff thought they could finish tasks faster by using the e-Tracker, the use of the tool was overall not perceived to be efficient, due to both the paper and electronic system in place at the time of the evaluation and the resulting dual workload. **Frequent users were, however, more likely to state that tasks could be completed faster by using the e-Tracker (p=0.01).**

The e-Tracker was largely considered dependable by respondents at HC and DH level, with a positive impact on the quality of work, improving productivity and preferable to only using paper-based tools as shown in *Figure 5*. Almost two thirds (61%) of HC and 62% of DH staff thought that the e-Tracker was in a format that quickly gave access to the immunization information required. Frequent users were more likely to positively experience the tool, including in terms of the enabling environment, data quality, and data use (i.e., *"e-Tracker speeds up our work and gives us information we need easily")*. Frequent users were highly appreciative of the quality of information available (including accuracy and completeness), improvements to productivity, efficiency and positive impact on work, and were overall satisfied with the tool. Frequent users were also more likely to record all vaccines, including those administered in outreach and mobile services, in the e-Tracker.

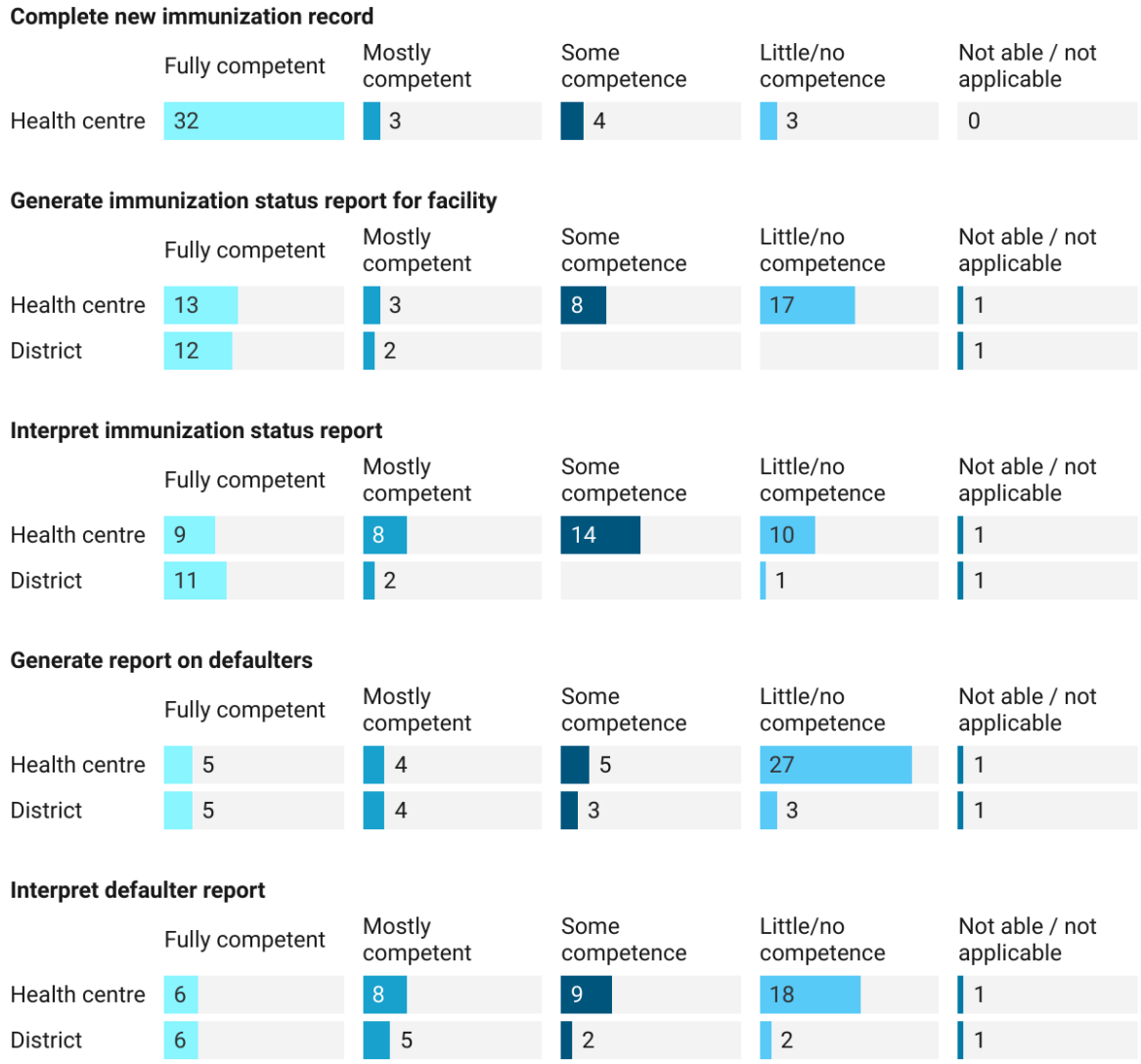
Figure 5: User satisfaction with the e-Tracker



When asked about the impact of the e-Tracker use on time and staff management, both HC and DH respondents reported that additional staff were required (although not always received); that staff had to be reorganized to cope with the additional workload; and that some staff had to take on additional responsibilities in view of the dual system in place. Only one third of HC respondents (33%) felt that the introduction of the tool had had no impact on staff management; this was shared between frequent and non-frequent users.

A standard e-Tracker competency assessment was conducted at HC level. Users appeared to be mostly (70%) competent at completing a new immunization record. There was limited competence in generating and interpreting immunization status and defaulter reports as shown below in *Figure 6.*

Figure 6: Competency of HC (n = 42) and DH (n = 16) staff to use the e-Tracker



Limited computer literacy appeared to not be a limitation of using or adopting the e-Tracker. Most users expressed interest in working with computers (89%), had at least moderate skills in using the hardware (93%), and felt that the equipment supported them in being more efficient at work (98%).

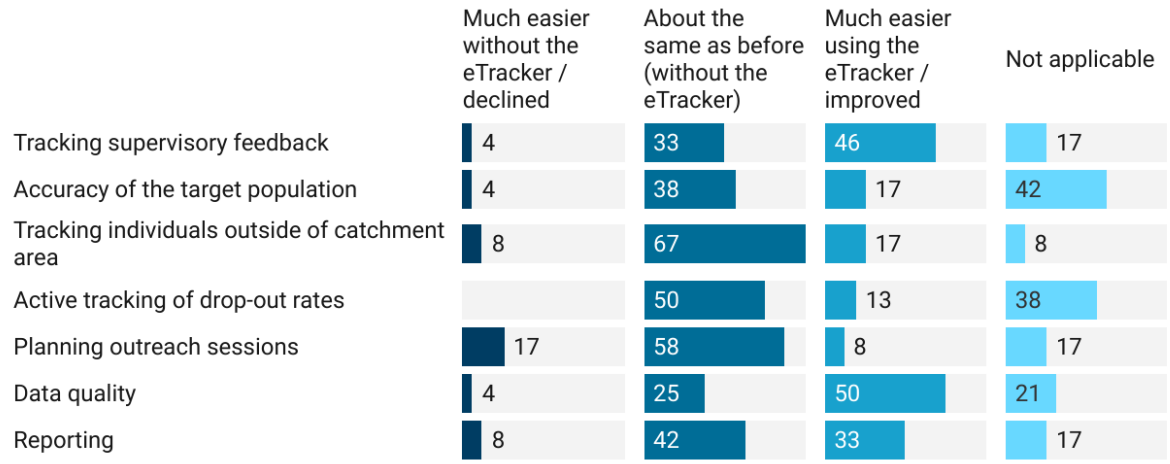
IMPACT: PERCEIVED BENEFITS OF THE TOOL

Slightly more than half (55%) of HC and 62% of DH staff felt that the e-Tracker provided sufficient information to enable them to do their tasks. **Frequent users were more likely to state that the tool provided sufficient information (p=0.04) and that they were able to access the needed information (p=0.003).**

Less than one third (32%) of HCs regularly used the e-Tracker to generate new immunization records for children that had lost their child vaccination card or came from outside their catchment area, however caregivers in HCs frequently using the tool acknowledged this as a perceived benefit of the e-Tracker.

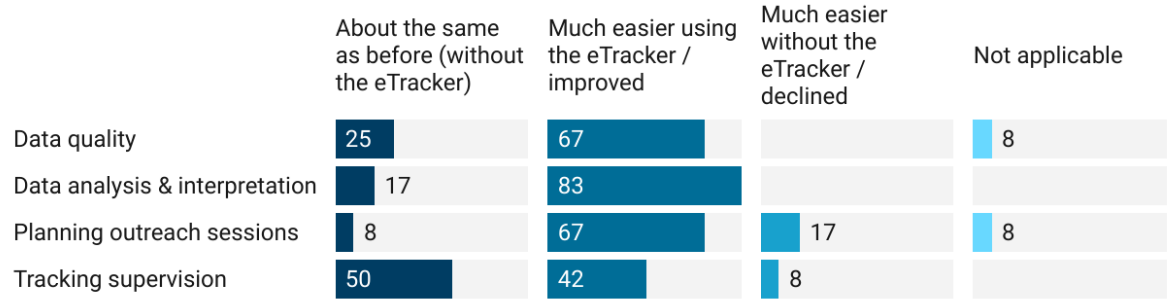
A pre-post assessment to understand the perceived benefits of the e-Tracker following its implementation was performed at both district and HC level. Findings from the pre-post assessment are presented below in *Figure 7*. Almost half (45%) of HC respondents reported that their activities were 'about the same as before, without the e-Tracker.' Among the 26% of respondents who reported improvement, the greatest benefit was perceived to be in the areas of data quality, tracking supervisory feedback and reporting.

Figure 7: Comparing activities pre-and post-introduction (HC, n = 24)



District level respondents, by comparison, reported a better experience following the introduction of e-Tracker More than half (65%) thought their activities had improved since the introduction of the e-Tracker, most notably in the area of data analysis and interpretation. This is summarized below in *Figure 8.*

Figure 8: Comparing activities pre-and post-introduction (DH, n = 12)



IMPACT: DATA QUALITY

The paper registry was still considered to be the most accurate source of a child's immunization history by 79% of the health center respondents. Rural HC users were more likely to consider the e-Tracker data quality to be better than the paper registry than urban users. However, only **half of the HC (50%) but 67% of district level staff felt that data quality had improved since the introduction of e-Tracker,** while only 27% of the HC and 23% of the district level respondents were fully satisfied with the accuracy and completeness of the immunization records generated by the e-Tracker. **Frequent users were more likely than non-frequent users to be satisfied with the accuracy and completeness of the e-Tracker data (p=0.03).** However, the e-Tracker had not yet notably impacted or improved regular reporting or monitoring of vaccine administration, which was still done using paper registries.

An on-site accuracy data check was conducted comparing inputs on several variables from three different data sources (i.e., the e-Tracker; the under-1 child paper register; and the child vaccination card). Across all HCs, only 21% of entries matched exactly. Frequent users were more likely to have entries match exactly, or only with some differences (80%). By comparison, 11% of entries from non-frequent users matched exactly or with some differences. There was not a close relationship between HW perceptions of data accuracy and accuracy confirmed during the on-site accuracy.

IMPACT: DATA USE

More than half of the HCs (58%) and district level (67%) respondents said that **data from the e-Tracker was used to guide supervisory activities in immunization;** frequent HC users (75%) were more likely to have supervisory activities guided by e-Tracker data than non-frequent users (56%). At the HC level, data were used for counter verification of data quality and to generate graphs and other visuals. Use of the e-Tracker at the HCs is summarized in *Figure 9*. At the district level, data were used for comparisons between data sources, prioritization of HCs for supervisory visits, identification of defaulters, and preparations for the Maternal & Child Health Week, an annual five-day campaign focused on maternal child health which includes immunization outreach for missed children. The review of e-Tracker data was reported by district level respondent as a routine aspect of supportive supervision visits, including determining the performance status for each facility and discussing data cleaning and analysis.

The e-Tracker appeared to not yet have impacted the accuracy of the target population data nor the possibility to track individuals outside of HC catchment areas. Only 17% of HC respondents thought that the accuracy of the target population had improved since the introduction of the e-Tracker, and only 13% thought that active tracking of vaccination drop-outs was easier using the e-Tracker. While 38% of HCs used the e-Tracker to manage vaccines for outreach services, **frequent users were more likely to record vaccinations administered in outreach and mobile services (p=0.03) and felt that planning outreach sessions was easier using the e-Tracker.**

Almost all of the HCs (96%) had an immunization defaulter-tracking mechanism in place. However, only 27% of HCs and 31% of DHs regularly used the e-Tracker to generate a list of defaulters. Defaulter tracking was still largely done by generating a list from the paper registers. There was no automated electronic reminder system in place anywhere.

Almost all districts (92%) had a data monitoring improvement plan. This was implemented through monthly coordination meetings and quarterly performance evaluations. These included feedback to HCs on their performance against specific indicators; monitoring HMIS and e-Tracker reports; cross-checking between paper register and e-Tracker data; follow-up to ensure tracking of identified defaulters and conduct of planned outreach sessions. Three-quarters of District EPI Supervisors (9) stated that they prioritized the needs of HCs based on available performance data (i.e., coverage and drop-out). However, the source of these performance data was primarily the paper-based data system (50%), followed by the e-Tracker (33%). More than half (58%) of District VPDP Supervisors stated that the ***e-Tracker has improved the quality of feedback*** **provided**. Almost half of the HC (60% frequent, and 22% non-frequent users) and DH level (42%) respondents also reported that **tracking supervisory feedback had improved since the introduction of the e-Tracker.**

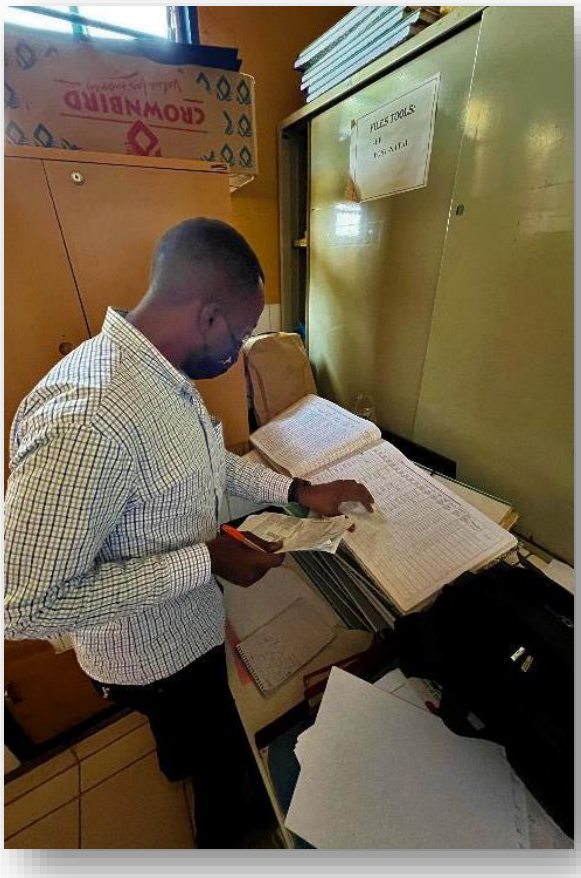
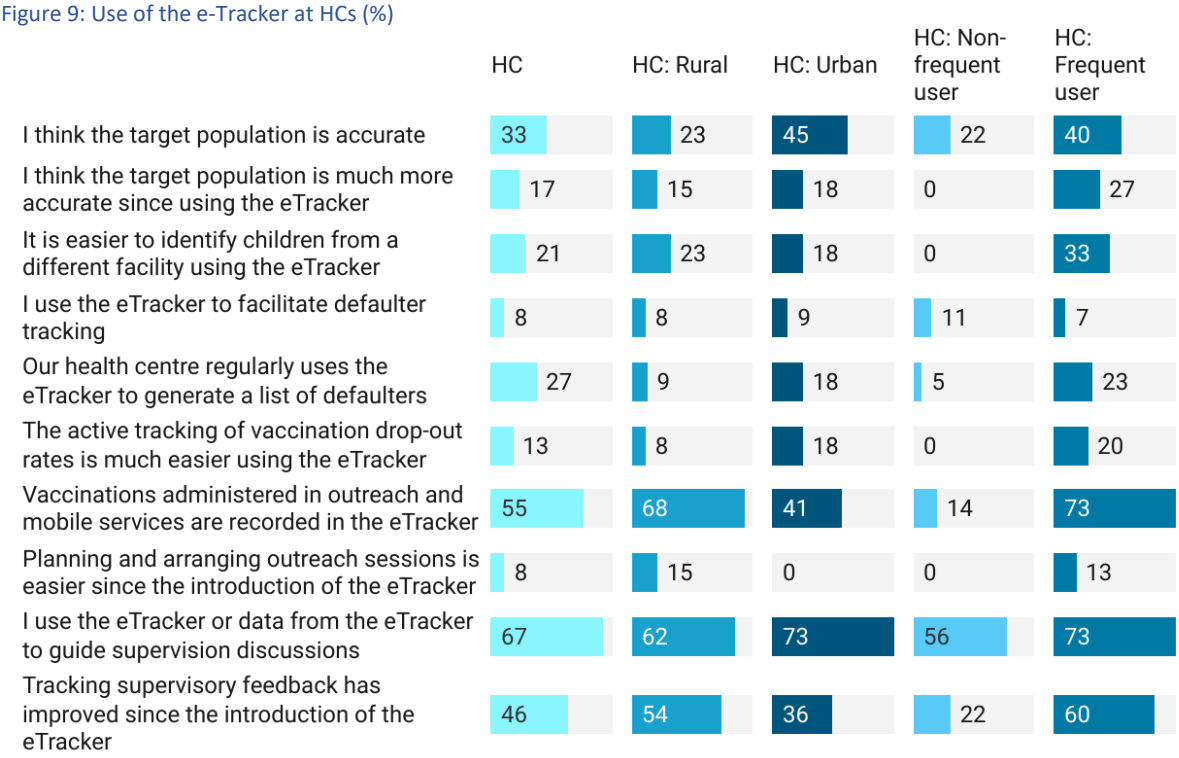
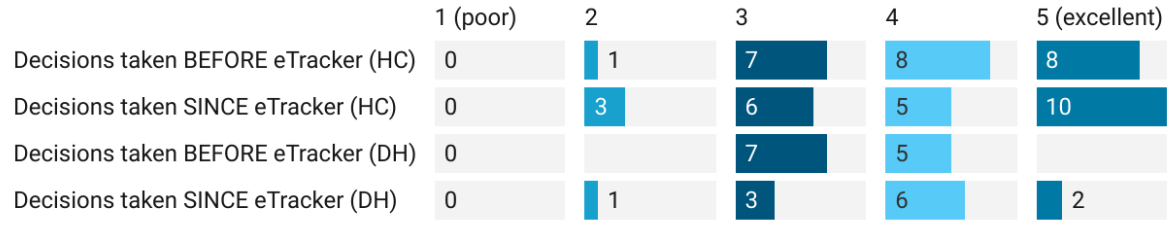


Figure 9: Use of the e-Tracker at HCs (%)



District level respondents, in particular, perceived an overall improvement in the quality of decisions made since the implementation of the e-Tracker (score 41vs. 45; n.s.), as below in *Figure 10*. Their overall perception was that the e-Tracker had positively impacted their work by improving the quality of supervision and feedback.

Figure 10: Quality of decisions made pre- and post- introduction of the e-Tracker



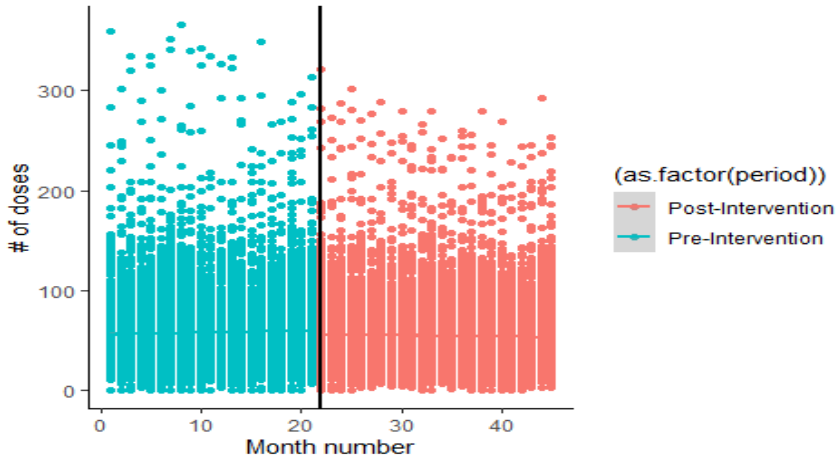
Given the incomplete use of the tool across the country, the ability to track individuals outside of a HC catchment area, or of those that were registered at a different health facility was still limited. Only 21% of HCs thought it was easier to identify children who were registered at another HC using the e-Tracker, all of whom were frequent users. While HWs were not convinced that the use of the tools would enable them to finish their tasks faster (60% frequent; 14% non-frequent), almost a third (29%) of the caregivers interviewed during the site visits said they had noticed the HC staff using an electronic tool to record their visit. More than a quarter (28%) of these respondents said they had noticed a difference to their immunization visits since the staff had started using the tool. In a pre-post assessment, **caregivers found that the HC was more organized and waiting times were less since the introduction of e-Tracker. It was also reportedly easier to search for a child if the caregiver did not have the child vaccination card.**

IMPACT: EFFECT OF E-TRACKER ON UPTAKE OF VACCINES

ITS ANALYSIS FOR EPI PROGRAM DATA ON PENTA3 UPTAKE

This trend analysis for the third does of Pentavalent vaccine shows that for the months after the introduction of the e-Tracker, there was a **decrease of administered doses** by 0.3 per month per facility compared to before. The baseline mean number of doses at time=0 (Jan 2018) is 52,57 doses per facility. For the months before the introduction of e-Tracker, there was an increase of 0.09625 doses per month. Compared to one month before introduction of the e-Tracker, there was a decrease in doses by 3.5665 post introduction.

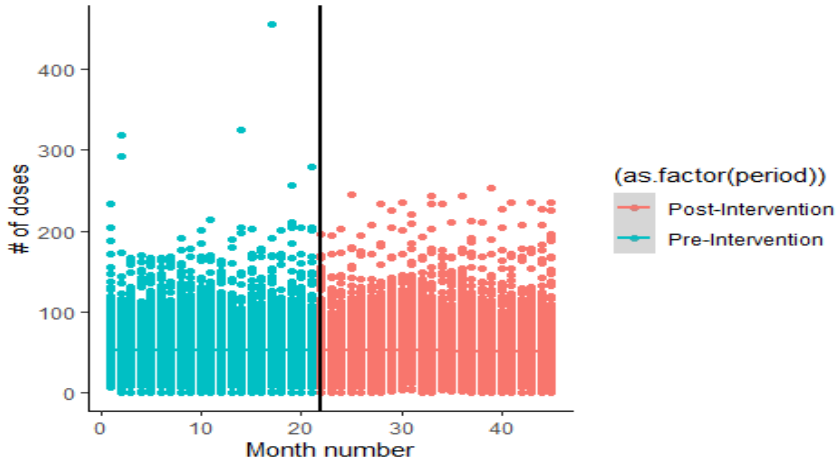
Figure 11: Doses of DPT Hep B Hib 3 administered (Jan 2018-Sept 2021)



ITS ANALYSIS FOR EPI PROGRAM DATA ON MR2 UPTAKE

The analysis of the data on the second dose of Measles-containing vaccine (MR2) reveals that for the months following the introduction of the e-Tracker there was an **increase of doses administered** by 0.007 compared to before. However, this increase was not statistically significant. The mean number of doses at time=0 (Jan 2018) was 52.5 doses per facility. For the months before e-Tracker use, there was a **decrease of 0.036 doses per month** (n.s.). Compared to one month before e-Tracker, there was an increase in doses by 0.18 post introduction (n.s.).

Figure 12: Doses of MR2 administered (Jan 2018-Sept 2021)



C. ECONOMIC FINDINGS

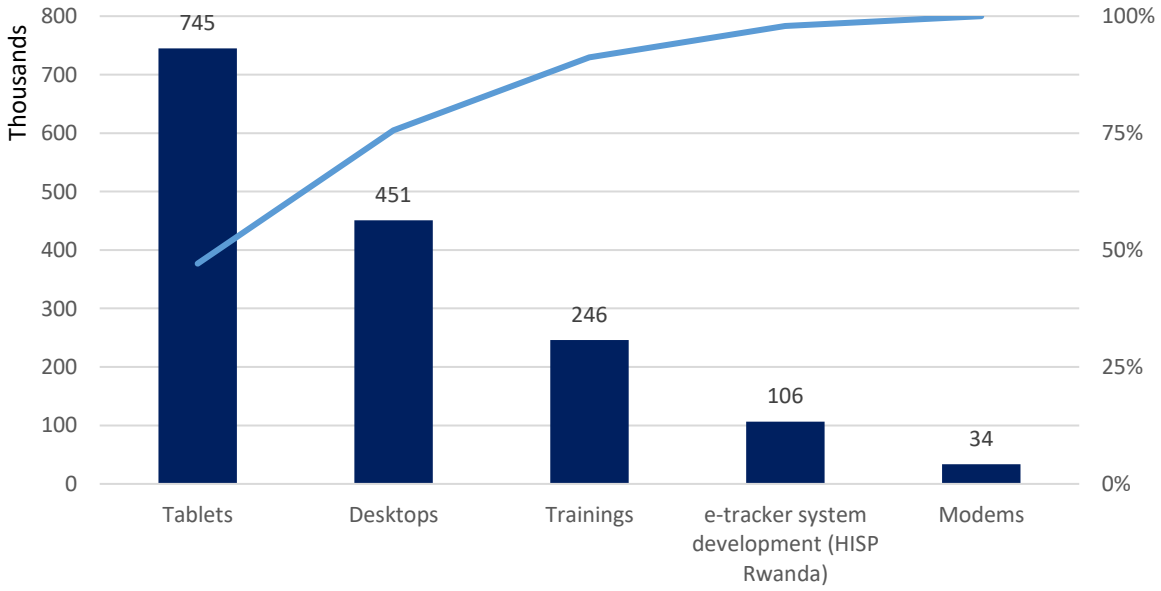
COSTS OF E-TRACKER

TOTAL FINANCIAL EXPENDITURES

The total financial expenditure of the e-Tracker in Rwanda, as incurred by the RBC, WHO and Gavi in 2019, amounted to **USD 1,581,229**. Spread over the 505 HCs and 37 districts in which it was implemented, the unit cost of implementing the e-Tracker was USD 2,917 per site.

Of the total expenditure, USD 106,200 accounted for the design and development of the system by Health Information Systems Programme (HISP) Rwanda funded by WHO, and USD 1,475,029 was incurred by the RBC for the roll-out through the utilization of Gavi funds and through a small government contribution. This figure is further broken down per item, as illustrated in the Pareto analysis in *Figure 13*. As illustrated, the majority (77%) of the overall financial expenditure was for the purchase of hardware by RBC which was funded by Gavi. Notably, the investment in tablets was redirected towards supporting the COVID-19 response which leveraged the DHIS2 platform for scheduling COVID-19 vaccinations and tracking their delivery through tablets in facilities which were different from the ones used for routine immunization. Therefore, despite constituting a part of the financial expenditures, the cost for tablets was not considered in the costs analysis, which instead included the annuitized cost of one computer per HC. Training was delivered to a total of 1,738 HWs through training of trainer (TOT) and cascade trainings at 3 administrative levels (i.e., central, DH and HC level) during a 3-day period. The trained workforce included officers from all levels down to community, data managers, district VPDP supervisors as well as nurses, vaccinators and the heads of HCs. The trainings costed a total of USD 246,066, of which 2% were incurred by government for officers and healthcare staff who acted as facilitators. The rest of the training costs reflects the expenditures for transportation, per-diems and the conference venue package paid for through Gavi funds. These trainings accounted for 15% of the total expenditure for implementation, while development costs contributed only 7% to the overall costs and were sustained by the WHO. No information on in-kind contributions from the local government were available (e.g., 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) and, therefore, were not considered in this analysis.

Figure 13: Pareto analysis of e-Tracker roll-out costs in thousands USD, 2021. The corresponding proportion (in %) of funds taken up by each cost item is illustrated by the yellow line.



ROUTINE OPERATING COSTS OF USING THE E-TRACKER

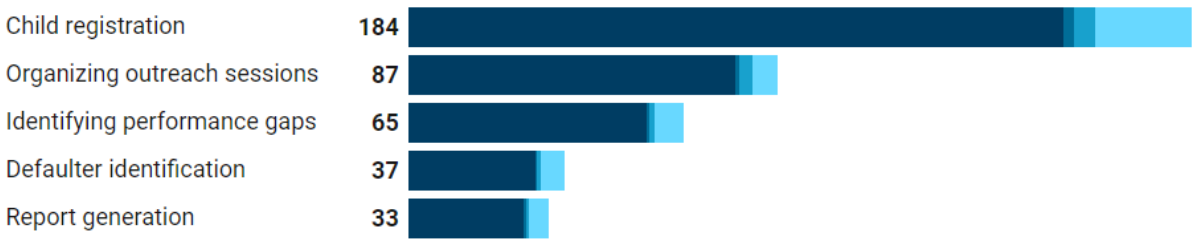
The average cost of performing immunization data management activities using the e-Tracker was estimated at USD 405.2 (95% CI: 350.1, 460.3) per health center with the cost entirely borne by the Government of Rwanda. This calculation excluded costs for immunization report transportation since these were transmitted electronically even before the e-Tracker implementation and, therefore, both the absolute as well as incremental cost vs. the paper system were not relevant. Furthermore, it did not consider the costs for vaccine quality monitoring and contacting defaulters as these activities were not performed using the immunization registries, neither paper nor electronic. That is, contacting defaulters was performed by community HWs or village leaders, not by sending SMS reminders through the e-Tracker. In addition, due to the short implementation of the e-Tracker, no refresher trainings had been performed by the time of the data collection. As such, no data for this activity were obtained and hence the activity was not considered in the reported findings. Finally, each facility was assumed to be endowed with a desktop computer for the use of the e-Tracker, which was considered a shared cost along with other durable goods costs collected for IT maintenance activities which are not specific to the VPDP and were, thus, apportioned across all reported activities. The cost of each computer was assumed to be approximately USD 500 annuitized over 5 years. This figure was obtained by converting the WHO CHOICE estimate of the unit cost of a computer in 2000 (I$ 1,518) to RWF using the International Monetary Fund (IMF) Purchasing Power Parities (PPP) conversion rate (IMF, 2022) and then back to USD using the 2021 RWF to USD exchange rate.

Table 5 below provides an analytical breakdown of the costs per HC for managing immunization data per activity and cost input, while *Figure 14* depicts the costs graphically. As illustrated, the largest cost input was personnel, accounting for 85% (USD 343.6) of the total cost per health center. Direct costs in supplies and durable goods for maintenance and printing activities, accounted for 4% of the total cost reported above (USD 16.1), driven mainly by the cost for maintenance activities. Finally, overhead costs accounted for the remaining 11% of the total cost (USD 45.4).

Table 5: Mean annual cost of immunization data management activities in USD with 95% CI per HC

		Activities					
		Child registration	Defaulter identification	Organizing outreach sessions	Identifying performance gaps	Report generation	Total
Inputs	Personnel	153.9 (114.9, 192.8)	29.8 (15.7, 44)	76.7 (48.1, 105.3)	56.1 (39.1, 73.2)	27.1 (18.7, 35.4)	**343.6 (289.8, 397.4)**
	Consumables + services	2.6 (1.4, 3.8)	0.4 (0.2, 0.6)	1.1 (0.5, 1.6)	0.6 (0.3, 0.9)	0.5 (0.2, 0.7)	**5.1 (3.8, 6.5)**
	Durable goods	5.1 (3.1, 7.1)	0.9 (0.5, 1.3)	3.2 (1.7, 4.6)	1.2 (0.8, 1.5)	0.7 (0.5, 1)	**11 (8.5, 13.6)**
	Total direct costs (a)	161.6 (122.5, 200.6)	31.1 (17, 45.3)	80.9 (52.3, 109.6)	57.9 (40.8, 75)	28.3 (19.9, 36.7)	**359.8 (305.9, 413.7)**
	Indirect costs (b)	22.8 (12.9, 32.7)	5.5 (2.4, 8.7)	5.7 (3.4, 7.9)	6.8 (4, 9.6)	4.6 (2.6, 6.6)	**45.4 (34.2, 56.7)**
	Total costs (a) + (b)	**184.4 (144.1, 224.6)**	**36.7 (22.1, 51.2)**	**86.6 (57.8, 115.3)**	**64.7 (47.4, 82)**	**32.9 (24.2, 41.5)**	405.2 (350.1, 460.3)

Figure 14: Total mean annual cost of immunization data management activities in USD per HC



Child registration was the costliest activity, with an average time per new child registered estimated to be 18 minutes, accounting for 46% of the total cost of e-Tracker. Notably this time related only to the registration of new children in the e-Tracker, as the time required to update an existing record was assumed to be negligible and not considered in the analysis. The reported cost of registering a child also reflects the fact that real-time

registration at the point of vaccination delivery was not performed and use of the paper registries has been maintained. Consequently, the costs of registering a child with the e-Tracker in Rwanda was calculated as the sum of the existing costs for this activity with the paper registry, plus the cost of inputting the same data on the e-Tracker. Notably, survey respondents outlined that child registration with the e-Tracker was predominantly done on a desktop computer by a single person, in most cases, the data manager. This position is not dedicated to the VPDP alone, and the data manager performs back-entry of data into the system during a limited period of time. Despite the ongoing use of paper registries, the reported cost of printing was relatively low as registries were printed and distributed to the HCs on a regular basis by higher-level administrative authorities. To this effect, HCs reported the printing of an average of 120 pages per year per HC at a cost of USD 0.01, which is reflected in the costs of printing reports and photocopying child vaccination cards, since registries are printed centrally. Other direct costs included durable goods for maintenance totaling USD 11 per HC.

Total annual cost of immunization data management for Rwanda

Based on the assumption that the sample of 24 HCs included in this evaluation was representative of the 505 HCs of the country delivering vaccination, and the annual operating cost of the e-Tracker (USD 405.2), the yearly recurrent cost of using the e-Tracker at a national scale was estimated at USD 204,626. Furthermore, based on the initial expenditure on the 3-day training for implementation (USD 246,066), an annual cost for refresher trainings of USD 82,022 was added, considering a 1-day training for 3 people from all the 505 HCs. In addition, the cost pertaining to the printing of immunization registries at the central level was considered, each registry containing 15 entries (i.e., one line per child) across 2 pages, each page costed at USD 0.02. Accounting for 4 visits for all 393,445 surviving infants in Rwanda in 2021 (UNPOP, 2021), this cost was calculated at USD 5,009 without considering the cost of their distribution to health centers. *Table 6* summarizes the total costs that Rwanda sustained for performing immunization data management activities using the paper registries and the e-Tracker. The resulting total annual cost of operating the e-Tracker was equal to USD 291,657 (i.e., approximately 18% of the financial expenditure incurred for its design and roll-out), translated to USD 0.09 per dose. No costs were considered for routine upgrades of the e-Tracker being DHIS2 freely available for users. Additionally, the cost of hosting data for all health-related data is borne by the National Data Center (NCD); this cost was not included.

Table 6: Annual average costs for immunization data management with the implementation of the e-Tracker

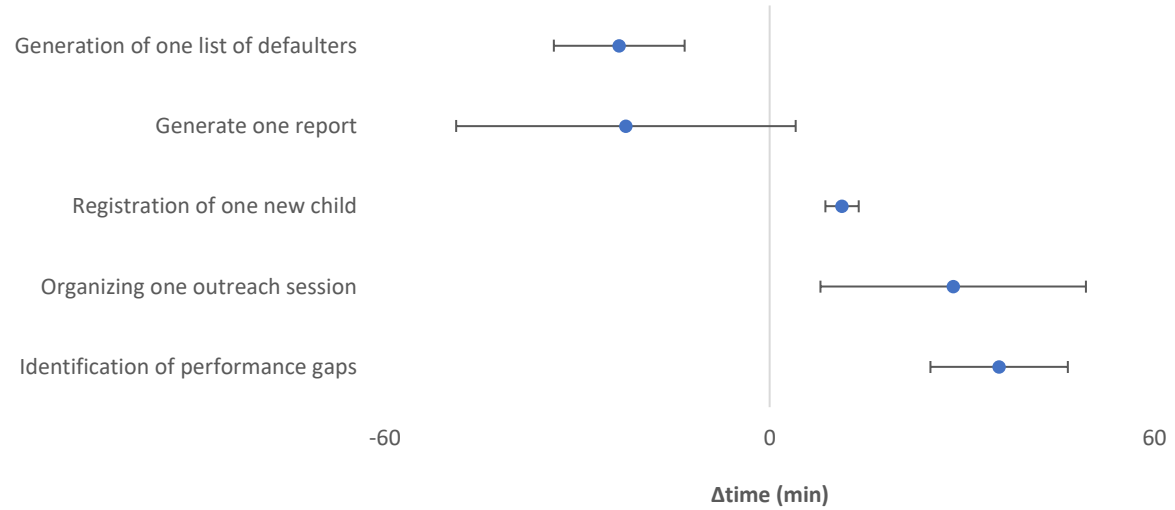
Item	Cost (USD)
Total yearly recurrent cost of using the e-Tracker in all HCs	204,626
Cost of printing registries at national level for all HCs	5,009
Cost of refresher trainings per year	82,022
Total annual cost of the e-Tracker	**291,657**

While no substantial differences were found between frequent versus non-frequent users of the e-Tracker, nor between urban versus rural HCs, notably, the costs associated with the identification of defaulters were higher for rural than urban HCs. More details on the costs per activity by subgroup and their explanation is provided in Annex 6.3.

COST IMPACT OF E-TRACKER COMPARED TO THE PAPER-BASED SYSTEM

The routine operating costs of performing immunization data management activities and immunization service delivery activities currently using both paper registries and the e-Tracker was compared to the costs of performing the same activities using only paper registries. As the analysis was cross-sectional and the biggest cost-driver was personnel, the differences in costs were mainly driven by the time spent to perform each activity, which is illustrated in *Figure 15*.

Figure 15: Change in time (in minutes with 95% CI) per unit of activity with the use of the e-Tracker as compared to using paper registries only.



As observed, the e-Tracker use had resulted in additional time for the new child registration, outreach organization and performance gaps identification processes, and in less time for defaulter identification. The impact of using the e-Tracker for report generation also showed a trend towards shorter times, although estimates for this activity are less precise due to higher variability in the reported times across HCs.

Table 7 reports the costs per activity per HC using the e-Tracker and using only paper registries, as well as the mean difference between the former and the latter. The analytical operating costs of performing immunization data management activities using paper registries are reported in Annex 6.4 per HC.

Table 7: Mean difference in costs per HC (n=24) for immunization data management activities with the e-Tracker and without (paper registries).

Activity	Mean cost with the eTracker (USD)	Mean cost without the eTracker – paper only (USD)	Mean difference in costs (USD)	P-value
Activities related to immunization data management				
Vaccination session execution: child registration	184.4 (144.1, 224.6)	106.3 (82.7, 129.8)	78.1 (31.5, 124.7)	0.01
Defaulter identification	36.7 (22.1, 51.2)	36.4 (23.9, 48.9)	0.3 (-18.9, 19.4)	0.85
Organizing outreach sessions	86.6 (57.8, 115.3)	63.3 (39.7, 86.9)	23.3 (-13.9, 60.5)	0.15
Identifying performance gaps	64.7 (47.4, 82)	47.9 (36.9, 58.9)	16.8 (-3.7, 37.3)	0.47
Report generation	32.9 (24.2, 41.5)	58.8 (44.8, 72.9)	-26 (-42.5, -9.5)	0.01
Total	**405.2 (350.1, 460.3)**	**312.7 (272.9, 352.5)**	**92.5 (24.5, 160.5)**	**0.09**
Additional activities related to the immunization programme				
Delivering outreach	1,021 (749.5, 0)	1,006.2 (736.3, 1276.1)	14.8 (-368, 397.6)	0.90
Emergency vaccine replenishments	0 (0, 0)	0 (0, 0)	0 (0, 0)	1.00
Total	**1,426.2 (1,149.2, 1,703.1)**	**1,318.9 (1,046.1, 1,591.7)**	**107.3 (-281.5, 496)**	**0.48**

Overall, the implementation of the e-Tracker in addition to the paper-based registry increased the costs of managing immunization data by 30% by an average USD 92.5 (95% CI: 24.5, 160.5) per health center.

This was due to an increase in the costs of **child registration** by 74% (p=0.01), with all HCs commenting that new child registration was performed first on the paper registries and then transferred in the e-Tracker. In only 3 out of 24 HCs (12.5%) was there a decrease in costs for child registration, although direct attribution of this effect to the e-Tracker was not possible. For two of these HCs, the reduction was reportedly due to varying numbers and profiles of the staff involved in the activity. Finally, another contributory factor influencing the observed cost impact was the overhead cost for each activity. This increased because higher staff time was dedicated to the management of immunization data with the e-Tracker compared to the paper registry (and staff time was the cost-driver for allocating overhead costs).

The cost of **organizing outreach sessions** was also higher after the implementation of the e-Tracker although this change was likely not explained by the use of the e-Tracker as most respondents reported that outreach sessions were organized mainly using the paper registers, even after the implementation of the e-Tracker. Similarly, an increase was also observed in the costs for identification of performance gaps, however at a smaller scale as 11/24 HCs reported no difference here before and after the implementation of the e-Tracker. Notably, one HC specified that they performed the activity using only the e-Tracker, while the rest reportedly did this using the paper registries.

For **defaulter identification**, a small cost decrease was observed per HC between the process including the e-Tracker vs. using only the paper registries. This finding is not attributable to the use of the e-Tracker since most HCs reported performing the activity using paper registries and vaccinations cards, not the e-Tracker.

The implementation of the e-Tracker was associated with cost reductions for **report generation**, with 27% of HCs generating reports using the e-Tracker whilst the rest were relying on paper registries. Overall, less time was spent generating reports after the implementation of the e-Tracker by both nurses and data managers (Figure 14).

Furthermore, regarding the broader impact of the e-Tracker on immunization service delivery, no cost differences were found in **emergency vaccine replenishments** since most of the sampled HCs (70.8%) reported zero stock-outs both before and after the implementation of the e-Tracker, and those who confirmed the occurrence of stock-outs throughout the year, did not report any difference after the implementation of the e-Tracker. However, the cost of **delivering outreach sessions** was increased by USD 14.8. Again, this is unlikely to be attributed to the e-Tracker, as there was limited evidence on its use in organizing outreach sessions and finding may thus be attributable to random variation in the resource needs (i.e., number of staff and time needed for delivering outreach across the years).

Finally, the cost impact of the e-Tracker between frequent and non-frequent users and between rural and urban HCs is reported in Annex 6.5. While no substantial differences were found, frequent users were found to incur more costs than non-frequent users in the identification of performance gaps and in the organization of outreach sessions with the e-Tracker. A cost increase was also observed for non-frequent users for defaulter identification, while frequent users experienced a cost decrease. Finally, rural health centers were observed to incur a smaller incremental cost, by 2/3, after the implementation of the e-Tracker compared to urban health centers. Urban HCs incurred notably higher costs for new child registration with the e-Tracker than rural HCs.

AFFORDABILITY AND SUSTAINABILITY

FINANCIAL AFFORDABILITY OF E-TRACKER

The full cost of operating the e-Tracker was considered within the general macro-economic context of Rwanda, which has experienced a stable macro-economic performance marked by high potential growth and relatively low inflation in the last years (Annex 6.6). Over the past 20 years, Rwanda has experienced a phase of steady economic growth with 5-year annual compound growth rates (CAGR) remaining stable between 6% and 8% from 2000 and 2021. Similarly, the growth rate of GDP per capita remained stable at about 5% except for the period between 2015-2021 where the CAGR dropped at 2%. However, IMF estimates predict a return to previous growth rates of GDP per capita for the period 2021-2027. Public debt over GDP has constantly increased in the last ten years from 18.8% in 2010 to 68.6% in 2020 but has reached a plateau and is expected to fall in the next years. Despite the demonstrated stability and positive trends in macro-economic indicators, Rwanda is still heavily reliant on external sources for financing its health expenditures. The share of health expenditure funded from external sources has shown a slightly increasing trend since 2010 reaching as high as 52.9% in 2019. This share, however, is generally higher for routine immunization activities. From 2017 to 2019, the share of expenditure in immunization funded from external sources was equal to approximately 85.3% of the total current expenditure (~USD 9,9 Million).[2]

While the expenditures for the design, development and roll-out of the e-Tracker were fully covered by external sources, the net cost of operating the e-Tracker of USD 128,735, which represents the incremental cost of the e-Tracker compared to operating only paper registries, was covered by domestic payers. This cost represents about 1.1% of the average budget allocated to routine immunization activities in 2017-2019 (both external and domestic sources), or 9% of the domestic expenditure for running the VPDP.

ECONOMIC IMPACT OF A FULLY ELECTRONIC SYSTEM: SCENARIO ANALYSIS

Until October 2022, the immunization data management system in Rwanda has been a dual process wherein the planning and execution of immunization services as well as the associated data-capturing and reporting processes were performed by HWs first on paper and later back-entered in the e-Tracker through the use of a desktop computer by a data manager. This process had resulted in an additional financial burden to the country of approximately USD 128,735 for immunization data management.

As Rwanda initiated the transition to a fully electronic system on 1 October 2022, an estimation of the associated costs was simulated based on assumptions of a paperless process in place. The assumptions made for each of the immunization-related activities considered in this evaluation are outlined in *Table 8.* A comparison is made between the previous dual process and a fully electronic process.

[2] 2019/2020 Backward Looking Joint Sector Review (BLJSR) summary report. Government of Rwanda, Ministry of Health. N°20/7515/DGPHFIS/2020

Table 8: List of assumptions per immunization data management activity with the use of the e-Tracker in the theoretical scenario of a paperless process

	Current dual process with paper-registries + e-Tracker	**Fully electronic scenario with only e-Tracker used**
Staff time		
Child registration	Usually one nurse registering a child on paper. The electronic data input is done at a second time on a computer desktop by the data manager. (estimated time: 18 minutes)	One nurse responsible for entering data on the e-Tracker per child. The time for data entry assumed to be the average time a data manager currently uses to perform the registration. (estimated time: 5 minutes)
Defaulter Identification	Usually one or more staff (nurse, data manager) generating a defaulter list on paper registries and, in a few cases, also on the e-Tracker (estimated time: 94 minutes)	Only one person (nurse or data manager) to execute the activity employing the average amount of time that data managers spend on pulling a list of defaulters from the e-Tracker currently. (estimated time: 8 minutes)
Performance Gaps Identification	Usually one or more staff (nurse, data manager) performing the activity on both paper registries and, in a few cases, also on the e-Tracker (estimated time: 149 minutes)	Only one person (nurse or data manager) to execute the activity employing the average amount of time that data managers spend on pulling a list of defaulters from the e-Tracker currently (estimated time: 98 minutes)
Report Generation	Either one nurse or one data manager performing the activity using both paper registries and, in a few cases, also the e-Tracker. (estimated time: 184 minutes)	Only one person (nurse or data manager) to execute the activity employing the average amount of time that data managers spend on generating monthly reports with e-Tracker currently (estimated time: 52 minutes)
Other costs		
Printing	Currently, reports and child vaccination cards are printed for immunization.	Printing of reports was eliminated from the fully electronic scenario, but printing of child vaccination cards is maintained**.**
Refresher trainings	Currently, no refresher trainings have been conducted and were added to the total cost of managing immunization data based on the initial investments in trainings during implementation (Table 6 – USD 82,022).	In the long-term, the capacity building component as well as monitoring of the use of the e-Tracker are theorized to be incorporated under the EPI routine supervision activities, without the need to provide annual trainings specifically on the use of the e-Tracker.

** Potential cost savings that may accrue from planning outreach sessions were not considered as there was no evidence of use of e-Tracker to perform this activity*

Based on the above assumptions, the annual cost for the routine operation of the e-Tracker in full electronic modality in Rwanda was calculated to be USD 240.5 (95% CI: 208.8, 272.3) per health center, as detailed in Annex 6.7. When compared to the costs of running the process only on paper (i.e., without the estimated incremental cost of adding the e-Tracker), cost savings of up to USD 72.2 per health center were predicted, as shown in *Table 9*.

Table 9: Mean costs for performing immunization data management activities under different scenarios (only on paper, as currently with paper and e-Tracker, and using the e-Tracker only based on simulation), in USD (95% CI).

Activity	Mean cost with paper - only	Mean cost with paper + e-Tracker (current situation)	Mean cost with e-Tracker – only
Vaccination session execution: child registration	106.3 (82.7, 129.8)	184.4 (144.1, 224.6)	86 (76.5, 95.5)
Defaulter identification	36.4 (23.9, 48.9)	36.7 (22.1, 51.2)	5.1 (3.8, 6.4)
Organizing outreach sessions	63.3 (39.7, 86.9)	86.6 (57.8, 115.3)	86.6 (57.8, 115.3)
Identifying performance gaps	47.9 (36.9, 58.9)	64.7 (47.4, 82)	43 (34.3, 51.6)
Report generation	58.8 (44.8, 72.9)	32.9 (24.2, 41.5)	19.8 (16.3, 23.4)
Total	**312.7 (272.9, 352.5)**	**405.2 (350.1, 460.3)**	**240.5 (208.8, 272.3)**

Based on the above simulation, the transition to a fully electronic system as compared to the current situation, where both paper and the e-Tracker are in use, represents a substantial reduction of 164.7 USD (or 41%) in the costs for immunization data management activities per health center.

Most cost benefits were realized for the specific activities of child registration, defaulter identification, and report generation, which is explained by the fact that the simulation considered the time of only one person needed to perform each activity with a fully electronic system. While the e-Tracker was limitedly used in outreach sessions, further cost reductions may be realized if a fully electronic system were to be used for this purpose as well.

Further incorporating the savings from avoiding the cost of printing the immunization registries centrally (USD 5,009), the transition to a fully electronic system may yield cost-savings of up to USD 170,204 per year for Rwanda, reducing the total annual cost for immunization data management for the country by 58% compared to the costs currently sustained (*Table 10*). As shown, this would halve the cost per dose for immunization data management.

Table 10: Total costs in USD for performing immunization data management activities under different scenarios (only on paper, as currently with paper and e-Tracker, and using the e-Tracker only based on simulation).

Cost component	Paper – only	Paper + e-Tracker (current situation)	e-Tracker - only
Routine operating costs	157,914	204,626	121,453
Printing of registries	5,009	5,009	0
Refresher training for e-Tracker	0	82,022	0
Total cost for Rwanda	**162,923**	**291,657**	**121,453**
Cost per dose	**0.05**	**0.09**	**0.04**

V. DISCUSSION

The findings of this evaluation highlight the complexity of rolling out an eIR at national scale during the COVID-19 pandemic, including both the programmatic and economic dimensions of its development and implementation. The discussion hereafter is structured around the evaluation framework and closely examines the following domains: the ecosystem; tool design and functionality; implementation experience and costs; and impact and sustainability. These domains, as previously noted, have a been mapped again the overall evaluation research questions, and are summarized below.

Has the implementation of the e-tracker improved immunization service delivery? [impact]

- Due to the limited period of implementation and the effect of the COVID-19 pandemic on both immunization delivery and the roll-out of the e-Tracker, use of the e-Tracker was not expected to have yet had a measurable impact on immunization outcome indicators (e.g., coverage, timeliness, or drop-out rates). In fact, the ITS analysis for DPT3 coverage data showed that for the two years following e-Tracker introduction there was actually a slight decrease of administered doses compared to before e-Tracker use.
- Impact in this evaluation, therefore, focused on process and output indicators, specifically on data quality and data use for decision-making, which are expected to result in improvements of the outcome measures.
- Improvements in these proxy measures were largely experienced by the more frequent users of the tool at HC level and by supervisors at the DHs. This included better access to information needed, improved data analysis and interpretation, better accuracy and completeness of data and easier reporting of immunization data, including from static clinics and outreach services.
- At the same time, the e-Tracker was deemed beneficial for the conduct of supervisory activities and was ultimately considered by its users to have improved the quality of their decisions related to immunization delivery.

What is the short- and medium-term economic and financial impact of rapidly implementing and scaling-up the e-Tracker in the whole country? How affordable and sustainable is it? [Impact, Affordability and Sustainability]

- The full initial investment of adapting and deploying the e-Tracker at national scale was approximately USD 1.6 million. Most implementation-related expenditures were attributed to hardware. Training was the second highest cost item accounting for 16% of the total cost.
- The use of the e-Tracker has led to an increase of costs for immunization data management activities by 30% compared to only using paper registries. The average cost per HC for performing these activities after the implementation of the e-Tracker is USD 405.2 or USD 0.09 per dose. The majority (85%) of this cost was accounted for by personnel costs and was related mainly to the activity of data entry for each child registered.
- The additional financial burden to the country for the e-Tracker was estimated at approximately USD 128,735 per year, representing approximately 1.1% of the average budget allocated to routine immunization activities in 2017-2019 (or 9% of the domestic expenditure for running the VPDP).
- Given the higher costs of the e-Tracker and the limited impact on immunization outcomes to date, it is highly unlikely that the system in its mode of use before October 2022 (i.e., in combination with the paper registries) would be cost-effective.
- Findings from a simulation exercise suggest that transitioning to a fully electronic system, based on eliminating the duplication of HW time, may result in process efficiencies and substantial cost reductions. This transition is more likely to generate a substantial cost saving as compared to a fully paper-based registry if proper equipment and infrastructure are available at the HCs, as well as provided that adequate training and supervision is performed.
- The macroeconomic context in Rwanda appears to be favorable. However, as the country relies heavily upon external funding, especially for the immunization budget, with only 16% of the budget covered by domestic sources, this may imply that the continuous operation of the e-Tracker could be difficult to maintain should external resources decrease in the future.

How interoperable is the e-Tracker with other RHMIS modules and the civil registration system? [Ecosystem, Tool]

- Despite displaying ideal features of an eIR, the limited interoperability of the e-Tracker at the time of the evaluation was perceived as a significant bottleneck to its effective use. This has subsequently changed with the implementation of new technical features, which now include interoperability with both the CRVS and RapidSMS.
- The additional interoperability with the vaccine logistics management module would further enhance the utility of e-Tracker.
- Sufficient stress-testing for full scale-up of additional features will need to be factored into any future implementation plans given the experience from other countries with similar systems 'collapsing' once fully scaled.

How can new evidence on tools and technologies, modalities, and governance of the e-Tracker inform further investments in other countries from domestic sources, health financing institutions and technical partners for its sustained operation? [Ecosystem, Impact, Affordability and Sustainability]

- A decision to further invest in the e-Tracker should be aimed at ensuring that it is effectively used as a data management and decision-making tool at all levels of the health system. Investments in strengthening digital infrastructure, enabling greater interoperability and improving data quality may create a favorable environment for sharable, high-quality immunization data which, in turn, may constitute a first step towards real-time, data-driven decision-making processes.
- Given the identification of specific barriers and enabling factors, it is recommended that an evaluation framework be developed to monitor the uptake and use of the e-Tracker, as well as to document the process changes as Rwanda transitions to a fully digital system. This evaluation should serve as a baseline assessment with a re-assessment of the situation within 1-2 years of the transition.
- The experience of Rwanda in this transition will be an important learning opportunity for other countries presently exploring implementing similar changes.

Importantly, the discussion also notes the limitations of the evaluation and provides a description of the COVID-19 pandemic as a major cofounding factor influencing the results. Recommendations on the way forward as the e-Tracker transitions to a fully electronic system are also included.

A. ECOSYSTEM

The Government of Rwanda has long been recognized for its progressive adoption of digital solutions. The 2021 Network Readiness Index (NRI) acknowledged Rwanda's governance mechanisms as a main strengthen (Portulans Institute, 2022), and the country has demonstrated **strong political commitment** and experience in implementing successful IT solutions. High levels of stakeholder engagement at subnational level and the political interest and funding availability at central level were acknowledged as strengths in the country's 2021 eIR Readiness Assessment (Sibomana et al., 2021). The Rwanda MOHP and RBC have demonstrated strong ownership throughout the e-Tracker development, and its plans for implementation are aligned with a clear vision for digital health outlined in both its Health Sector Strategic Plan IV (2018-2024) and National Digital Health Strategic Plan. The national rollout strategy of the e-Tracker was clearly articulated, though it faced substantial delays amidst the pandemic. Most notable was the one-year delay in fully transitioning from the legacy paper-based system to use of only the digital system, though the government has refocused its efforts and commitment post-pandemic, with the transition to a fully electronic system commencing on 1 October 2022.

Based on the findings of this evaluation, **limited access to the internet** remains a significant challenge with more than a third (36%) of the HCs and still 15% of the districts reporting insufficient internet availability. This aligns with the NRI 2021 finding that the country faces challenges around mobile tariffs, and handset prices and locations with limited internet access (Portulans Institute, 2022), and somewhat aligns with findings of a recent RBC assessment of the e-Tracker which reported that only 75% of HCs had internet access (Sibomana et al. 2021). In addition, while most HCs (77%) and DHs (92%) reported **sufficient access to hardware** (e.g., computers,

tablets, smartphones), old desktop computers were still found in use with limited data upload capacity, and there was an observed shortage of tablets available to clinical staff as these had been reallocated for the COVID-19 response. As frequent users did note better access to hardware at HCs, efforts should be made to strengthen IT infrastructure and upgrade equipment as the country transitions to a fully electronic system. Meanwhile, tablets have been repurposed from use for COVID-19 response to use in PHC settings including immunization in most health facilities.

From an economic perspective, the macroeconomic ecosystem appears to remain favorable for the implementation of the e-Tracker. Rwanda is showing a relatively stable macroeconomic trend, with a good GDP growth rate and recovering after a brief contraction due to the COVID-19 emergency. Public debt over GDP increased due to COVID-19 and reached almost 80% in 2021, but the IMF forecasts expects a plateau in 2023, with a subsequent descending trend. Nonetheless, the country still heavily relies upon external funding, especially for the immunization budget, with only about 16% of this budget covered by domestic sources. This may imply that the maintenance of the e-Tracker could be difficult for the government to maintain should external sources decrease in the future.

B. TOOL DESIGN AND FUNCTIONALITY

The e-Tracker satisfies many of the functional requirements on an "ideal" eIR, as characterized by the *Electronic Immunization Registry: Practical Considerations for Planning, Development, Implementation, and Evaluation* (PAHO, 2017). It was developed as part of the DHIS2 HISP community of practice with appropriate local expertise and, overall, was considered a 'good' system by its users. The tool was largely deemed to be dependable by staff at both the HC and DH level, exerting a positive impact on the quality of work, improving productivity and preferable to only using paper-based tools. However, due to the continued use of the dual system until October 2022, the e-Tracker could not have measurably improved efficiencies at the time of the evaluation, particularly at the HC level. With only approximately 30% of HMIS data being entered in the e-Tracker, there was limited benefit to the HW as the tool did not provide sufficiently complete information to inform decision making.

Additionally, as data were largely entered into the e-Tracker by data managers/clerks, the tool was rarely used for real-time data entry at the point of vaccine administration. A lack of harmonization of e-Tracker entry forms with the paper registers was highlighted by HWs as further increasing complexity of use, an issue which has become less important with the transition to the full electronic system. Challenges in the actual use of the tool have been previously documented (e.g., challenges in logging-in, running system cache cleaners, and the inability to update events), and many of these are likely related to a capacity gap which could be resolved through additional focused training and ongoing supervision, rather than to technical issues inherent in the tool itself (Sibomana et al., 2021).

Overall, HWs expressed trust in the e-Tracker and that system data would not be lost. Interestingly, rural users were more likely to trust the system than urban users. Two explanations may provide some insights into this finding. First, urban users are more used to working with electronic tools in all aspects of life and, therefore, could be more critical of any technical glitches. Second, rural users might have a more stable and thus predictable catchment population and, therefore, could use the tool more easily in line with its inherent functions.

Despite displaying ideal features of an eIR, **limited interoperability** of e-Tracker was perceived as a significant bottleneck its effective use. While the ability to identify persons for immunization via the NIN existed at the time of the evaluation, the e-Tracker was not yet interoperable with the CRVS. This has subsequently changed with the introduction of a new interoperability feature. The e-Tracker's interoperability with RapidSMS has also been enabled as part of the transition to a fully electronic system and is now being operationalized. In addition, it has been suggested that interoperability with the vaccine logistics management module could further enhance the utility of e-Tracker. Sufficient stress-testing for the full scale-up of these features will need to be factored into the roll-out plan given the experience from other countries with similar systems 'collapsing' once fully scaled up.

Importantly, there are lessons to be drawn from the experience of implementing other electronic registries in Rwanda. For example, HIV-cased based surveillance data (OpenMRS) faced similar challenges with automation and interoperability as facilities were using a paper-based process to record HIV-surveillance case data which

were then manually entered into DHIS2 by data managers. A recent randomized controlled study comparing the older version of OpenMRS and the newer enhanced OpenMRS with greater interoperability showed that the core clinical tools of the enhanced package was more frequently used, including for updating records, establishing patient summaries, and viewing laboratory results. Users of the enhanced package also reported greater support for the specific features of alerts and reminders (Fraser, 2022). It is conceivable that HWs are more likely to use a tool such as the OpenMRS or e-Tracker when it has interoperability features that improve the efficiency of their daily routine and assist in direct decision making. Similar to the findings of this evaluation, the earlier study on OpenMRS also found differences in the level of use between HWs and data managers, including in the performance of core clinical activities such as creating and updating records. Clinical staff had less technical experience and were less likely to use computers outside work or access the internet for a range of applications. The authors indicate the need for further improvements in usability and workflow and in both IT support and training for clinical staff (Fraser, 2022). This is well aligned with present evaluation of the e-Tracker calling for both additional IT training and provision of additional hardware coupled with enhanced supervision to support HWs in their effort to perform real-time data entry and use of these data for their day-to-day program decisions.

C. IMPLEMENTATION

IMPLEMENTATION EXPERIENCE

It has been challenging to implement an electronic system at one point in time at national scale, particularly as the e-Tracker's introduction coincided with the beginning of the COVID-19 pandemic. Based on the findings of this evaluation, less than a third of HCs were using the tool for reporting of immunization data into the HMIS, and in the HCs visited, there was a substantial backlog of immunization data that needed still to be entered into the system. While an earlier attempt had been made to use PBF for reducing such a data backlog on BCG vaccines (i.e., as an ad-hoc update of a nominal register to better align immunization with CRVS data), a similar approach was not followed for the rest of the immunization data and implementation of the PBF scheme has been discontinued.

The recent decision to transition to a fully electronic system and to integrate the e-Tracker with the CRVS should favor a more consistent and efficient use of the tool by reducing the workload of both clinical staff and data managers. Findings from this evaluation show that HC and DH staff felt that the implementation of e-Tracker to date had actually increased their workloads due to the need for parallel recording, resulting in earlier requests for additional staff and the need for HR reorganization. The same situation was described by Sibomana et al. in 2021 who further highlighted the high turnover of HWs and data managers.

In addition, many staff expressed feeling inadequately prepared for e-Tracker use. Despite reports of adequate computer literacy and timely access to IT support, **limited IT training** might have been inhibiting e-Tracker use, as only 25% of HC and DH staff felt they had been adequately trained. In addition, the vast majority of HC and DH staff did not fully understand their roles and responsibilities in using the e-Tracker and felt inadequately equipped to carry out their responsibilities. This extended to limited competency displayed in some of the tool's functions. With the switch to a fully electronic system additional training (i.e., on the use of the e-Tracker, data analysis, report generation, scheduling appointments and using the tool for defaulter tracking) and updated training materials will be required. A learner-centered training plan which aims to fill capacity gaps by performing additional on-the-job trainings, delivering regular refresher trainings, offering a mix of online and in-person courses and strengthening supervision and mentorship approaches through enhanced accountability of DH supervisors will be critical.

IMPLEMENTATION COSTS

In terms of costs, the full initial investment of adapting and deploying the e-Tracker at national scale was approximately USD 1.6 million, which represents around 13.8% of the country's average annual expenditures for immunization in the years 2017-2019. However, the financing of the implementation of the e-Tracker was almost entirely borne by external funders, namely WHO and Gavi. This parallels the experience in neighboring countries including Zambia and Tanzania where, for example, the initial implementation of the eIR was driven by development partners, including PATH, and supported by BMGF and Gavi. While the Government of Rwanda did not incur any financial outlay, it did contribute in-kind through allocation of senior government and

healthcare staff to support the conceptualization, planning, implementation and monitoring of the system. A full quantification of these in-kind contributions was not possible due to the paucity of relevant data; however, it is reasonable to assume that the government's contribution in terms of staff time and resources made available to the implementation was considerable and required strong local commitment. Despite not resulting in financial disbursement, these contributions do have an opportunity cost and may constitute a barrier in settings with lower endowments of resources or less political will.

The highest implementation-related expenditures were attributed to hardware (e.g., computers, tablets and modems). The high share of hardware costs over the total implementing costs is consistent with findings of Mvundura et al. (2019), who saw a similar situation when evaluating the implementation of electronic immunization registries in Tanzania and Zambia. In Rwanda, 77% of HCs and 92% of DHs reported sufficient access to hardware, although shortages had been observed during the evaluation visits. Tablets purchased for the e-Tracker had been relocated ad-hoc for the management of vaccination data of the COVID-19 vaccination effort. This may have contributed, among other causes, implementation challenges and to the need for doing data back-entry rather than being able to input data in real-time at the vaccination site. Of note, this situation has subsequently changed with the tablets being returned to support the transition to the fully electronic system.

Training was the second highest cost item in the implementation of the e-Tracker accounting for 16% of the total cost. It was estimated that the cost of the 3-day training for each HW was approximately USD 142. Nonetheless, only a quarter of HC and DH staff thought they had been adequately trained for using the tool. This perception could reflect that the necessary amount of training was inadequately estimated at the planning stage; that the training was ineffective in transferring the necessary skills and knowledge; or that, at the time of the assessment, the training needed to be repeated due to competencies fading over time, or due to high staff turnover. In addition, the repeated COVID-19 lockdowns interfering with face-to-face trainings may have added to this unsatisfactory assessment.

Finally, the cost of development and customization of the eIR to the Rwanda setting was limited, at approximately USD 100k, 7% of the total implementation costs. This cost was lower than the estimates from Mvundura et al. (2019) in Tanzania and Zambia where system design and development costs accounted for respectively 22% and 14% of the total implementation cost. This difference may be explained by the fact that while Tanzania and Zambia each developed their own bespoke eIR with substantial external technical and implementation support, Rwanda opted for using the DHIS2 e-Tracker platform designed to be more readily adapted to local situations and benefiting from an active community of practice. In addition, in Rwanda, the necessary domestic technical and IT expertise was readily available, avoiding an over-dependency on external software engineering support.

Overall, the cost of developing and deploying the e-Tracker in each of the 505 HCs delivering vaccination and in the 37 district hospitals in Rwanda was estimated as USD 2,917 per site. This figure is higher than the average estimated expenditure per health facility ranging between USD 709 and USD 1,320 for 3 regions in Tanzania but comparable to the costs for the 1 province in Zambia (USD 2,591), as reported by Mvundura et al. (2019) who have attributed differences in implementation costs per facility to the various deployment strategies employed in the different contexts of each country. When comparing the implementation costs per child, Tanzania and Zambia's deployment expenditures amounted to USD 1.17-1.82 and USD 8.21 per child, respectively (Mvundura et al., 2019), compared to that of Rwanda's at USD 2.78 per child. The cost per child in Rwanda are markedly lower than Zambia's costs but justifiably higher than Tanzania's costs because of differing birth cohorts in each country.

D. PROGRAMMATIC IMPACT

Due to the limited period of implementation and the effect of the COVID-19 pandemic on immunization delivery and the roll-out of the e-Tracker, use of the tool was not expected to have had a measurable impact on immunization outcome indicators (e.g., coverage, timeliness, or drop-out rates). Thus, the assessment of impact in this evaluation necessarily focused on several process and output measures (e.g., data quality and data use for decision-making as well as user and client satisfaction) which are assumed to result in changes of the above outcome measures. Improvements in these proxy measures were largely experienced by the more frequent users of the tool at HC level and by supervisors at the DHs.

Unsurprisingly, given the incomplete use of the e-Tracker for immunization data recording at the HC level, improvements noted in **data quality** were seen by only half of the HCs compared to two thirds of DH staff, with frequent users reporting more positive views. Only about one quarter of staff at HCs and at the DHs were fully satisfied with the accuracy and completeness of immunization records generated by the tool. The paper registry was, therefore, still considered the most accurate source of immunization data. Interestingly, frequent users were more likely to state that e-Tracker data were the more accurate, supporting the premise that more frequent use of the tool helped to generated trust in the system eventually leading to improved data quality.

By comparison, half of the DH staff perceived improvements in data monitoring by using the tool because of reported reductions in paperwork and data errors, as well as progress in drop-out recuperation. Other reported benefits of the tool at the district level included improvements in the quality of decisions made as well as more effective data analysis, interpretation and use of data for planning purposes. These differences between the HC and DH level were likely due to the limited use of the tool at the HC level. District supervisors with direct access to the tool, good connectivity and direct feedback from the national (RBC) level more regularly used the tool to inform their decisions. A situation in which vaccinators at the HC level were still largely using paper-based tools, with data managers taking responsibility for the e-Tracker data entry and analysis, would have continued to hinder data use for decision making for the local immunization service delivery. Empowering vaccinators to manage and use immunization data at the vaccination site will likely make a difference, and it will be important to closely monitor this situation following the recent switch to a fully electronic system. For this, ensuring availability of sufficient tablets at all sites is a prerequisite.

The e-Tracker enabled some improved **data use for decision-making** with notable variability for defaulter identification, outreach services and supervision. While almost all HCs had a defaulter tracking mechanism in place for the identification of un-or under-immunized children, less than a third of HCs and DHs regularly used the e-Tracker to generate a list of defaulters. Refresher training with ongoing supervision in using the tool for this activity will be warranted to allow the generation of defaulter lists to be more efficiently performed. By being able to better identify and track defaulters, an eIR could contribute to more equitable vaccine coverage by allowing for the identification and targeting of interventions to reach un- and under-immunized children (Pancholi, et al., 2020).

Of note, the implementation of the e-Tracker did not substantially affect the costs for defaulter identification nor impact defaulter contacting. However, Rwanda is now integrating the e-Tracker with RapidSMS for client notifications which could enhance opportunities to contact defaulters more efficiently and reduce missed opportunities for vaccination, further decreasing drop-out rates (Secor et al., 2022).

The e-Tracker was not fully used to organize and deliver outreach sessions due to its current mode of use with desktop computers. Similarly, while DH staff acknowledged using immunization data to plan outreach services, the role of the e-Tracker in this remains unclear. Incremental costs were observed both for the organization and the delivery of outreach sessions following the implementation of the tool. While in principle there is great potential for the e-Tracker to be used both for the planning of outreach services, allowing for more targeted outreach activities to specific groups or individuals as well as for decision-making support during outreach activities (Pancholi, et al., 2020), in practice, the use of the e-Tracker for outreach will only be feasible with the use of additional hardware such as tablets or smart phones. In addition, its utility in supporting outreach activities could be further enhanced with a further interoperability between the tool and an eLMIS to support the traceability of vaccine stock (PAHO, 2017).

Slightly more than half of HCs and more than two third of DH staff used data from the e-Tracker to guide supportive **supervision** activities. Frequent HC users were more likely to be linked with DH supervisors who stated that they used the electronic data to guide supervision. The tool is widely used to provide feedback from the national level via the DH to the HC level on immunization data submitted and this feedback is then used to guide supervisory discussions. In addition, most DHs used performance data to prioritize the needs of HCs; at least a third of these data originated from the e-Tracker. These findings are consistent with the notion that improved immunization services management and efficiencies, including increased focus on training, performance management, direct feedback and supervision, are key benefits of an eIR (PAHO, 2017). The e-Tracker could still be leveraged better to support these activities. The implementation of the e-Tracker does not

seem to have had a cost impact on the execution of supervisory visits from district to HC level to date, as the frequency of the activity and the time and number of personnel involved appears to have remained unchanged.

Importantly, despite the limited use of the tool at the point of vaccination, more than a quarter of caregivers who had noticed that electronic tools had been in use in their HCs considered these as more organized, with less waiting times, and found it easier to search for a child without vaccination card. Albeit limited, such improving caregiver satisfaction provides a promising outlook for the further scale-up of the tool.

Finally, results from the ITS analysis for DPT3 coverage data showed that for the two years following the e-Tracker introduction (October 2019 - September 2021), a decrease of administered doses compared to before e-Tracker use was seen**.** These findings corroborate WUENIC data that reported a decrease in routine vaccination with Penta3 vaccination coverage decreasing from 98% in 2019 to 91% in 2020 and 88% in 2021, and MR1 vaccination coverage decreasing from 96% in 2019 to 94% in 2020 and 87% in 2021. Given that the introduction of the e-Tracker in Rwanda coincided with the COVID-19 outbreak with several stringent lockdowns, which majorly affected vaccination services, any measures of uptake and coverage of routine vaccines would have been heavily impacted and, thus, confounding the potential impact of the e-Tracker on these outcome measures.

E. ECONOMIC IMPACT

The implementation of the e-Tracker has led to a doubling of costs compared to only using paper registries since it reflects a duplication in activities (i.e., paper plus electronic) for child registration. This process has resulted in an additional financial burden to the country of approximately USD 128,735 per year (i.e., a 23% increase in costs for immunization data management). The vast majority (85%) of this cost was accounted for by personnel costs and related mainly to the activity of data entry for each new child visit. Indeed, the time spent by staff for data entry alone generated about two thirds of the whole cost of using the e-Tracker.

It was expected that the use of the e-Tracker would reduce the cost of all activities that require retrieving immunization data (e.g., generating immunization reports, identifying defaulters, etc.) due to the greater ease of retrieving electronic data as compared to data on paper. However, the findings of this evaluation suggest that the e-Tracker was limitedly used to perform these activities, with the paper registry still considered the most trustworthy source of information. This may explain why no significant difference in costs compared to the paper registry was seen with the only exception of the cost of registering children. The greater trust and reliance in the paper-based registry will need to be carefully taken into consideration in the ongoing transition to a fully electronic registry.

Given the higher costs of the e-Tracker and the apparent limited impact on immunization outcomes, it is unlikely that the system in its current mode of use (i.e., in combination with paper registries) would be cost-effective. Even beyond the possible confounding effects of the COVID-19 pandemic, the results of the evaluation do not support the assumption that the previous use of the e-Tracker would have improved the performance of the immunization program given its limited impact on informing decision-making and service delivery. The switch to a fully electronic system with greater interoperability, coupled with investments in strengthening the digital infrastructure, will likely create a favorable environment for sharable, high-quality immunization data which, in turn, may constitute a first step towards real-time, data-driven decision-making processes and finally results in a beneficial impact on immunization service delivery. However, these benefits may take time to realize, and it will continue to be difficult to quantify and value or to attribute them to a specific intervention such as the implementation of the eIR.

The findings of the simulation exercise suggest that the ongoing transition to a fully electronic system will result in process efficiencies and substantial cost reductions, as hypothesized in the ToC. The transition is more likely to generate a substantial cost saving as compared to the full paper registry if proper equipment (e.g., tablets) and infrastructure (e.g., internet connectivity) are available at the HC level, and if adequate training and supervision will be performed. HWs must be equipped with adequate digital skills and the capacity to fully use the e-Tracker and continue to be supported with refresher trainings and ongoing supportive supervision. The latter should reinforce and facilitate the change management necessary for fully adopting the e-Tracker in daily use as the single immunization registry and for ensuring its sustainable use. As more staff are trained and can autonomously perform tasks electronically, the e-Tracker data can be increasingly used for day-to-day decision-

making. Further programmatic benefits can be realized from more efficient and accurate defaulter identification and tracking and from additional performance reviews. Overall, this can effectively contribute to increasing ownership and motivation in the data-driven performance of immunization service delivery, optimizing the sustainability and allocation of resources over immunization data management tasks.

F. LIMITATIONS OF THE EVALUATION

This evaluation has several limitations. First, there was a relatively short period between the e-Tracker roll-out (2019-20) and the data collection (Q1 2022) which did not allow the tool to be widely used, nor initial implementation problems resolved. The transition to a fully electronic system did not commence until 1 October 2022, after the completion of data collection for this evaluation. Second, the sample of 24 HCs and 12 DHs coupled with the purposive sampling strategy may have impacted the external validity of the findings. While the sample has been shown post-hoc to be representative of all country HCs offering vaccination with regard to several characteristics, including type and size of health facilities, their immunization performance and the use of the e-Tracker for reporting immunization data, a slight oversampling of HCs with higher dropout rates and larger catchment areas as well as those in urban areas could have potentially biased findings towards lower use of the tool. Finally, the estimates of the implementation costs of the e-Tracker, did not include in-kind contributions from the local government (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). While these local contributions did not require additional financial disbursement, they do have an opportunity cost that should be considered in the full cost of implementation. Nonetheless, estimating these costs ex-post was deemed too prone to bias and, thus, infeasible. The analysis was limited to the available data on financial expenditures.

Some potential biases may have also influenced the findings. Firstly, the data collected and reported consisted primarily of perceptions reported by healthcare staff during interviews, both for the programmatic, as well as economic components. The self-reporting of past and present perceptions carried an inherent information bias. Recall bias was relevant, especially in the cost impact analysis comparing the e-Tracker and the previous paper-based registry. As the system was swiftly implemented in the whole country, a before and after design was the only option available to quantify the differences of the e-Tracker on data management and its costs. Nonetheless, the results of the before and after analysis are consistent with the findings comparing frequent and non-frequent users. Alternative secondary sources were explored to validate these data and increase the reliability of estimates obtained from primary data collection. Regarding the quantitative data used for estimating the cost of the e-Tracker, some statistical outliers were excluded from the analysis due to their considerable impact on mean estimates. This resulted in a further reduction of the sample size in some of the activities considered in the cost analysis. This reduction was nonetheless relatively small, with a maximum of 2 outliers per variable taken out from the analysis.

G. INFLUENCE OF THE COVID-19 PANDEMIC

The COVID-19 pandemic is a notable confounder in this evaluation. The pandemic substantially shifted government priorities and delayed the e-Tracker scale-up plan, including the transition to fully electronic use, the integration with the CRVS and RapidSMS for client notifications and the availability of hardware and human resources which had been redirected towards the COVID-19 response. In addition, the pandemic impacted routine immunization services and reduced the demand for routine vaccinations as a result of the repeated lockdown measures and other COVID-19 related accessibility factors. Together this has made it impossible to demonstrate the anticipated impact of the tool on primary immunization outcomes, including coverage, timeliness of vaccinations and drop-out rates. This evaluation, as a result, focused on the more proximal process and output measures to ascertain directional progress in the implementation and impact of the tool.

H. CONCLUSION

The findings of this evaluation confirm that despite implementation challenges, the e-Tracker was perceived by HWs at all levels to be a valuable contribution to the management of the country's immunization program.

While the dual system has naturally added cost to the health system, the ongoing transition to a fully electronic system will likely be cost saving based on the simulation conducted as it would potentially reduce the health worker burden experienced by use of the dual system.

The further use and expansion of the e-Tracker to inform data collection, analysis and decision making on immunization should be enabled so that the full potential of the system can be realized which in turn may assist with reaching improved immunization outcomes. It is only when the e-Tracker is used in this way that the system will be cost-effective and that the investments made in its development and implementation will have positive returns. This will require strengthening the overall ecosystem, with specific attention to the IT infrastructure, in addition to maintaining the recently introduced interoperability features, such that the tool can be fully functional. Ensuring that refresher training and ongoing supervision adequately enable both use of the e-Tracker and the use of data will also be paramount.

Given the findings of this evaluation which highlighted specific barriers and enabling factors, it is recommended that a monitoring framework be developed to assess the uptake and use of the fully electronic e-Tracker, as well as the process changes required, as Rwanda continues its digital journey in transitioning to a fully electronic system. The experience of Rwanda in this transition will be an important learning opportunity for other countries presently exploring implementing similar changes. A re-assessment of the situation within 1-2 years of the transition could be helpful for deriving such lessons learned. Potential indicators to monitor would include the ability for real-time data entry at the vaccination site, use of the system data for immediate decision-making for program planning, including defaulter identification and tracking, outreach activities and finally the potential impact of use of the e-Tracker on immunization coverage, timeliness and drop-out rates, as well as on the identification and ultimate reduction of zero-dose children.

VI. ANNEXES

ANNEX 1: THEORY OF CHANGE

Vision	Reduce morbidity and mortality from VPDs by enhancing equitable access to vaccines and strengthening immunization delivery within PHC (IA 2030)				
Mission	Improve immunization program performance (equitable coverage and system efficiency) by sustained use of eIR				
Strategic Outcome	1. Functioning eIR as part of a broader health information system	2. Improved immunization data quality	3. Increased use of immunization data for decision-making	4. More efficient, affordable, and sustainable eIR use	5. Increased stakeholder satisfaction and engagement
Output	a) eIR is functional and interoperable with other health information systems. b) Data flow and feedback mechanisms between administrative levels is improved. c) Linkages between data systems enable estimation of vaccine effectiveness, impact and causality assessment of serious AEFI.	a) Data are complete, sufficiently granular, accurate and timely. b) HWs at all levels understand data quality dimensions and are motivated to improve it. c) More updated and precise information is available on size of target populations for different vaccines. d) Data facilitate the identification of un- and under-immunized individuals and communities.	a) HWs at all levels are capable, empowered and motivated to make data-enabled decisions to improve planning (e.g. analyze data by geography, SES, gender, etc.). b) The ability to uniquely identify individuals targeted by immunization services is improved.	a) Country ownership of the eIR is enhanced with adequate system governance. b) All levels of the health system have access and the capacity to use the eIR. c) Time required to organize vaccination sessions, record vaccine events, establish defaulter lists and generate monthly reports is reduced. d) Financial resources allocated are adequate to sustain and periodically update the eIR.	Time savings and knowledge gains increase HW motivation to use the system. User confidence in eIR data quality is enhanced. Caregiver satisfaction with immunization services is increased, e.g., by benefitting from receiving notifications
Input & Process External environment;	d) Appropriate IT and facility infrastructure (security, integrity, electricity, internet) is in place.	e) Competency and proficiency of eIR users at all levels is ensured.	c) Reporting flow of case-based data from vaccination sites to national level is seamless.	e) An e-health policy environment is in place. f) Sufficient technical and governance capacity is generated.	Feedback from stakeholders (government, funders, users, clients) is used to

Human Resources; Systems & tools	e) Data recording and reporting is user-friendly and efficient (including revised paper-based forms). f) Interoperability is established with HMIS, civil registration (CRVS), surveillance, pharmacovigilance and logistics management systems, including in the private sector.	f) Data quality and consistency checks are in-built. g) Periodic data quality audits are performed. h) SOPs, job aids, training and supportive supervision tools for eIR use are available.	d) Interactive data dashboards are available that enable data visualization. e) HW capacity to use immunization data is strengthened at all levels. f) HWs have the ability to identify zero-dose children and to track defaulters. g) Data can be generated to monitor performance indicators at all levels. h) Client usage patterns reveal HF management issues and help reduce unnecessary supervisory visits.	g) The eIR is continuously maintained and updated (e.g., help desk available) h) Costs of implementation of the eIR and costs avoided are well known. i) A budget line exists for maintaining and updating the eIR.	continuously improve the system. HWs are empowered to use saved time to improve the quality of service delivery.

Note:
When using the ToC as basis for the evaluation approach the following will need to be done:

1. Existing challenges to be tackled by the electronic systems will be included in the introductory narrative.
2. Final health outcomes at the vision levels will potentially be modeled: morbidity, mortality (DALYs, QALYs).
3. Immunization outcome indicators at the mission level will be added: e.g., % un-immunized; % under-immunized; tracer vaccine coverage; dropout rates; vaccination timeliness; missed opportunities for vaccination.
4. Evaluation indicators will be further defined for each of the final input and output parameters.
5. Activity-based costing and estimation of avoided costs will be performed.
6. Evaluation will use historical (reference to earlier evaluations/data) and geographical comparisons.

ANNEX 2: DATA COLLECTION TOOLS

Tools to be shared in a separate file.

ANNEX 3: SAMPLE SELECTION AGAINST SAMPLING CRITERIA

Criteria		Population (505)	Sample (24)
Health center type	FBO/NGO	139	11
	Public	342	13
Size of catchment population <1yr	High	234	19
	Low	247	5
Penta3 drop-out	High	33	5
	Low	248	16
	None	200	3
MR drop-out	High	41	2
	Low	143	8
	None	297	14
Location	Rural	435	14
	Urban	46	10
e-Tracker performance		29.6%	28%

ANNEX 4: LIST OF DISTRICT HOSPITALS AND HEALTH CENTERS INTERVIEWED

Province	District	District Location	District Hospital	Health center	Location of Health Centre	Type
East	Gatsibo	Rural	Kiziguro District Hospital	Kabarore	Rural	Public
				Rwembogo	Rural	Public
	Kayonza	Rural	Rwinkwavu District Hospital	Ruramira	Rural	Public
				Kabarondo	Urban	Public
	Rwamagana	Urban	Rwamagana District Hospital	Avega Rwamagana*	Urban	Public
				Rwamagana	Urban	Public
Kigali	Gasabo	Urban	Kibagabaga District Hospital	Gatsata*	Urban	Public
				Remera*	Urban	Public
	Kicukiro	Urban	Masaka District Hospital	Gahanga*	Urban	Public
				Kicukiro	Urban	NGO/FBO
North	Burera	Rural	Butaro District Hospital	Cyanika*	Rural	Public
				Gahunga*	Rural	Public
	Musanze	Urban	Ruhengeri District Hospital	Kabere*	Rural	Public
				Busogo	Rural	Public
South	Gisagara	Rural	Gakoma District Hospital	Gakoma	Rural	Public
				Gikonko	Rural	Public
	Huye	Urban	Kabutare District Hospital	Rusatira Kinazi	Rural	Public
				Cusp Butare	Urban	Public
	Muhanga	Urban	Kabgayi District Hospital	Nyarusange	Rural	Public
				Gitarama	Urban	NGO/FBO
West	Karongi	Urban	Kibuye District Hospital	Kirambo Gitesi	Rural	Public
				Rubengera	Urban	NGO/FBO
	Rubavu	Urban	Gisenyi District Hospital	Kabari*	Rural	Public
				Nyundo*	Urban	Public

*indicates non-frequent (health center) users

ANNEX 5: COMPLETE PROGRAMMATIC FINDINGS AS MAPPED AGAINST TOC STRATEGIC OBJECTIVES

The programmatic analysis was conducted against the four strategic outcomes of the Theory of Change (ToC). Each question of the various data collection forms was mapped against the ToC to provide a detailed and holistic appreciation for the complexity of the tool, its implementation, and its expected outputs; as well as the enabling environment required for its successful adoption. This analysis explored input, process and output areas related to each strategic outcome. This report is intended to support program managers, providing detailed insights into the use of the tool, as well as the challenges and successes of its implementation. As Rwanda transitions away from a dual system, abandoning paper-based tools, these insights can assist program managers in their planning and monitoring of successful scale-up to full electronic use of the eIR.

STRATEGIC OUTCOME 1: FUNCTIONING EIR AS PART OF A BROADER HEALTH INFORMATION SYSTEM

INPUT/PROCESS

Access to appropriate IT, hardware, and electricity was good throughout the country and did not appear to be hindering the implementation of the e-Tracker (77% of HCs and 92% of DHs had sufficient access to hardware (computers/tablets/smartphones) and 89% of HCs and 92% of DHs had sufficient access to electricity). Access to the internet was, however, a concern in almost half of HCs (36% of HCs - 27% frequent; 9% non-frequent - and 15% of DHs did not have sufficient access to internet). **Better access to hardware at the workplace enabled the more frequent use of the e-Tracker (p=0.01).**

The e-Tracker was largely considered to be user-friendly by HC frequent users (67%) (33% non-frequent) and DH staff (83%). Rural users (62%) were slightly more likely than urban users (45%) to think the tool was user friendly. Whilst 45% of HC and 62% of DH staff thought they could finish tasks faster by using the e-Tracker, the use of the tool was not seen to be efficient, due to both the paper and electronic system in place and the resulting dual workload. **Frequent users were more likely to state that tasks could be completed faster by using the e-Tracker (p=0.01).**

More than half (55%) of HC and 62% of DH staff felt that the e-Tracker provided sufficient information to enable them to do their tasks; and 61% of HC and 62% of DH staff thought that the e-Tracker was in a format that quickly gave access to the vaccination information required. According to respondents, improvements could be made to the format of the e-Tracker with the e-Tracker set-up more-closely mirroring the requirements of the paper register. **Frequent users were more likely to state that the e-Tracker provided sufficient information to enable them to do their tasks (p=0.04) and that they were able to access vaccination information needed, when required (p=0.003).**

Less than one third (32%) of HCs regularly used the e-Tracker to generate new immunization records for children that had lost their Child Vaccination card, however caregivers serviced in HCs frequently using the tool acknowledged this as a benefit of the e-Tracker.

OUTPUT

Half (50%) of HC and three-quarters (75%) of DH staff felt that the e-Tracker was functioning when required. IT service support (including support from supervisors, IT, and user-guides) was made available by the MoH with the e-Tracker roll-out. This assisted in making the e-Tracker dependable, with functioning hardware and was well-regarded by respondents. HC (83%) and DH (92%) respondents agreed that they had timely access to IT support; with non-frequent users perceiving slightly more positively the quality of timely access to support from the district hospital or other places (89% versus 80%).

Overall, rural users were more satisfied with the timeliness of IT support provided than urban users (p=0.005). Frequent users were more satisfied with this support than non-frequent users (p=0.02), while non-frequent users in urban areas were less satisfied with this support than those in rural settings (p=0.05) and urban frequent users were more satisfied, than urban non-frequent users ((p=0.07). Rural users were more satisfied with overall software support provided than those in the urban areas (p=0.02). In the urban setting, frequent users were happier with the software support than those using the tool less often (p=0.08). **Similarly, rural users were more likely to think that problems in the software get fixed in an acceptable timeframe** (p=0.02).

The system is not yet interoperable with other health information systems including pharmacovigilance (i.e., reporting of adverse events following immunization (AEFI)), vaccine-preventable disease surveillance, and logistics management. Plans are currently underway to integrate the e-Tracker with the civil registration and vital statistics system (CRVS), as well as an existing electronic medical record (EMR) system. A Health Information Exchange (HIE) is being established, with the support of the Health Information System Program Rwanda (HISP) with full implementation expected by Q3 2022.

STRATEGIC OUTCOME 2: IMPROVED IMMUNIZATION DATA QUALITY

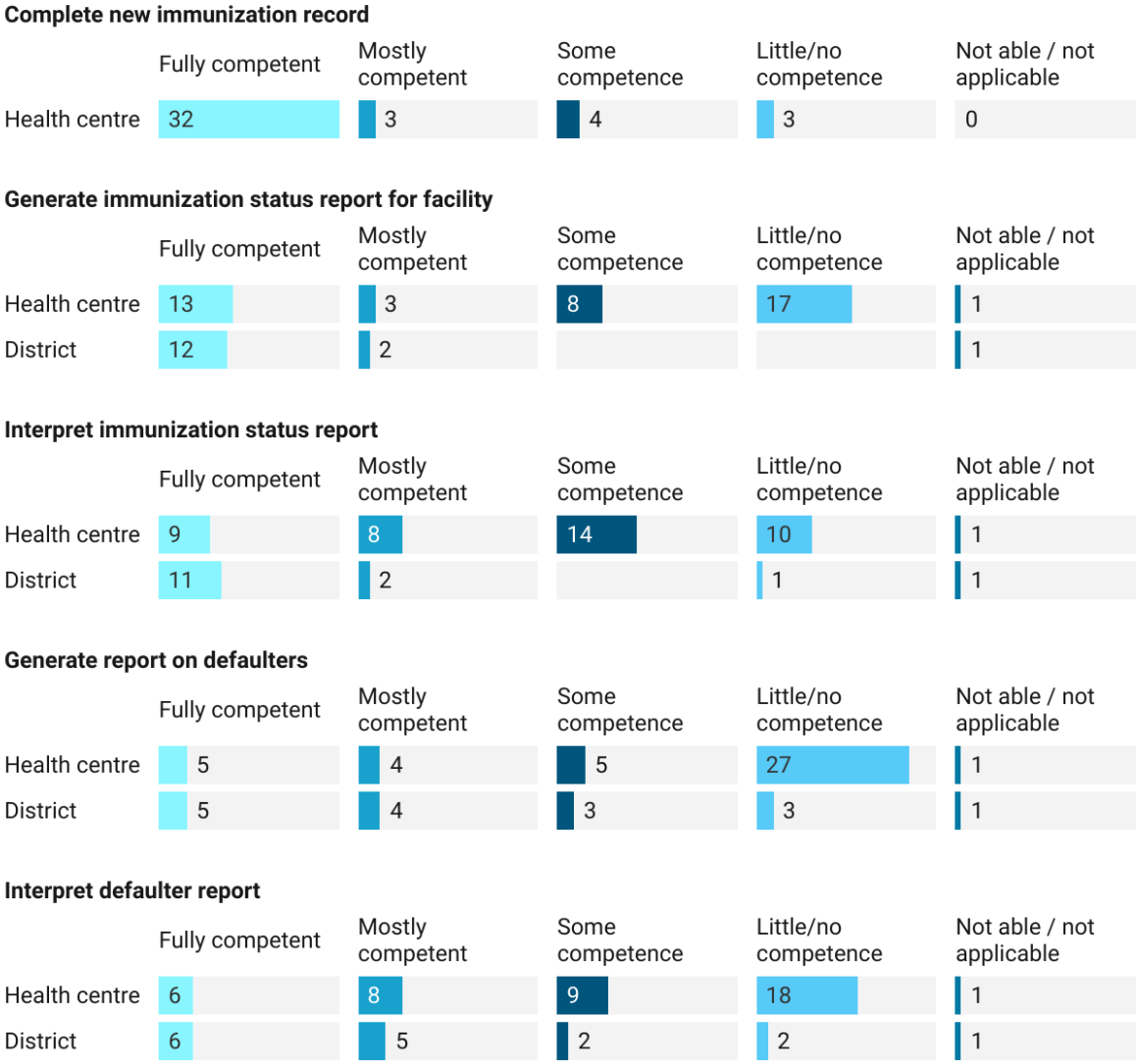
INPUT/PROCESS

Limited computer literacy appeared to not be a limitation of using or adopting the e-Tracker. Users had an apparent large interest in working with computers/tablets/laptops, had at least moderate skills in using the hardware, and felt that the equipment supported them in being more efficient at work.

At the same time, **only 25% of HC and DH staff thought they were adequately trained** on using the tool; and almost all (96%) HC immunization staff voiced additional training needs. Similarly, 71% of HC and 92% of DH staff did not fully understand their roles and responsibilities in using the e-Tracker or felt adequately equipped to carry out their responsibilities. Urban users were more likely to understand their roles and responsibilities in using the e-Tracker, than rural users (p=0.03).

The available user guides and help functions were found useful by 89% of HC and 92% of DH staff; although there was an acknowledgement that training materials for the e-Tracker need to be updated.

A standard e-Tracker competency assessment was conducted. Users at HCs appeared to be fully/ mostly (70%) competent at completing a new immunization record however there was limited competence in generating and interpreting immunization status and defaulter reports (Figure 5). Study enumerators voiced concerns around the lack of skills and training of local users; lack of knowledge of what was available within the tool; users not having time to use it and having forgotten how to use it; forgotten passwords; and only data managers using the tool, but not first-line vaccinators. Respondents at DHs had more competency in generating and interpreting immunization status reports than reports on defaulters (discussed further below).



When asked about the impact of the e-Tracker use on time and staff management, both HC and DH respondents said that additional staff were required (although not always received); that staff had to be reorganized to cope with the additional workload; and that some staff had to take on additional responsibilities. This was largely because of the dual-systems in place which prohibited the potential benefits of the e-Tracker to be experienced. One third of HC respondents (33%) said that there was no impact on staff management after the introduction of the tool at health center level; this was shared between frequent and non-frequent users.

More than half of HC (58%) and DH (67%) respondents said that **data from the e-Tracker was used to guide supervisory activities in immunization;** frequent users (75%) were more likely to have supervisors who said they used the data to guide their supervision than non-frequent (56%). At HCs, data were used for counter verification of data quality; and to generate graphs and other visuals. At DHs, data from the e-Tracker were used for a comparison between data sources; prioritization of health centerss (i.e., HCs with poor data quality were given priority during supervision); the identification of defaulters; and preparations for the Maternal & Child Health Week[3]. A review of e-Tracker data was typically part of supportive supervision visits, as listed by DH respondents including performance status for each HC as well as a discussion on data cleaning and analysis.

[3] The Maternal and Child Health Week is an annual 5-day campaign focusing on antenatal care, family planning and early childhood. Child health services include deworming, vaccinations, nutrition and prevention programs. Many children who may have missed vaccines are reached during this outreach program and there is strong political will supporting its implementation.

Regular data quality and consistency checks are not yet in-built in the e-Tracker and whilst periodic data quality audits were conducted, the e-Tracker was not yet impacting this process.

OUTPUT

The paper registry was considered to be the most accurate source of a child's immunization history by 79% of HC respondents. When comparing the situation before and after introduction of the e-Tracker (pre-post analysis) **half of HC (50%) and 67% of DH staff felt that data quality had improved since its introduction** however only 27% of HC and 23% of DH respondents were fully satisfied with the accuracy and completeness of its immunization records generated by the e-Tracker. **Frequent users, however, were more likely than non-frequent users to be satisfied with the accuracy and completeness of the e-Tracker data (p=0.03).**

An on-site accuracy data check was conducted comparing inputs on a number of variables from three different data sources i.e., the e-Tracker; the under-1 child paper register; and the child vaccination card (home-based record). Across all HCs, 21% of entries matched exactly. Frequent users were more likely to have entries match exactly, or only with some differences (80%), whilst 11% of entries from non-frequent users matched exactly or with some differences (oftentimes because the e-Tracker is not in use).

There was not a close relationship between perceptions of accuracy and accuracy confirmed during the on-site accuracy check however three of the five (60%) HCs whose data matched exactly in the on-site accuracy check were fully or partially satisfied with the accuracy and completeness of the immunization records in the e-Tracker. Half (4) of the eight HC entries where there were mostly differences, were not satisfied with accuracy and completeness. HWs explained the discrepancies by the fact that they largely used paper registers above the e-Tracker; that typing errors exist on children's names; that the e-Tracker format does not match that of the register; and that data entry is only done when time allows; 79% of respondents did not think that the e-Tracker helped to track individuals outside of their catchment areas.

The e-Tracker appears to not yet have impacted the accuracy of the target population data and the possibility to track individuals outside of HC catchment areas. Less than a fifth of HC staff (17%) thought that the accuracy of the target population had improved since the introduction of the e-Tracker (pre-post). The HC target population was considered accurate by only 33% of HC respondents. Similarly, 13% thought that the active tracking of vaccination drop-outs was easier using the e-Tracker. Whilst 38% of HCs used the e-Tracker to manage vaccines for outreach services, **frequent users were more likely to record vaccinations administered in outreach and mobile services (p=0.03).** However, only 8% of HC respondents felt that planning and arranging outreach sessions was easier using the e-Tracker; these were frequent users. Overall, about one third (38%) of HC staff found that the e-Tracker assisted them in responding to some of their immunization program challenges.

STRATEGIC OUTCOME 3: INCREASED USE OF IMMUNIZATION DATA FOR DECISION-MAKING

INPUT/PROCESS

Almost half (47%) of frequent users thought that data reporting has been more accurate and timely since the introduction of the e-Tracker. However, there was a discrepancy in how HCs used the e-Tracker for reporting. Some HCs reported that the e-Tracker provided reliable, real-time data, meaning they no longer needed to consult the registers and received more feedback; whilst other HCs used it only for data review and analysis, but used paper registers to prepare reports; in some instances because of a lack of training, and in others because they do not have time.

The majority of HCs and DHs had performance monitoring charts, dashboards or other means of data visualisation available, and these were largely up-to-date; however these charts were largely in paper-format (only 1 HC, and 3 DHs used an electronic performance monitoring tool).

Almost all (96%) HCs had an immunization defaulter-tracking mechanism in place; however less than a third of HCs (27%) and DHs (31%) regularly used the eTracker to generate a list of defaulters. Defaulter tracking was largely done by generating a list from the paper registers, and providing this list to the CHWs. In some instances parents were phoned, particularly if the child was outside of the center's catchment area, but no automated electronic reminder system was in place anywhere. **Frequent users (3 frequent users versus 1 non-frequent) were more likely to think that e-Tracker had improved defaulter tracking** (n.s.).

Only 21% of HCs thought it was easier to identify children who were registered at another HC using the e-Tracker. Reasons for this included: staff not knowing how to use the e-Tracker; finding the e-Tracker difficult to use; or having perceived limited access to the tool. Of the 21% of HCs, 100% were frequent users and 60% were rural users.

Almost all DHs (92%) had a data monitoring improvement plan. This was implemented through monthly coordination meetings and quarterly performance evaluations. These included feedback to HCs on their performance against specific indicators; monitoring HMIS and e-Tracker reports; cross-checking between paper register and e-Tracker data; follow-up to ensure tracking of identified defaulters,and conduct of planned outreach sessions. Whilst a third of DH EPI supervisors (4/12) said there had been no changes in monitoring immunization data improvement plans, some DH EPI supervisors (6/12) perceived the monitoring of these plans to have improved (as a result of reduced paperwork, a reduction in errors, and progress in drop-out recuperation). It was however noted that improvements were difficult to detect: "*Changes might be enormous but difficult to assess due to the inefficient use of e-Tracker".*

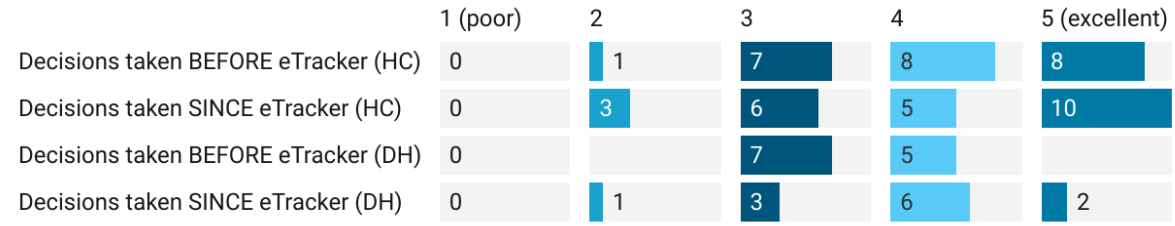
Three-quarters of DH EPI Supervisors (9) stated that they prioritized the needs of health centers based on available performance data (coverage and drop-out). The source of these performance data were primarily the paper-based data system (50%); followed by the e-Tracker (33%).

More than half (58%) of DH EPI Managers stated that the ***e-Tracker has improved the quality of feedback provided***. Almost half of HC (60% frequent, and 22% non-frequent) and DH (42%) respondents also think that **tracking supervisory feedback has improved since the introduction of the e-Tracker** (pre-post assessment).

OUTPUT

DH respondents perceived an improvement in the quality of decisions made since the implementation of the e-Tracker (score 41vs. 45; n.s.):

Quality of decisions made pre- and post- introduction of the e-Tracker



At HCs, the e-Tracker was most frequently used for forecasting vaccine requirements, followed by determining needs for immunization and outreach sessions, and planning for staff needs. Decisions on how to run the immunization program were largely taken during HC monthly meetings. **No major change was recorded in the decision-making process, at HC level, since the introduction of the e-Tracker.**

At DHs, EPI supervisors used the e-Tracker mainly for program monitoring and evaluation; adjusting their visits to health centers with poor performance; the comparison of local HC data with HMIS aggregated data to find ways to improve the use of the e-Tracker; provision of feedback to HCs including on their performance based on identification of low coverage / high drop-out rates; to plan the Maternal Child Health Week; for identifying the necessity for offering additional immunization sessions and for monthly reporting. Supervisors also checked whether the e-Tracker was working well and tried to identify any challenges amongst its users. Less than a third of HCs (27%) and 69% of DHs regularly used the e-Tracker to generate monthly reports.

The majority of DH EPI supervisors (at DHs) thought that planning (67%), data analysis and interpretation (83%) was much more effective since the introduction of the e-Tracker (pre-post analysis).

STRATEGIC OUTCOME 4: MORE EFFICIENT, AFFORDABLE, AND SUSTAINABLE EIR USE

Refer to economic analysis

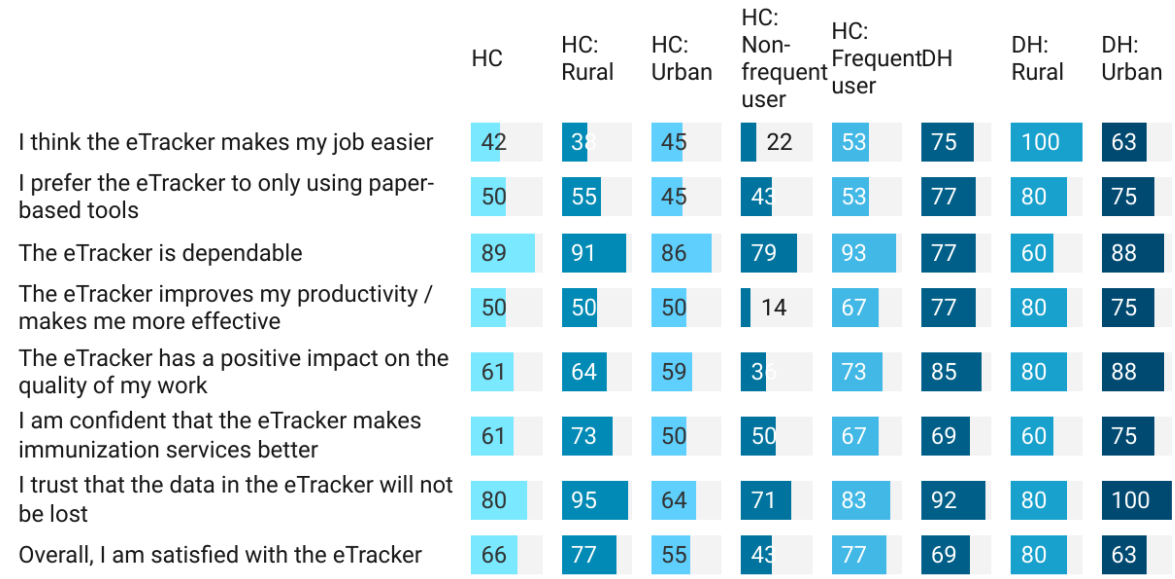
STRATEGIC OUTCOME 5: INCREASED STAKEHOLDER SATISFACTION AND ENGAGEMENT

OUTPUT

Overall, the e-Tracker was largely considered dependable by respondents at HC and DH level, with a positive impact on the quality of work, improving productivity and preferable to only using paper-based tools (Figure 8). Frequent HC users were more likely than non-frequent users to state that the e-Tracker had improved their productivity and made them more effective (p=0.004) and that it had a positive impact on the quality of their work (p=0.04).

The majority (92% DH; 80% HF) of respondents trusted that the data in the e-Tracker would not be lost; with rural users more likely to trust the system than urban users (p=0.02). Frequent users were more likely than non-frequent users to be overall satisfied with the tool (p=0.06). HC respondents (58%), however, did not think that the e-Tracker had made their jobs easier (due to use of the dual system); whilst 75% of DH EPI supervisors agreed thought that it made their job easier. It is noted that central level respondents similarly did not think that, at the time of data collection, the e-Tracker made their role easier given the additional requirements for the dual system, as well as the ongoing work to establish the additional features of the e-Tracker.

Figure 8: User satisfaction with the e-Tracker



Almost a third (29%) of the caregivers interviewed during the site visits said they noticed the HC staff using an electronic tool to record their visit; and 28% of these respondents said they had noticed a difference to their immunization visits since the staff had started using the tool; all of these caregivers were at HCs who frequently use the tool. In a pre-post assessment, **caregivers found that the HC situation was better since the e-Tracker has been introduced; the HC was more organized; waiting times were less; and it was easier to search for a child if the caregiver did not have the Child Vaccination Card.**

ANNEX 6: ECONOMIC ANALYSIS AND FINDINGS

6.1 DATA INPUTS FOR COST CALCULATIONS

Official salary scales for selected Health Centre and District Hospital personnel

Healthcare staff profile in primary data	Staff profiles used from the Official Gazette 2020	Gross salary / month (RWF)
Head of Health Center	Health Center Manager A0/A1	473,075
EPI Supervisor (District)	Director of Nursing and Midwifery	687,684
M&E Officer (District)	Planning, M&E Officer	405,493
Nurse A0	Nurse/Clinical Officer A0	328,317
Nurse A1		
Vaccinator		
CHO-Community Health Officer	Community & Environmental Health Officer A1/A0	328,317
Data Manager (District)	Data Manager	405,493
Data Manager A1/A0	Data Manager A1/A0	281,415
Accountant A1	Accountant A1	
Nurse A2	Nurse A2	194,503
DH Technician	Infrastructure Maintenance Officer A1	281,415
Hired Company		
Assistant Head of Health Center	Administrative Assistant to the Head of Referral Hospital	281,415
All the staff*		294,863.50
Cost of paper**	Paper is sold as a packet of 1000 paper sheets and the cost of a packet is 5000 RWF in average	5
	Cost of printing a registry was estimated at 20 RWF per page + 18% VAT (3.6 RWF)	23.6 (Registries)

* Calculation of the average of the salaries of personnel performing immunization activities
** Information provided by Rwandan partner institution for the research, CIIC-HIN

6.2 BROADER IMPACT OF THE E-TRACKER ON IMMUNIZATION SERVICE DELIVERY

The focus of the economic analysis was primarily focused on the costs of immunization data management, as the impact of implementing the e-Tracker on immunization costs are to be expected mainly in this area. Nonetheless, we assumed that using the e-Tracker may also have a broader impact on other costs of the immunization program. For this reason, with the objective of estimating the net cost of using the e-Tracker compared to the previous paper-based registry, the incremental analysis considered two further activities. These activities refer to the cost of delivering outreach sessions and the cost of emergency vaccine replacement. In the former, it was theorized that better data on defaulters through the use of the e-Tracker might contribute to the more efficient delivery of outreach activities, by potentially leading to a reduction in frequency or an increase in their size. Along the same line of thought, through a better and more accurate estimation of the monthly vaccination cohorts, HCs were hypothesized to be able to better manage vaccine stock based on the expected forecasted demand and better planning of immunization services. This would lead to a reduction of stock-outs and thus in fewer emergency vaccine stock replenishments during the year. While the e-Tracker is not directly used to perform these activities, the information and benefits of the use of the e-Tracker can inform these activities and indirectly lead to reduced costs for the immunization program, and thus they were included in a broader analysis for the cost impact of the system.

6.3 SUBGROUP ANALYSIS – COST OF USING THE E-TRACKER

6.3.1 Frequent vs. non-frequent users

In the selected sample, frequent users for the use of the e-Tracker are higher than those incurred by non-frequent users. Overall, frequent users incur higher costs to perform immunization data management activities with the e-Tracker. Notably, identifying defaulters was the only activity for which non-frequent users incurred higher costs.

Mean cost of e-Tracker in USD per HC (95% CI) based on the direct and indirect costs of immunization data management activities per frequent (n=15) and non-frequent (n=9) users of the e-Tracker. P-values for the significance of the difference between the means of the two groups are shown at the 95% confidence level.

	Non-frequent User (n=9)	Frequent User (n=15)	P-value
Child registration	172.1 (-197.2, 541.4)	191.3 (-90.7, 473.2)	0.84
Identifying defaulters	39.5 (-85.4, 164.4)	35 (-56.9, 127)	0.85
Organizing outreach	83.9 (-1.1, 168.9)	88 (23.6, 152.3)	0.80
Identifying performance gaps	53.8 (13.4, 94.3)	71.6 (16.5, 104)	0.80
Report generation	28.3 (-18.8, 75.3)	35.6 (-1.1, 72.4)	0.80
Total	**377.6 (-26.2, 781.4)**	**421.5 (114.1, 729)**	**0.82**

6.3.2 Rural vs. urban HCs

Rural HCs incurred 8% more costs than urban HCs for immunization data management activities. Notably, urban HCs incur 1/3 of the costs of rural HCs for outreach session organization and defaulter identification. Again, despite their location, HCs reported to base the organization of outreach sessions on paper registers, and specified that the use of the e-Tracker is done after the delivery of the outreach session for back-entry of data. Furthermore, rural health centers reportedly incur 37% less costs for report generation, while practically no difference was observed for identifying performance gaps. The small sample size for each group however does not allow for any conclusions to be drawn.

Mean cost of e-Tracker in USD per HC (95% CI) based on the direct and indirect costs of immunization data management activities per rural (n=13) and urban (n=11) users of the e-Tracker. P-values for the significance of the difference between the means of the two groups are shown at the 95% confidence level.

	Urban (n=11)	Rural (n=13)	P-value
Child registration	206.3 (10.6, 402)	163.8 (-156.3, 483.8)	0.29
Identifying defaulters	20.9 (-89.4, 131.1)	49.7 (-50.3, 149.7)	0.35
Organizing outreach	56.6 (-15.9, 129.1)	116.4 (43.7, 189)	0.22
Identifying performance gaps	64.2 (25.9, 102.5)	65.1 (31.4, 98.7)	0.57
Report generation	40.1 (0, 80.2)	25.1 (-16.8, 66.9)	0.57
Total	**388 (145.6, 630.5)**	**420 (72.7, 767.3)**	**0.38**

6.4 COST IMPACT

Cost of immunization data management activities using paper registries only

Mean cost of paper registry in USD per HC (95% CI) based on the annual direct and indirect cost of immunization data management activities (n=24)

		Activities					
		Child registration	Defaulter identification	Organizing outreach sessions	Identifying performance gaps	Report generation	Total
Inputs	Personnel	87.9 (65.2, 110.5)	30.4 (18.1, 42.8)	55.2 (31.8, 78.6)	43.1 (32.2, 54)	52.2 (38.2, 66.1)	**268.8 (229.7, 307.9)**
	Consumables + services	2.4 (1.6, 3.2)	0.7 (0.3, 1)	1.25 (0.5, 2)	0.63 (0.4, 0.9)	0.68 (0.4, 0.9)	**5.6 (4.4, 6.8)**
	Durable goods	2.2 (1.4, 3.1)	0.6 (0.4, 0.9)	1.53 (0.7, 2.4)	0.71 (0.5, 0.9)	0.87 (0.6, 1.2)	**6 (4.7, 7.3)**
	Total direct costs (a)	92.5 (69.8, 115.2)	31.7 (19.4, 44.1)	58 (34.6, 81.5)	44.5 (33.5, 55.4)	53.7 (39.8, 67.6)	**280.4 (241.3, 319.5)**
	Indirect costs (b)	13.8 (7.5, 20)	4.7 (2.6, 6.7)	5.3 (2.5, 8.1)	3.5 (2.3, 4.6)	5.1 (3.1, 7.2)	**32.3 (24.8, 39.8)**
	Total costs (a) + (b)	**106.3 (82.7, 129.8)**	**36.4 (23.9, 48.9)**	**63.3 (39.7, 86.9)**	**47.9 (36.9, 58.9)**	**58.8 (44.8, 72.9)**	**312.7 (272.9, 352.5)**

6.5 SUBGROUP ANALYSES – COST IMPACT OF USING THE E-TRACKER VERSUS THE PAPER-BASED REGISTRY

6.5.1 Frequent vs. non-frequent users

Frequent users incur overall more costs for all activities, driven by the activity of child registration. However, a decrease in costs after the implementation of the e-Tracker was observed for frequent users for report generation and defaulter identification. In more detail, for report generation, decremental costs were observed in 7/15 frequent users while no cost difference was observed in 5/15. One "frequent user" HC with decreased costs reported to generate reports uniquely using the e-Tracker, while of two HC using both registers and the e-Tracker, one observed a reduction in costs and the other no difference. On the other hand, for defaulter identification, decremental costs were observed in 12/24 samples HCs, with 7/15 frequent users reporting a decrease in the time the activity takes to perform after the implementation of the e-Tracker.

Mean cost difference between the e-Tracker and paper registry in USD per HC (95% CI) based on the direct and indirect costs of immunization service delivery activities per frequent (n=15) and non-frequent (n=9) users of the system. P-values for the significance of the difference between the means of the two groups are shown at the 95% confidence level.

	Non-frequent User (n=9)	Frequent User (n=15)	P-value
Immunization data management activities			
Child registration	56.2 (-336.5, 448.9)	91.7 (-205.5, 388.8)	0.58
Identifying defaulters	8.7 (-173.6, 191.1)	-4 (-132.8, 124.9)	0.44
Organizing outreach	7.8 (-163.2, 178.7)	32.6 (-100.4, 165.5)	0.71
Identifying performance gaps	7.6 (-37.7, 52.9)	22.7 (18.3, 58.6)	0.09
Report generation	-15.4 (-68, 37.2)	-32.4 (-73.5, 8.7)	0.25
Total	**64.8 (-405.8, 535.5)**	**110.6 (-243.7, 464.9)**	**0.39**
Activities related to the immunization program			
Delivering outreach	33.4 (-8,313.3, 8,380.2)	4 (-5,464.2, 5,472.2)	0.48
Emergency vaccine replenishments	0 (-2.2, 2.2)	0 (-1.9, 1.9)	1.00
Total	**98.2 (-8,261.8, 8,458.2)**	**114.6 (-5,365, 5,594.3)**	**0.53**

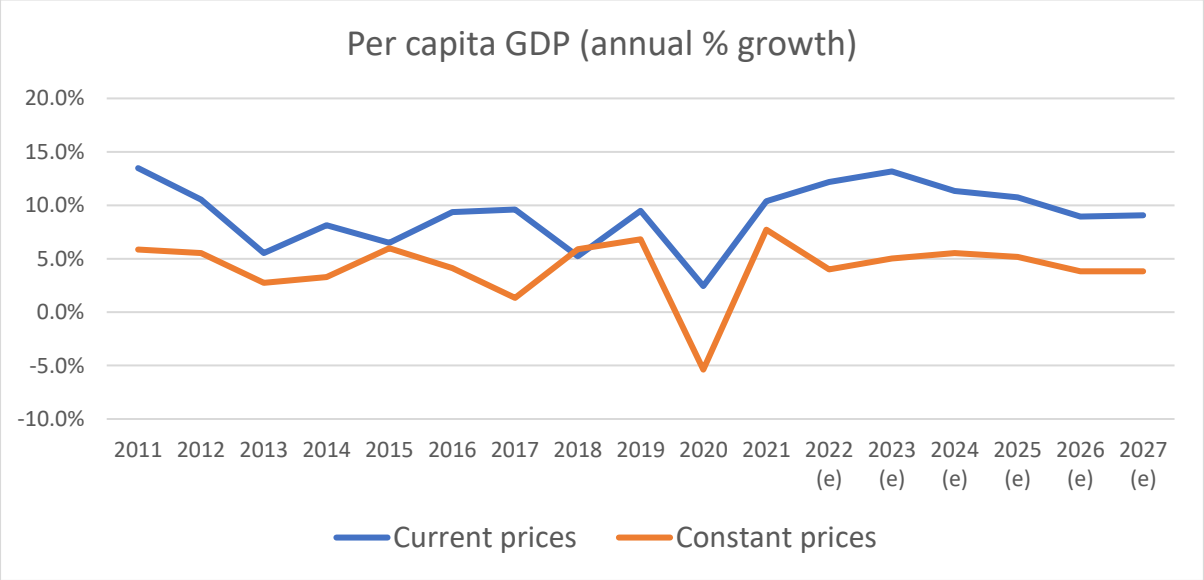
6.5.2 Rural vs. urban sites

Incremental costs were observed in both rural and urban HCs for all activities. Overall, urban HCs incurred almost three-times the incremental costs of rural HCs for immunization service delivery activities, driven by child registration costs. Notably, lower costs compared to the paper-based registries were observed for urban health centers for defaulter identification and report generation, the latter observed also for rural HCs.

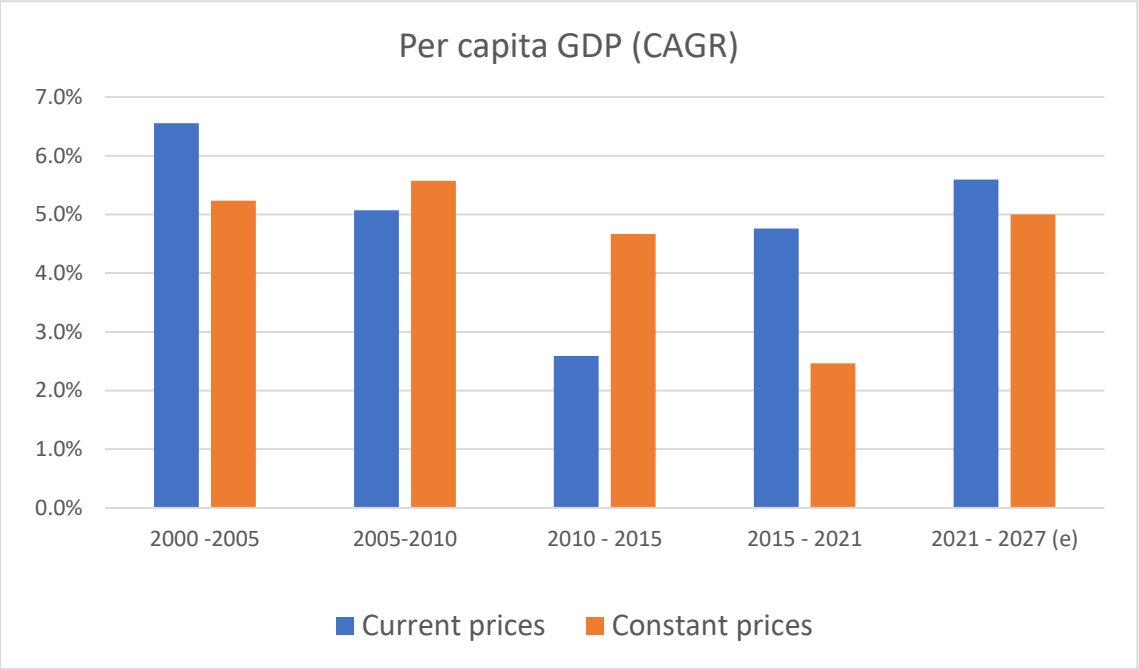
Mean cost difference between the e-Tracker and paper registry in USD per HC (95% CI) based on the direct and indirect costs of immunization service delivery activities per rural (n=13) and urban (n=11) users of the system. P-values for the significance of the difference between the means of the two groups are shown at the 95% confidence level.

	Urban (n=11)	Rural (n=13)	P-value
Immunization data management activities			
Child registration	111.1 (-112.9, 335.2)	49.1 (-288.6, 386.9)	0.21
Identifying defaulters	-5 (-159.7, 149.7)	3.8 (-139.7, 147.3)	0.30
Organizing outreach	25.8 (-120, 171.6)	17.5 (-133.8, 168.7)	0.90
Identifying performance gaps	8.7 (-33.7, 51.2)	23.4 (18.3, 61)	0.69
Report generation	-7.1 (-52.6, 38.3)	-43.7 (-90, 2.6)	0.22
Total	**133.5 (-181.5, 448.5)**	**50.1 (-351.3, 451.4)**	**0.34**
Activities related to the immunization program			
Delivering outreach	45.4 (-6,424.4, 6,515.3)	-16.3 (-6,483.5, 6,450.9)	0.87
Emergency vaccine replenishments	0 (-2.3, 2.3)	0 (-2, 2)	1.00
Total	**178.9 (-6,298.6, 6,656.4)**	**33.8 (-6,445.9, 6,513.4)**	**0.30**

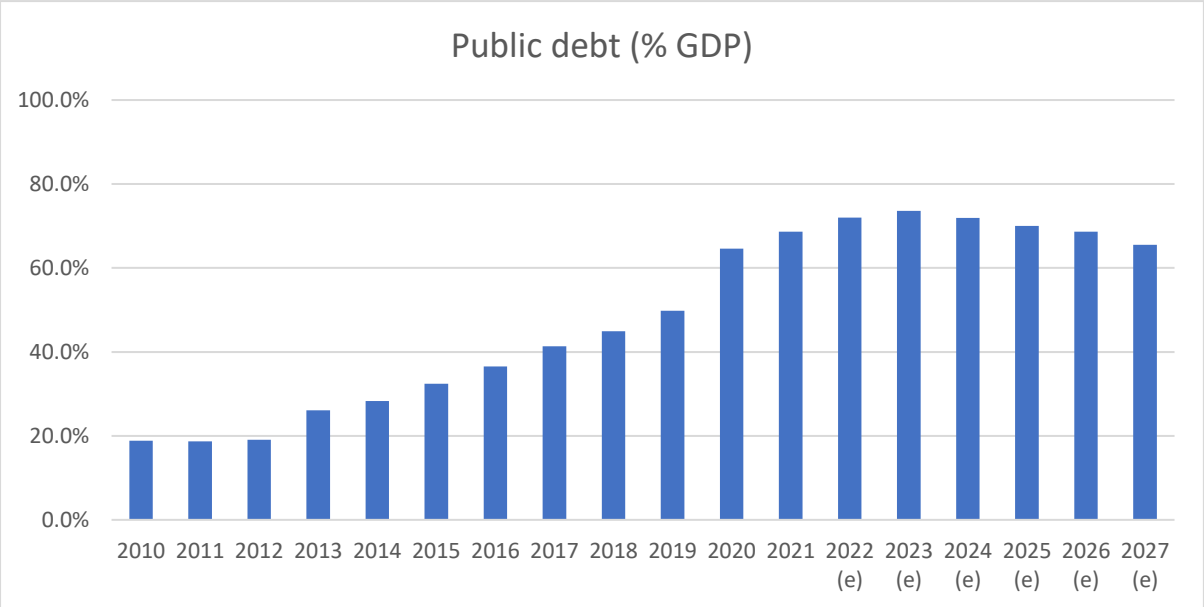
6.6 RWANDA MACRO-ECONOMIC INDICATORS



* (e) stands for expected



* (e) stands for expected



* (e) stands for expected

6.7 PAPERLESS E-TRACKER PROCESS SIMULATION

Mean cost of a paperless e-Tracker in USD per HC (95% CI)

		Activities					
		Child registration	Defaulter identification	Organizing outreach sessions	Identifying performance gaps	Report generation	**Total**
Inputs	Personnel	69.5 (62, 77)	4.6 (3.3, 5.9)	76.7 (48.1, 105.3)	37.8 (29.3, 46.4)	17.1 (13.6, 20.6)	**205.7 (174.7, 236.7)**
	Consumables + services	1.6 (0.8, 2.4)	0.1 (0, 0.1)	1.1 (0.5, 1.6)	0.4 (0.2, 0.5)	0.3 (0.2, 0.3)	**3.4 (2.4, 4.4)**
	Durable goods	3.1 (1.8, 4.4)	0.1 (0, 0.1)	3.2 (1.7, 4.6)	0.9 (0.6, 1.1)	0.4 (0.3, 0.5)	**7.7 (5.7, 9.6)**
	Total direct costs (a)	74.3 (66.6, 81.9)	4.7 (3.5, 6)	80.9 (52.3, 109.6)	39.1 (30.5, 47.6)	17.8 (14.3, 21.3)	**216.8 (185.7, 247.9)**
	Indirect costs (b)	11.8 (6.1, 17.4)	0.4 (0.2, 0.6)	5.7 (3.4, 7.9)	3.9 (2.7, 5.1)	2.1 (1.4, 2.7)	**23.8 (17.5, 30)**
	Total costs (a) + (b)	**86 (76.5, 95.5)**	**5.1 (3.8, 6.4)**	**86.6 (57.8, 115.3)**	**43 (34.3, 51.6)**	**19.8 (16.3, 23.4)**	240.5 (208.8, 272.3)

VII. RESOURCES

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