IDEA

IMMUNIZATION DATA:
EVIDENCE FOR ACTION

A Realist Review of What Works to Improve Data Use for Immunization

Evidence from low- and middle-income countries

Pan American Health Organization

World Health Organization
REGIONAL OFFICE FOR THE Americas

PATH

Immunization Data: Evidence for Action. Realist Review of What Works to Improve Data Use for Immunization, Evidence from Low- and Middle-Income Countries

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Contents

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For more information on the report, please contact digitalhealth@path.org

Abbreviations

AFIX	Assessment, Feedback, Incentives, and eXchange
AMRS	AMPATH Medical Record System (Kenya)
BID	Better Immunization Data
BLN	BID Learning Network
BRICKS	Building Routine Immunization Capacity, Knowledge, and Skills
CABI	Centre for Agriculture and Biosciences International
CDC	United States Centers for Disease Control and Prevention
CDSS	computerized decision support system
CONAPO	Consejo Nacional de Población (Mexico)
CONSORT-SPI	Consolidated Standards of Reporting Trials Statement for Social and Psychological Interventions
DDM	Data for Decision-Making
DEPIC	data entry via phone image capture
DESIRE	Decision Support and Integrated Record-keeping (Kenya)
DHIS	District Health Information Software
DIT	data improvement team
DPAT	district product availability team
DPT	diphtheria-pertussis-tetanus containing vaccine. DPP1 is the first dose, DPT3 the third
DQA	data quality audit
DQIP	data quality improvement plan
DQR	data quality review
DQS	data quality self-assessment
EHR	electronic health record
EIR	electronic immunization registry
EMR	electronic medical record
EPI	Expanded Program on Immunization
eRegistries	electronic registries
EVM	Effective Vaccine Management
GRADE	grading of recommendations assessment, development, and evaluation
HBR	home-based record
HCW	health care worker
HIS	health information system
HMIS	health management information system
IDEA	Immunization Data: Evidence for Action
IDQi	Improving Data Quality for Immunizations
IIS	immunization information system
IISA	Immunization Information System Assessment
IMPACT	Information Mobilized for Performance Analysis and Continuous Transformation
ISDS	immunization and surveillance data specialist
JSI	John Snow, Inc.
KBS	knowledge-based system
LGA	local government area (Nigeria)
LMIC	low- and middle-income country
LMIS	logistics management information system
M&E	monitoring and evaluation
MCH	maternal and child health
mHealth	mobile health
MMAT	Mixed Methods Appraisal Tool
ODK	Open Data Kit
PAHO	Pan American Health Organization
PDSA	Plan-Do-Study-Act
Penta	pentavalent vaccine, usually for diphtheria, pertussis, tetanus, Haemophilus influenzae type B, and hepatitis B. Penta3 is the third dose.
PEPFAR	The United States President's Emergency Plan for AIDS Relief
PRISM	Performance of Routine Information System Management
PSI	Population Services International
QIT	quality improvement team
QRM	quarterly review meeting
RAPID	Rapid Appraisal of Program Implementation in District
RCT	randomized control trial
RED	Reaching Every District
RED-QI	Reaching Every District Using Quality Improvement Methods
RHIS	routine health information system
SAGE	Strategic Advisory Group of Experts on Immunization of the World Health Organization
SIAs	supplementary immunization activities
SNNI	Sistema Nominal Nacional de Inmunización (Uruguay)
Swiss TPH	Swiss Tropical and Public Health Institute
TImR	Tanzania Immunization Registry
TOC	Theory of Change
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VALUE	Vaccine and Logistics Evaluator
VBA	Visual Basic for Applications
VIMS	vaccine information management system
vLMIS	vaccine logistics management information system
WHO	World Health Organization
wVSSM	Web-based Vaccination Supplies Stock Management (Tunisia)
ZEIR	Zambia Electronic Immunization Register

Executive Summary

Data quality is a cornerstone of well-functioning health systems. Sound and reliable information enables better resource allocation, more targeted care, policy development, and implementation, and more effective health education and training. Calls to improve the quality and use of data feature prominently in several national plans of action and in global strategies like the Global Vaccine Action Plan.

The Global Fund to Fight AIDS, Tuberculosis and Malaria; US President's Emergency Plan for AIDS Relief (PEPFAR); and Gavi, the Vaccine Alliance; among others have also identified data quality and use as strategic focus areas. Despite the significant resources invested in developing national health information systems and the volume of health data available, the actual use of data in decision-making remains a challenge. As decision-makers and other stakeholders consider how to best allocate finite resources with the goal of improving immunization coverage and equity, there is a need to better understand what works to improve data use in decision-making and to identify effective and ineffective approaches, as well as any knowledge gaps.

The goal of the Immunization Data: Evidence for Action (IDEA) project is to identify, review, synthesize, and disseminate what works to improve the use of immunization data and why it works. In partnership with the Pan American Health Organization, the Health Systems Analytics team at PATH conducted a "realist" systematic review of existing research evidence to answer two principal research questions:

01. *What are the most effective interventions to improve the use of data for immunization program and policy decision-making?*
02. *Why and how do these interventions produce the outcomes that they do?*

The realist review approach, unlike a traditional systematic review, does not exclude evidence based on study design or quality. By considering information and evidence from a broader range of sources, realist reviews are well suited for studying complex interventions[1]. We developed a Theory of Change (TOC) based on our review of existing health information and data use frameworks and logic models, as well as systematic reviews on topics related to health information system strengthening and evidence-informed decision-making to guide the review (see Figure 1). The TOC framed our hypothesis of the theorized mechanisms and contextual factors that work together to help decision-makers translate immunization data into information, and ultimately action. We identified intermediate outcomes as the necessary precursors to data use, including data quality and availability, analysis, synthesis, and discussion of data. The ultimate outcomes of interest in this review are the data use actions that are based on the World Health Organization's Global Framework to Strengthen Immunization and Surveillance Data for Decision-making[2]. The TOC guided our analysis of how interventions led to improved data use; it also evolved iteratively over the course of the review as we gathered new evidence.

We reviewed 426 documents from published and grey literature and identified ten categories of data use interventions (Box A). We shared preliminary findings with

BOX A.

Intervention categories identified

01. Electronic immunization registries
02. Logistics management information systems
03. Health management information systems
04. Decision support systems
05. Data quality assessments
06. Data review meetings
07. Peer learning networks
08. Supportive supervision, mentorship, and on-the-job training
09. Training
10. Multicomponent interventions

immunization stakeholders during a workshop in May 2018; based on the feedback we also identified areas in which experience and evidence from other health sectors were applicable and expanded our search, adding another 123 documents to the body of literature reviewed.

Because of the nascence of the field, much of the immunization sector's knowledge on data quality and use interventions has not been rigorously evaluated or published. In addition to including studies and evaluations that applied scientific research methods or evaluation design, we also considered literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as *promising strategies*, which we define as strategies that have not yet proven successful, but have potential for future success. We assessed the quality of studies using the Mixed Methods Appraisal Tool (MMAT), a checklist designed by Pace et al. for systematic literature reviews for appraising the quality of quantitative, qualitative, and mixed methods studies[23]. We coded the included records and synthesized the evidence according to domains in the TOC. We rated the certainty of evidence after considering the study design and study quality, the number of studies and their agreement, and the context dependence of the evidence. The results were summarized in an evidence gap map matrix (see Figure 4) and in a synthesis table (Annex 5).

Despite the growing recognition that quality, timely, and accessible data are essential to every country's ability to deliver vaccines effectively to its population, few data use interventions have been rigorously studied or evaluated. There is limited evidence of how data can be effectively used to support data-driven action and decision-making. We found more evidence on the intermediate outcomes of data use interventions on data quality, availability, analysis, synthesis, interpretation, and review. The information and evidence we collected permitted us to develop stronger evidence-informed theories about what works to improve the quality and use of data, for whom, and under what circumstances. We reached the following conclusions.

Multicomponent interventions were the most prevalent and often more effective.

Nearly all the interventions we reviewed leveraged more than one data use strategy. The more comprehensive the set of strategies, and the more they addressed barriers at various stages of data use (e.g., data availability, data quality, and data use skills) and touched upon multiple mechanisms driving data use behaviors and actions, the more likely they were to achieve results. By addressing different facilitators of data use, the multicomponent interventions employed interconnected, mutually reinforcing strategies that appeared to have a greater collective effect than a single intervention. Notably, successful intervention packages included strategies that addressed:

- *skill sets and capacity of data users;*
- *gaps in feedback mechanisms;*
- *data use within existing systems, workflows, and workloads;*
- *user-centered design principles;*
- *interaction between data producers and data users, and structured problem-solving;*
- *data use culture and motivation to use data; and*
- *long-term commitment of financial and human resources.*

Interventions that took a health systems approach to institutionalizing data use were more likely to be successful and sustainable.

Interventions were more successful over the long term when they focused on systematizing data use at all levels of the health system and as part of decision-making processes. This occurred by routinely conducting data review meetings at all levels, making national guidelines and protocols on data use available to frontline staff, creating dedicated staff positions at all levels of the health system to oversee data management and use activities, and incorporating training in data use in national in-service and pre-service training curricula.

We found limited or mixed evidence on the effectiveness of health management information systems, including electronic immunization registries, on data use, but they remain promising interventions for improving data use when accompanied by complementary activities.

Transitioning from paper to computerized health management information systems across all levels of the health system seems to have made higher-quality data more available to decision-makers and may have contributed to better data use at the district level when complemented by activities that reinforce data use. The effect on data use at the facility level, however, remains less conclusive. In many countries, the significant operational challenges, extended time required for a return on investment, and absence of complementary data use activities have contributed to the mixed results presented in the research literature. Full transition to computerized systems may be more successful when they are incrementally phased in only once a reliable foundation of data use infrastructure, human resource capacity, and skill base has been established.

Moderate- to high-certainty evidence exists to suggest that computerized logistics management information systems (LMISs) have made higher-quality data more available to decision-makers to improve management of supply chains.

Computerized LMISs that were implemented at district levels and higher seem to have had more success than similar efforts to digitize routine service-delivery data at a facility level. There were often fewer operational challenges when they were implemented at district and higher levels, where Internet connectivity, electricity, and information technology support were more reliable. In addition, we hypothesize that data users may have greater knowledge of how to use supply chain data to take action directly compared with routine service delivery data, which are more commonly collected for reporting by frontline health workers who feel little connection to or agency over the data. Although implementing computerized LMISs as a single intervention improves data quality and use, there were even greater gains in data use and supply chain performance when LMISs was complemented by other data use activities.

There is a dynamic, cyclical relationship between data quality and data use.

Although poor data quality was an important barrier to data use, we found limited evidence that single-component interventions to improve data quality led to improvements in data use. Conversely, we found stronger evidence that data quality improved through the use of data. As decision-makers started using their data more and identifying inconsistencies with data quality, they took more corrective actions to improve data quality.

This review was limited by several factors. Notably, our findings relied on what was reported in the literature, which sometimes lacked a thorough description of the factors that contributed to an intervention's success or failure and may have caused us to miss important contextual considerations. Our focus on routine immunization data helped to manage the scope of the review but risks further siloing immunization programs. We expanded the review to include literature from other health sectors (HIV and maternal and child health, specifically); however, these efforts were not as comprehensive and likely failed to capture all the available evidence on the topic. We also found limited studies and evaluations that included cost-effectiveness analyses and therefore were unable to examine the cost-effectiveness of interventions included in this review. Many promising reviews of data use more broadly are under way. The entire body of work should be considered together to inform strategic and cross-programmatic investments in interventions to improve data use.

This review targets various audiences and intends to provide relevant information and evidence on the most effective practices so that policy and program decision-makers, as well as funders and implementers, may choose and implement approaches with the highest impact on improving the use of data to expand vaccine coverage and equity, and ultimately reduce, or even eliminate, vaccine-preventable diseases. We anticipate that these findings will also be of interest to researchers and evaluators to prioritize gaps in the existing knowledge. Our recommendations are segmented by audience group to encourage action.

CHECKLIST OF ACTIONS TO SUPPORT DATA USE

Theory of Change Data Use Actions	How to improve data use at the **HEALTH FACILITY LEVEL?**	How to improve data use at the **HEALTH DISTRICT LEVEL?**	How to improve data use at the **NATIONAL LEVEL?**
Implementers (and national level actors)	***Cross-cutting actions*** ☐ The data use intervention's design is based on an assessment of current data quality and use challenges and their root causes, including assessing the mechanisms, behavioral drivers, and contextual factors that may act as barriers or facilitators to specific data use actions.[1] ☐ The intervention specifies the data use actions (from the TOC) it aims to support. ☐ The data use actions are actionable by the intervention's intended users and are of significance to the program itself. ☐ All parties are clear which data use action the intervention will reinforce and strengthen. ☐ The intervention has a clear theory for how it will work. ☐ It is clear how the intervention will use multiple mechanisms and behavioral drivers to achieve its intended data use actions. ☐ The intervention clearly targets specific bottlenecks known to constrain data use in the intervention setting. ☐ The intervention aligns with national guidelines on processes and procedures for data collection, analysis, and use by health care workers. ☐ During the design and conception phase of the intervention, an M&E strategy was developed to measure whether data are being used as intended and as defined by the data use actions it is intended to address.		
	☐ The intervention establishes or strengthens feedback loops between data collectors (e.g., health care workers in a facility) and decision-makers at higher levels. ☐ Implementers support harmonization across projects and alignment with local policies and guidelines on health care workers' roles and responsibilities in relation to data analysis and use.	☐ District level health workers have the needed tools and training to deliver effective supportive supervision, including ways to provide proper feedback to facility health care workers and ways to support the intended data use actions. ☐ District level staff have clarity on their roles and responsibilities in relation to data analysis and use.	☐ Data use strategies focus efforts on increasing use of evidence in policy decision-making. ☐ Data Improvement Plans (DIPs) include actionable recommendations. ☐ DIPs are monitored to ensure facilities and districts take action on the recommendations.

1 *Refer to the IDEA TOC which outlines the potential mechanisms (demand, access/availability, quality, skills, structure & process, communication), behavioral drivers (capability, motivation, opportunity), and contextual factors..*

Theory of Change Data Use Actions	How to improve data use at the **HEALTH FACILITY LEVEL?**	How to improve data use at the **HEALTH DISTRICT LEVEL?**	How to improve data use at the **NATIONAL LEVEL?**
Policymakers and Multilaterals	***Cross-cutting actions*** ☐ The intervention aligns with national guidelines on processes and procedures for data collection, analysis, and use by health care workers.		
	☐ Health facilities are equipped with sufficient human resources—including dedicated staff where feasible—to perform tasks associated with data collection, management, and analysis. ☐ Front-line health worker training curricula focuses on training staff to use routine service delivery data for decision-making and problem solving and shifts perceptions away from data serving the sole purpose of reporting up through the system.	☐ Tools that organize data into meaningful information are implemented with complementary strategies for discussing data analyses and determining actions to be taken. ☐ Strategies are implemented to improve the quality of supportive supervision to focus on improving data use skills and practices.	☐ National guidelines contain well-defined processes and procedures for data collection, analysis, and use by health care workers across all levels of the health system. ☐ National guidelines include clear guidance on various types of decision-making informed by data, as well as guidelines for how health workers are expected to use data in various scenarios.

Theory of Change Data Use Actions	How to improve data use at the **HEALTH FACILITY LEVEL?**	How to improve data use at the **HEALTH DISTRICT LEVEL?**	How to improve data use at the **NATIONAL LEVEL?**
Funders	***Cross-cutting actions*** ☐ Investments address documented bottlenecks to data use and use multi-component and theory-driven approaches to resolving those challenges. ☐ Investments are funded based on what is known to work, or has high likelihood of success in a given context. ☐ Investments are aligned with national policies and strategies for data use or ehealth and with other investments. ☐ Investments are accompanied with a robust M&E plan that will contribute to filling existing evidence gaps, including cost-effectiveness.		
	☐ Data quality investments have been equally balanced with strategies to improve data use.	☐ Investments include components of quality improvement methodologies to provide structured approaches to interpret data, prioritize problems, and find solutions.	☐ Investments are geared towards data use strategies end efforts to increase use of evidence in policy decision-making.

Background

Within global health, it is widely acknowledged that a cornerstone of well-functioning health systems is data of high enough quality to guide decision-making. In recent years, investment in health information systems (HISs) and interventions to improve the quality and use of health data, including in the immunization field, have increased.

Calls to improve the quality and use of data feature prominently in several national plans of action and in global strategies like the Global Vaccine Action Plan. The Global Fund to Fight AIDS, Tuberculosis and Malaria; US President's Emergency Plan for AIDS Relief (PEPFAR); and Gavi, the Vaccine Alliance; among others have identified data quality and use as strategic focus areas. The World Health Organization (WHO) Strategic Advisory Group of Experts (SAGE) on Immunization established the Working Group on Quality and Use of Global Immunization and Surveillance Data in August 2017 to review the current state of data collection, use, and impact and to propose recommendations to improve the quality and use of data from immunization programs[3]. Twenty years ago, SAGE made a recommendation to improve immunization data use and quality[4]. The Pan American Health Organization (PAHO) and numerous other regional offices of WHO have issued recommendations for further strengthening the analysis and use of data at all levels of immunization programs[5].

Data-informed decision-making is a process in which people convert data into usable information through processing, analysis, synthesis, interpretation, and review and discussion; they then use this information to decide on a course of action. In immunization, this could mean using data and information on vaccine supply to prevent stockouts or using individual-level patient data to decide which patients or communities to target for vaccine outreach. Despite the significant resources invested in developing national HISs and improving the timeliness, quality, and presentation of available information, the literature suggests that these efforts have not guaranteed the use of data for decision-making, especially at the level of health care delivery[6]. Furthermore, collecting high-quality data (see page 15 for a definition) does not guarantee that the data will be used[7]. The extent to which decision-makers use data in the decision-making process can depend on various behavioral and organizational factors. Decisions are often informed by multiple sources of information, of which only one source is data[8]. Investments in data use interventions assume that decisions informed by high-quality data are more likely to be effective and thus contribute to improved service delivery and overall program performance.

Although the barriers to data use in health decision-making have been studied extensively[6,9–13], to date, there is no formal review of evidence from existing efforts to strengthen immunization data use. As decision-makers and other stakeholders consider how to best allocate finite resources with the goal of improving immunization coverage and equity, there is a need to take stock of the existing evidence and identify effective and ineffective approaches, as well as any knowledge gaps.

The goal of the Immunization Data: Evidence for Action (IDEA) project is to identify, review, synthesize, and disseminate *what works* to improve use of immunization data and *why* it works. To this end, through this review we seek to:

- *articulate a Theory of Change (TOC) that illustrates key mechanisms and outcomes related to strengthening data use;*
- *synthesize existing evidence (published and unpublished) related to strengthening the use of immunization data; and*
- *provide information and evidence so that various audiences and stakeholders may choose and implement the approaches with the highest impact on improving the use of routine immunization data.*

This review was a collaborative effort between PATH and PAHO. The review team was composed of health systems researchers with expertise in immunization, measurement and evaluation, and evidence-informed policymaking from PATH's Health Systems Analytics team, as well as immunization and data use experts at PAHO.

Methods

The review was guided by the IDEA steering committee, which was composed of ten global and regional senior leaders in the areas of immunization, data quality, and use from PAHO, WHO headquarters, Bill & Melinda Gates Foundation, PATH, US Centers for Disease Control and Prevention (CDC), United Nations Children's Fund (UNICEF), Gavi, and the Swiss Tropical and Public Health Institute (Swiss TPH), as well as country representatives from both the BID Learning Network (BLN) and Improving Data Quality for Immunizations (IDQi) project core countries. The committee helped guide the direction of the work to ensure its relevance for multiple agencies, countries, and decision-making bodies. We validated the review protocol with the steering committee to ensure the rigor and policy relevance of the proposed methods and outcomes. A summarized version of the protocol is described here.

The review sought to answer two principal research questions:

01. *What are the most effective interventions to improve the use of data for immunization program and policy decision-making?*
02. *Why do these interventions produce the outcomes that they do?*

We focused on routine immunization data, which we defined as data that are continuously collected by HISs and used by the immunization program for service delivery; this excluded surveillance, financial, and human resources data. We adopted the definition of data-informed decision-making described by Nutley and Reynolds[14] as a process where people turn raw data into usable information through the analysis, synthesis, interpretation, and review of data and use this resulting information to decide on a course of action. Because data can be used for different purposes by different types of data users, there is a lack of consensus on what actions constitute data use[15]. In immunization programs, there are various actions that an immunization program could take for which data are useful. These include, but are not limited to, policy decisions around financing and the addition of new vaccines; system actions around supply chain and human resources management; actions for individual children, such as identifying and following up on defaulters; and actions for performance management, such as monitoring health facility performance and targeting supervision activities. At the outset of the review, we had limited information on how the literature on effectiveness would quantify and measure data use, so we adopted the specific immunization data use actions suggested by the WHO Global Framework to Strengthen Immunization and Surveillance Data for Decision-making in our TOC[2]. Because we considered health care professionals to be the principal users of routine health data, we did not examine how the target recipients of health care services, such as patients and communities, use routine health data.

Greater consensus exists around a common definition of data quality. WHO's data quality review (DQR) framework defines data quality according to four dimensions: completeness and timeliness, internal consistency, external consistency, and external comparisons of population data[16]. However, we

also acknowledge that, increasingly, data quality is examined through the lens of "fit-for-use" or "fit-for-purpose" concepts, which emphasize the data user's expectations and whether the data are of adequate quality for the specific use cases for the data[17].

To answer our research questions, we conducted a realist review of the evidence and learnings on what works to improve data use. Realist reviews are typically driven by a theoretical understanding of how the context and causal mechanisms interact to produce certain outcomes[1]. The approach is methodologically flexible and well suited for studying complex interventions[18]. By providing explanations for why interventions may or may not work and under what circumstances, realist reviews can lead to more pragmatic and actionable conclusions. We chose a realist review over a more traditional systematic review because it matched well with the objectives of this review; specifically, it allowed for:

- *more purposive and theoretically driven identification and assessment of the evidence;*
- *inclusion of multiple types of information and evidence;*
- *an iterative process;*
- *an emphasis on explaining why (or why not) an intervention works and in what ways; and*
- *informed choices about further use or research*[18].

This approach made it possible to include various types of information and evidence, such as experimental and nonexperimental study designs, grey literature, project evaluations, and reports. It also allowed us to take an iterative approach. We developed a TOC to guide our analysis and hypothesis testing and modified it based on our review of the literature. We also had the flexibility to orient our data collection iteratively and purposively to fill gaps. For example, after a preliminary review and synthesis of the evidence on immunization data use, and validation with our steering committee and immunization stakeholders, we expanded our search to literature outside of immunization for certain intervention categories. We applied our findings from the review to develop stronger evidence-based theories on what works to improve the quality and use of data, for whom, and under what conditions, which can inform the development, implementation, and evaluation of subsequent research.

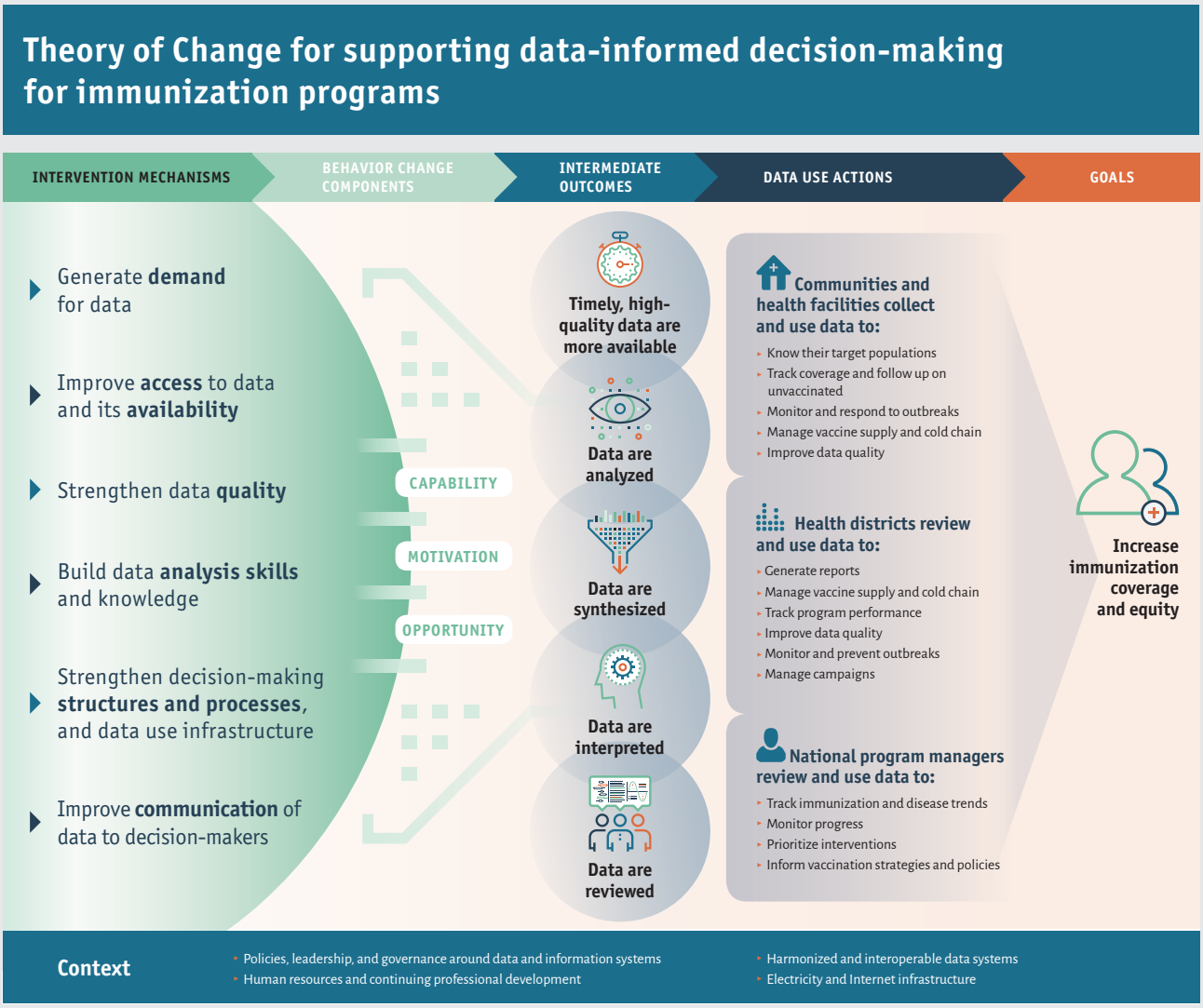
The review included eight steps:

01. *development of a TOC based on our review of systematic reviews and related literature;*
02. *systematic review of effectiveness (peer-reviewed and grey literature);*
03. *review of promising strategies to inform possible effectiveness and why and how the interventions work;*
04. *extraction and coding of text data based on the TOC;*
05. *quality assessment of studies and evaluation of effectiveness;*
06. *preliminary data synthesis and validation of findings with the IDEA steering committee and other immunization stakeholders;*
07. *second round of data collection and review of literature on data use interventions in other health sectors; and*
08. *final data synthesis and evidence gap map development.*

We developed our TOC (Figure 1) based on our review of existing health information and data use frameworks and logic models, as well as systematic reviews on topics related to HIS strengthening and evidence-informed decision-making. The TOC **mechanisms** have been identified as facilitators to data use; we hypothesize that, in order to be effective, any intervention must incorporate one or more of these mechanisms[14,19,20]. As data use is ultimately a human behavior, we included **behavioral** drivers: capability, motivation, and opportunity[21]. These lead to **intermediate outcomes**, including analysis, synthesis, and discussion of data to turn them into information. Following these are the **outcomes** of interest in this review: **data use actions** based on the WHO Global Framework to Strengthen Immunization and Surveillance Data for Decision-making and that specify where data are used, by whom, and for what purpose[2]. When information is used to make a decision and change a practice, it should lead to improved performance of the immunization system and better population health (**goals**). Finally, the entire process greatly depends on local **context**[22]. Annex 2 defines each mechanism.

We searched PubMed, POPLINE, CABI (Centre for Agriculture and Biosciences International) Global Health, and African Journals Online for published evidence. Due to the broad definition and wide variation in how data use is conceptualized, our search terms, described in Annex 1, were designed for

FIGURE 1.



greater precision than sensitivity. We heavily snowballed relevant references and purposively filled gaps with additional searches on specific intervention categories. Using the same search terms, we obtained grey literature by searching vaccine and digital health conference, implementer, and technical agency websites, such as TechNet-21, the Global Digital Health Forum, BLN webinars, and others. We also contacted key stakeholders and members of our steering committee to identify projects and interventions.

We included studies and evaluations from published or grey literature that applied scientific research methods or evaluation design (see Table 1 for complete inclusion and exclusion criteria); we referred to these records as evidence. We assessed the quality of records from the immunization literature that qualified as evidence using the MMAT, a checklist designed by Pace et al. for systematic literature reviews for appraising the quality of quantitative, qualitative, and mixed methods studies[23]. We also included literature (grey or published) that did not qualify as a study or evaluation if it described an intervention that was theoretically plausible to improve data use, as judged by our TOC. We referred to these records as *promising strategies*, which we define as strategies that have not yet proven successful, but have potential for future success.

TABLE 1.

Inclusion and exclusion criteria for research evidence

Inclusion criteria	Exclusion criteria
Focus on routine health system data (HIS, EMR, EHR, immunization registers [paper and electronic], immunization cards, supply chain data/LMIS, etc.)	Focus on the use of research evidence, surveillance data, survey data, or other nonroutine sources and types of data
Focus on immunization data	Focus on other health sector data (MNCHN, reproductive health, HIV/AIDS, etc.)*
Studies, evaluations, reports, and/or descriptions of interventions to improve routine data use (including data quality as an intervention)	Not specific to a particular intervention (e.g., studies describing the barriers or facilitators of data use)
Outcome examined is use of routine data for immunization decision-making	Outcome examined is data quality alone or something other than data use
Intended user of data is a health worker, decision-maker, or manager	Intended user of data is a recipient of health care services (e.g., patients or communities)

** We later broadened the review to include other health sector data for the following intervention categories: data quality assessments, home-based records, decision support systems, data review meetings, peer learning networks, supportive supervision, training, and multicomponent interventions.*

EHR = electronic health record; EMR = electronic medical record; HIS = health information system; LMIS = logistics management information system; MNCHN = maternal, newborn, child health, and nutrition

We did not restrict the literature gathered by date of publication, but much of the literature collected had been published within the last 15 years. We primarily focused on interventions implemented in low- and middle-income countries (LMICs); however, in a limited number of cases, we considered relevant publications from high-income countries.

Records were included after full-text screening. Three members of the PATH and PAHO review team were involved in reading the full-text records and coding text segments according to a coding tree based on the TOC. Approximately 20% of the records were cross-reviewed and coded to ensure consistent coding among reviewers. We grouped the interventions into nine primary intervention categories. Although not all interventions were digital, we aligned most of the intervention categories with the WHO Classification of Digital Health Interventions[24].

We examined the characteristics of the intervention or intervention package, including the intervention designs and strategies, the types of health care professionals and levels of the health system targeted, implementation settings, and outcomes. We examined how the interventions functioned and what mechanisms made them successful. We also sought to understand the reasons why interventions did not show evidence of effectiveness. The PATH and PAHO technical teams discussed coded text segments at a synthesis workshop with the objective of identifying common themes and patterns. We also organized each document in a Microsoft Excel workbook to track each document or intervention's metadata. These data were then visualized using Tableau in an evidence gap map (see Figure 4).

We presented a synthesis of our preliminary findings during a workshop in Washington, DC, in May 2018, with members of the IDEA steering committee and other immunization stakeholders (see agenda and list of participants in Annex 4). During the workshop, we identified gaps in the literature. For intervention categories that had limited evidence and were applicable outside of immunization, we decided to expand the review to include evidence from other health sectors. The expanded evidence was gathered for the following intervention categories: data quality assessments, home-based records (HBRs), decision support systems, data review meetings, peer learning networks, supportive supervision, training, and multicomponent interventions.

Rating the Certainty of Evidence

Unlike traditional systematic reviews of effects, realist reviews generally do not exclude evidence based on study design or quality. We took the same approach but adapted various methods of quality appraisal to help the reader interpret the value of each evidentiary claim in this report. We adopted the grading of recommendations assessment, development, and evaluation (GRADE) terminology of "certainty of evidence," which indicates our certainty that the true effectiveness of the intervention lies in the range we are reporting[25]. We considered certainty to be a combination of internal validity of the included studies (e.g., study design and study quality), the number of studies and their agreement, and the context dependence of the evidence.

After the review team assigned MMAT scores to the records included as evidence, two members of the review team recorded the study and evaluation outcomes in the intervention synthesis table (Annex 5) and considered the four constructs described in Table 2 below to determine the level of certainty for each evidentiary claim. The certainty of evidence rating of high, moderate, low, or very low was ultimately a subjective estimation based on these four constructs.

TABLE 2.

How we assessed the certainty of evidence

Input to inform the certainty of evidence	Explanation
Study design	We considered experimental and quasi-experimental designs to improve the certainty of estimates of intervention effectiveness. We considered experimental designs to provide the highest certainty evidence. However, other methods may be more important for assessing certainty of claims on how and why the intervention works.
Quality	We used the MMAT to score the quality of the literature on routine immunization data use that qualified as evidence.
Number of studies	A greater number of studies with similar findings improved our certainty in those findings. Studies with conflicting findings weakened the certainty of evidence.
Context dependence	We considered evidentiary claims for highly context-dependent interventions to have lower certainty, or we specified the conditions under which the claims hold true. For example, for certain interventions composed of multiple strategies, it was not possible to fully disentangle the effects of individual strategies. In such cases, we recognized how other strategies may have influenced the overall effect of the intervention.

Findings

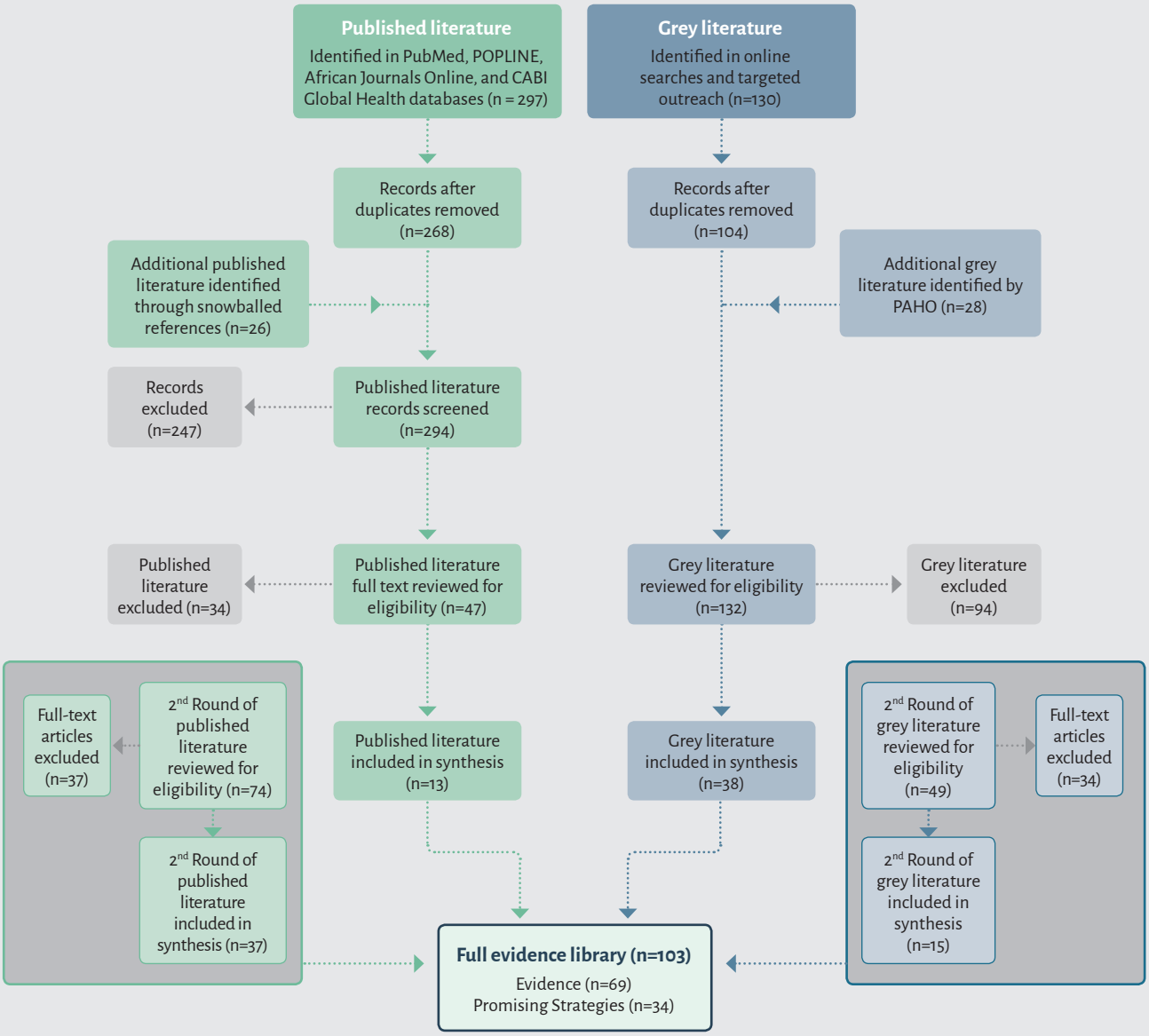
We conducted an initial round of data collection, review, and synthesis of the literature focused on immunization data quality and use between January and April 2018. We retrieved 294 unique documents from the published literature; upon title and abstract screening, we included 45 documents for full-text review. Our search of the grey literature resulted in 132 documents reviewed in full for eligibility.

After the first round of synthesis, we conducted a second round of data collection between June and August 2018, in which we expanded the review to consider literature on data quality and use from other health sectors. During the second round of data collection, 123 additional unique documents were retrieved, including 74 from the published literature and 49 from the grey literature. Ultimately, 103 articles were included in the review (Figure 2). We determined that 69 of the articles were research evidence, as they reported results from a study or evaluation, and 34 were promising strategies.

A detailed list of included records is provided in Annex 3. Africa was the most represented region in the review, and immunization registries were the most reported primary intervention type. Most documents described projects with multiple intervention components. Documents tended to report on multiple intermediate outcomes and data use actions (Figure 3).

FIGURE 2.

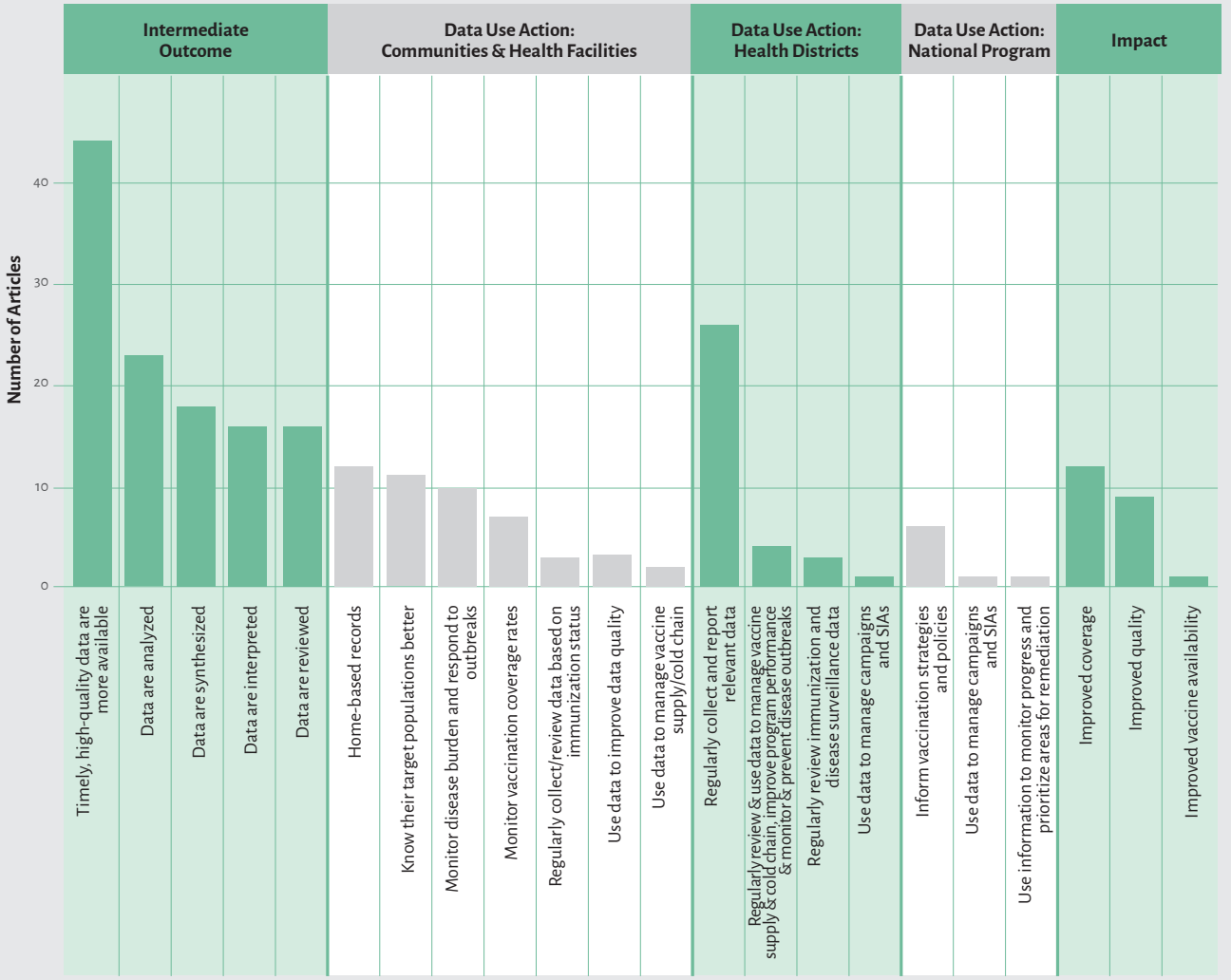
PRISMA flow diagram



**Grey boxes indicate new literature obtained after a second round of data collection, which included literature from immunization and other health sectors.*

FIGURE 3.

Intermediate outcomes and data use actions reported



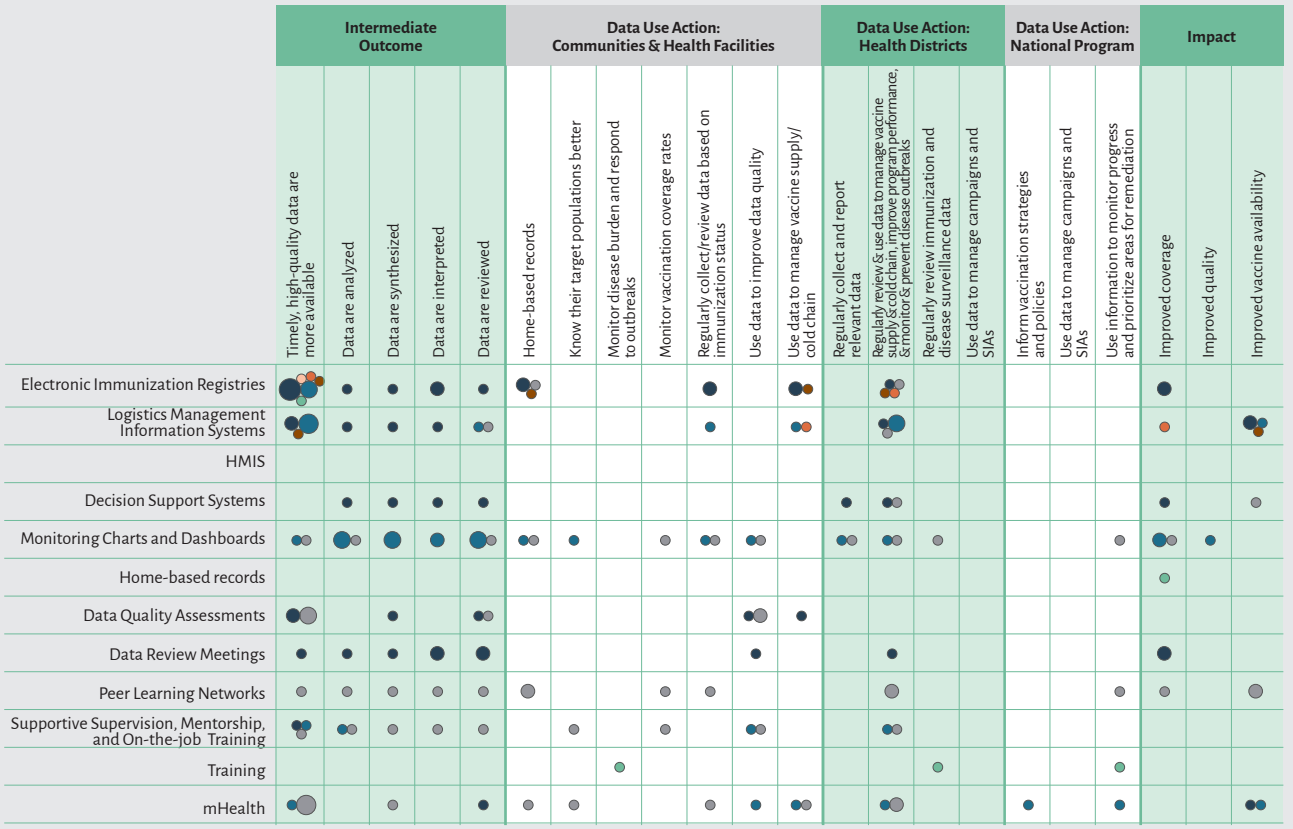
Evidence Gap Map

This matrix (Figure 4) visualizes all the pieces of evidence and promising strategies included in the review according to which primary intervention type, intermediate outcomes, data use actions, and impact indicators they pertain, and the quality of each piece of evidence as determined by the MMAT score. The gap map helps to visualize both the quality of evidence and the number of studies, which were two of the four inputs we assessed to determine the certainty of the evidentiary claims in the report.

The gap map illustrates greater coverage of evidence and promising strategies for intermediate outcomes and certain data use actions, but most cells in the matrix include only one or two single studies (or promising strategies). For example, the district-level action "regularly review and use data to manage vaccine supply and cold chain, improve program performance, and monitor and prevent disease outbreak" had greater coverage than other data use actions. Many gaps exist regarding national-level data use actions.

FIGURE 4.

Evidence Gap Map



Evidence presented in the gap map includes studies and evaluations of immunization data use interventions that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

Strong, Moderate, and Weak categories apply only to the study quality. Reviewers appraised each study using the Mixed Methods Appraisal Tool (MMAT) checklist, which translates into a percentage score. 'Strong'-quality studies scored 75-100%; 'Moderate'-quality studies scored 50-74%; 'Weak'-quality studies scored 0-49%. More information on the MMAT approach can be found in the Rating the Certainty of Evidence section.

To access the interactive gap map, please visit public.tableau.com/profile/path5412#!/vizhome/IDEAgapmap/FORPUBLICPUBLISH

The color of a circle indicates the strength and directionality of the evidence

- Strong quality evidence
- Moderate quality evidence
- Weak quality evidence
- Promising strategy
- Weak quality counterevidence
- Moderate quality counterevidence
- Strong quality counterevidence

The size of a circle indicates the amount of evidence available

- One piece of evidence reviewed
- Two pieces of evidence reviewed
- Three pieces of evidence reviewed

A blank square on the gap map indicates no evidence from immunization data use interventions was identified

1. Electronic Immunization Registries

HISs generally fall into one of two categories: those that handle data records of individuals and those that collect aggregated data; the latter are generally referred to as health management information systems (HMISs)[26]. Patient registries, electronic medical records (EMRs), and electronic health records (EHRs) fall into the first category. An immunization registry is the most basic and widely used tool for recording individual child immunization history. While most LMICs still use paper-based immunization registries, the proliferation of information and communication technologies, as well as Internet connectivity, has generated significant interest in transitioning to electronic systems.

Electronic immunization registries (EIRs) are computerized, confidential, population-based databases that contain data on vaccine doses administered[27]. WHO's classification of digital health interventions places EIRs within the system category, "identification registries and directories," because they provide multiple functionalities, or digital health interventions, such as data storage and aggregation and routine collection and management of health indicator data[24].

EIRs are capable of overcoming barriers to data use related to access and availability and data quality in our TOC that are common to paper-based registries. Regarding access and availability, EIRs have the potential to make it easier for health workers to extract patient data compared with paper-based registries. Countries with paper-based systems tend to rely on aggregated facility- or district-level data on vaccine doses given to monitor immunization coverage, whereas EIRs can facilitate individual-level monitoring and follow-up[28]. Regarding data quality, EIRs are intended to address challenges in paper-based registries related to tracking children who receive vaccinations at multiple facilities and absent, incomplete, or unreadable data recording or conflicting data across multiple paper records. This requires the ability to generate and assign unique patient IDs across facilities. EIRs can also address behavioral mechanisms such as opportunity-related barriers to data use. For example, by streamlining workflows, EIRs can eliminate the need for numerous paper records (e.g., tally sheets, docket, vaccination/health card, and paper registry), therefore allowing health workers more time and opportunity to use data to improve service delivery.

We included studies of EIR interventions and promising strategies. Most projects packaged EIRs as part of multicomponent interventions. The Better Immunization Data (BID) Initiative is a set of multicomponent interventions that includes an EIR, called the Tanzania Immunization Registry (TImR) in Tanzania and the Zambia Electronic Immunization Register (ZEIR) in Zambia, along with data use strategies, such as WhatsApp peer learning and networking platforms, on-site mentorship, and targeted supportive supervision and training. The EIR also includes a stock management tool used to support the management of vaccine inventory. In Zambia, a module for child immunization records was added to SmartCare, an EMR system in which individual patient records are stored on smart cards issued to patients. In Vietnam, ImmReg is a web-based application that can be accessed via a computer or mobile phone. In each of these projects, health workers register pregnant women and newborns directly into the EIR. In other projects, such as Guatemala's SIGSA Web, Uruguay's National Immunization Program Register (Sistema Nominal Nacional de Inmunización, or SNNI), and Kenya's AMPATH Medical Records System (AMRS), data are captured in paper registries at the facility level and then entered in the EIR by district-level data entry personnel. EIR functionalities can include options to automatically generate lists of children due for vaccinations and send vaccination reminders via text message to caretakers. In some systems, health workers can directly schedule appointments or order new vaccine stock. EIRs also automatically produce reports for district and provincial health managers, who use them to monitor vaccine stocks and plan immunization coverage.

Most of the literature we found focused on EIRs instead of paper-based registries; this was likely due to the temporal bias favoring our outcomes of interest and the establishment of EIRs. We examined the extent to which this literature assessed the effectiveness of EIRs at improving data use. We highlighted the lessons learned and challenges encountered by countries transitioning from paper-based to electronic systems. Most literature on EIRs came from countries in Latin America, where implementation of EIRs has been progressing rapidly and

for a longer period of time. We found some literature from Africa and Asia and evidence from a systematic review of EIR implementation in high-income countries.

We found moderate-certainty evidence that EIRs improved data use at the district level and very low-certainty evidence of their effect on data use at the health-facility level.

We identified one nonexperimental evaluation of EIRs on data use outcomes[29] and one evaluation of the impact of an EIR on vaccine coverage[30]. In Tanzania, low-certainty evidence was available from an external nonexperimental mixed-methods evaluation of the multicomponent BID Initiative conducted in 2017. This was supplemented with project monitoring and evaluation (M&E) data, which measured data use outcome indicators, although through methods with a high risk of bias. The external evaluation in Tanzania found improvements in health workers' confidence and ability to produce and interpret reports at midline compared with baseline; however, data use capacity and data-informed action were similar to baseline[29]. The stock management component of the system was not being used consistently as a result of the prioritization of new vaccine information management system (VIMS) tools for stock management and the need for more training of nurses in task areas such as stock adjustments. The evaluation noted that it may have been too early to measure significant changes in data use behavior owing to multiple delays in implementation, such as delays associated with developing customized, scalable EIR software in the context of Tanzania's evolving information system architecture. In Zambia, the external BID evaluation is ongoing. Project M&E data from BID in Tanzania and Zambia found that the proportion of health workers reporting data quality barriers to data use dropped by more than half from baseline to midline[31,32]. Health workers' skills and knowledge related to data use also increased. At project midline, more health workers at both facility and district levels self-reported the ability to identify defaulters, areas with low coverage, and levels of vaccine stock. Among the same facility health workers, 89–99% reported taking action based on their data at midline compared with 61–79% at baseline.

A pre-post evaluation of the ImmReg EIR in Vietnam conducted in 2015 found that ImmReg had a significant impact on improving full immunization coverage of children under 1 year old, from 75.4% (pre-intervention) to 81.7% (post-intervention) to 99.2% (one year post-intervention) ($p < .01$). ImmReg also helped boost on-time vaccination rates, even after the project ended[30]. Caretakers also considered the automatic text message reminder feature very useful in helping them bring their children to immunization events on time. It was difficult to assess the EIR's effectiveness in isolation; it was likely that text message reminders contributed to the improvements observed in immunization coverage. The evaluation also found that automatically generating the monthly immunization report saved time for health workers, and health workers perceived the data in ImmReg to be more accurate than the data in paper registries. Both factors could have contributed to increased data use. In addition, while the relative impact of making timely data more available to health workers was difficult to discern and not explicitly evaluated, it was presumably an important factor.

Even in high-income countries, there was a paucity of studies that measure the impact of EIRs on data use. A 2015 systematic review of 240 studies of immunization information systems (IISs) in high-income countries found that 209 studies evaluated systems in the United States, 26 studies examined the national system in Australia, and 5 studies evaluated other national systems[33]. The review included both published literature and unpublished literature in the form of conference abstracts. Most studies were nonscientific, cross-sectional studies and those that involved only a single pre- or post-measurement of the intervention population. No studies included outcomes that measured the use of IISs by vaccination providers to make decisions about client vaccinations. However, this review did find evidence that establishing an IIS improved vaccination rates, suggesting that while unmeasured, the IIS did lead to improved data use.

We found moderate-certainty evidence that EIRs improved data quality, synthesis, review, analysis, and interpretation and mixed evidence on the effect of EIRs on data availability.

The external BID midterm evaluation found that the EIR did not solve all issues with data quality in Tanzania[29]. Although system validation checks had the potential to improve accuracy of data reporting, instances remained where the validation rules allowed data to be entered incorrectly. The midline evaluation found that a small percentage of nurses were not confident and accurate in registering a new child in the system, and a significant amount of data was missing in the EIR due to its inconsistent use. At the time of the midterm evaluation, the improved EIR developed by BID to address challenges with the original system was not yet operational in the evaluated region. Some of the reasons found for inconsistent use were high user workloads, the need to maintain parallel reporting systems, difficulty entering data quickly when the Internet connection was slow or erratic, lack of trained staff (staff turnover and rotation), and faulty equipment or equipment under repair (e.g., tablets or bar code scanners). Project M&E data from BID found an improvement in self-reported data analysis capacities among facility health workers in Tanzania and Zambia. In Tanzania, results showed a more than twofold increase from baseline to midline in health workers' ability to

identify defaulters, areas with low coverage for the third dose of diphtheria-pertussis-tetanus vaccine (DPT3), and vaccine stock balance.

In Kenya, an observational study of an EIR embedded in the AMRS also showed the challenges with consistent use and data entry. Like other EIR models, the Kenyan AMRS required that clinicians complete paper encounter forms recounting patient information in free text, which data clerks with basic computer skills and minimal medical knowledge then entered into the AMRS[34]. During the early phase of implementation, clinicians and other users were learning and adjusting to new forms and workflows, which often disrupted routine tasks and existing workflows and affected record keeping and data quality. However, an assessment of the system data concluded that after four years of implementation, extensive use of the patient encounter form and full integration into the workflow resulted in notable improvements in data quality. Similarly, in Guatemala, district-level data entry personnel entered data based on facility paper records in the SIGSA Web immunization registry module. Sending the primary records to the district proved logistically challenging and prevented facilities from accessing the paper registries for a specific period. According to the 2013 final project report, the module was never fully realized due to the failure to find a satisfactory way to collect and enter the primary data in the EIR and a change in government in 2011, which led to the project losing its high-level support[35].

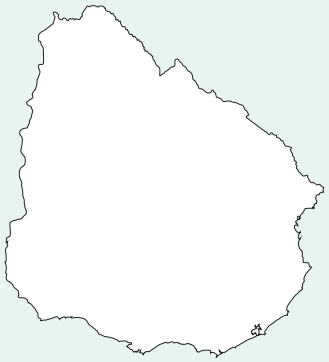
The 2016 cross-sectional mixed-methods evaluation of Zambia's SmartCare EIR on data quality outcomes found minimal use of the immunization SmartCare module that was added in 2011. Even though other modules were used, the evaluation of the immunization module found that only 10 out of 204 facilities had any immunization data in the national database[36]. In the 10 facilities that used SmartCare for immunization data, there was poor consistency between aggregated health information in facility forms and the facility-level data in SmartCare. Of projects reviewed, SmartCare was a unique example of a single-component EIR intervention, suggesting the importance of addressing the other mechanisms in the TOC to facilitate implementing and using EIRs. For instance, the SmartCare evaluation identified factors that undermined acceptance of SmartCare by clinic staff: concerns about the impact of the system on clients and increased wait times; parallel paper and electronic data entry, which made it unrealistic for vaccinators themselves to enter data as they vaccinated clients; doubts about the system's sustainability in light of past failed attempts and related concerns about data loss; and frequent power outages that contributed to burdensome data entry backlogs. Facility staff also recognized that SmartCare had greater potential for data analysis than paper records, but they generally lacked the skills and training on how to use SmartCare data for analysis. Some facility staff could express a plan for data use, but others could not identify ways to use SmartCare data for action[37].

Further reinforcing these findings, a 2016 systematic review of electronic registries used in LMICs for maternal and child health (MCH) found evidence that these registries were associated with improved data quality owing to the ease of electronic feedback and functionalities such as logical checks and warning prompts for improbable or missing data entries[38]. In addition, a 2015 systematic review of IISs in high-income countries found eight abstracts that quantified school use of IISs in the United States and demonstrated that the IISs improved data completeness and accuracy. The IIS thereby became a more useful tool for assessing the student immunization status[33].

Over the last decade, countries in Latin America have invested significant resources in developing national immunization registries. Uruguay and Mexico were the first countries to use EIRs, followed by Panama[39]; subnational registries have also existed in several countries (Argentina, Brazil, Colombia). As of 2017, 11 countries and territories in Latin America had introduced EIRs, and 8 were in the process of creating and rolling out their systems[40]. Trumbo et al. reported on two case studies of the challenges and lessons learned from efforts to improve data quality in Peru and Mexico[40]. Mexico, one of the region's first countries to implement an EIR, established PROVAC in 1991. The system was used to record and monitor patient immunization status and to calculate immunization coverage. However, issues with data quality and coverage discrepancies led Mexico to stop using PROVAC in 2013. Key challenges included the accelerated inclusion of new vaccines, insufficient resources and information technology personnel devoted to the system, and poor data-recording practices. Population denominators were never validated against the National Population Council's (Consejo Nacional de Población) data, and some numerators were based on distributed rather than administered doses. A data reconciliation by Consejo Nacional de Población in 2013 found that population denominators had been underestimated, which led to overestimated coverage (e.g., 99% DPT3 in 2012 versus 83% DPT3 in 2013). Because of open source coding, users and administrators in different regions created different versions of the system, which caused inconsistencies. In 2013, Mexico developed a new EIR that has overcome the past challenges. Peru created the Padrón Nominal in 2012, a census database of children under 6 years of age, and began collecting immunization data alongside data from other health programs. As in Mexico, the Padrón Nominal experienced difficulties reconciling discrepancies in denominator data.

CASE STUDY

Uruguay's National Immunization Program Register as a mixed-paper and electronic system



Uruguay's SNNI database provides an example of a mixed-paper and electronic system. Paper forms, which vaccinators fill out for each vaccine administered, are sent to the department level, which creates an electronic backup of the data and then submits the data every week or every other week to the central office in Montevideo. The SNNI database is therefore maintained only at the national level[39]. Facilities do not have direct access to the system; rather, the national database generates standardized reports that track defaulters and other program quality indicators, which are sent electronically to facilities where vaccinators use them to track down defaulters. Consequently, this feature has limited the system's utility in terms of improving data use by health workers beyond defaulter tracking. Since 2005, however, the country has been transitioning to a fully electronic system by making the system software available to all vaccination centers. The shift to electronic data entry has reportedly had trouble with uptake given that the paper form is so fully integrated into the vaccinators' workflow. That said, the SNNI is considered a model for the region, largely owing to its successful implementation and high-quality data. A 2006 independent data quality assessment commissioned by PAHO found that data in SNNI were very high quality[39]. Factors that were thought to contribute to the high level of data quality in the system included integration of the paper register form into the vaccinator workflow, as immunizations are recorded immediately upon vaccination, which leads to complete records and a strong culture of workplace feedback and informal facility-level data quality monitoring in Uruguay.

Although the Padrón Nominal helped contribute to better cooperation among different agencies that oversee vaccines, public financing, social programs, and civil registration, it remains incompletely implemented because of challenges like lack of funding. The two case studies from Mexico and Peru highlighted the importance of sustainable funding and a well-trained workforce for EIR sustainability. Integration with other health services, as in Peru's case, can help ensure sustainability despite limited resources and competing priorities. Danovaro-Holliday et al. noted that most new EIRs are now developed as part of the larger HIS[28].

Challenges Associated with Point-of-Service Data Entry

Literature from high-income countries suggests that immunization data entry at the point of service improves the quality of data, reduces misclassification of immunization needs, saves time, and is well accepted[41,42]. A review of progress and lessons learned from implementing EIRs in Latin America identified data entry as close to vaccination as possible as a characteristic of an ideal EIR[28], but most EIRs in the Americas still involve data entry by a vaccinator or data clerk from a paper record. Some countries in Africa have attempted full transition to an electronic system with point-of-service data entry, with mixed results. In Uganda, a report on the MyChild App concluded that, based on infrastructural limitations and lack of necessary structures such as continuous technical support and capacity-building, an EIR could not be fully realized[43]. As in the findings of the Kenyan AMRS evaluation[34], most health workers who used the MyChild App were computer illiterate; this led to increased workload during service delivery until health workers became proficient (taking three months to one year). Further, lack of electricity and connectivity in many health center, outreach, and mobile clinic settings was a barrier to point-of-service data entry and continued to require complementary paper-based records[43]. Other countries in Africa have yet to fully transition to point-of-service entry into electronic systems. In Nigeria, for example, the routine immunization module pilot in the District Health Information Software (DHIS) 2 involves data entry by district-level authorities from data captured in facility summary forms[37]. Some facilities, however, use mobile phone technology to transfer immunization data directly to the DHIS2 platform. Mobile phones and other tools, such as digitization of paper records, aim to overcome the challenges of point-of-service data entry.

Paper to Electronic

We found interventions that used innovative technology to digitize child health data captured on paper. Such interventions sought to address the challenges associated with manual data entry at the point of service or at higher levels (e.g., district level). Examples included the MyChild Card implemented

by the Shifo Foundation in Uganda, Afghanistan, and The Gambia; the mScan smartphone application implemented by VillageReach in Mozambique; and phone image capture in the context of immunization survey data collection in Thailand[44–48]. In the case of the MyChild Card intervention, services provided during a child's visit to the health facility were recorded on a specially designed visit slip on Smart Paper Technology. The visit slips were then transferred to the district hospital or health office, where they were scanned to update the EHRs automatically. The mScan application was different in that it collected aggregated data on administered vaccinations using a smartphone camera to capture the image, thus eliminating the need to transport paper records from the facilities to the district level.

We found low-certainty evidence that tools used to digitize paper immunization records contributed to improved data quality.

In Thailand, data entry via phone image capture (DEPIC) was used to digitize immunization history records from MCH logbooks for a survey. DEPIC was shown to provide more complete data on child immunization history compared with the records manually entered into the electronic HIS[47]. Other methods of digitizing paper records via scanning technology have shown promising results in the formative research. Results of formative research showed that mScan could accurately capture and digitize data from paper forms, achieving 99% accuracy in field testing. The mixed-methods nonexperimental evaluations of the MyChild Card in Uganda, Afghanistan, and The Gambia showed:

- *increased efficiency of health centers in registering children and their health services;*
- *significant reduction in the amount of time spent by health workers on administration and reporting as a result of eliminating multiple different registers and reports; and*
- *improved data quality (completeness, timeliness, and consistency), since all children who received vaccines were registered.*

In Tanzania, BID experimented with a scannable simplified paper registry in remote, low-volume health facilities with limited Internet connectivity. The paper registries were scanned at the district levels and uploaded directly into the EIR. The external evaluation found that many of the facilities that used simplified paper registries did not have their data entered into the EIR because of difficulties with transporting paper registries from facility to district levels for scanning and costs associated with the process[29]. There were also challenges with the scanners misreading data, which required a substantial amount of time to verify and correct the data. As a result of challenges with the simplified paper registry, all districts in the Arusha Region decided to transition their facilities to electronic data entry at point of care.

A mixed-methods study conducted in Canada found no differences in data quality between records that were scanned and those that were manually entered, and improvements in the timeliness of data entry were mixed[34].

In addition to paper-to-electronic scan technology, mobile health (or mHealth) solutions have been used to improve the collection and recording of vaccination data. In Peru, an Open Data Kit (ODK) mobile phone application was used to record vaccinations administered during a yellow fever vaccination campaign, making real-time data available on vaccinations administered[49].

Summary of Findings

- **Few EIR interventions** in LMICs have been rigorously evaluated, but there is evidence of electronic registries for MCH more broadly leading to improved data quality.
- **Evidence from high-income countries** shows that IISs have improved vaccination rates and lead to improvements in data quality.
- **There is moderate-certainty evidence** that EIRs may improve data use at the district level when used consistently and mixed evidence of their effect on data use at the health-facility level.
- **Evidence from EIR implementation** in LMICs suggests that implementation of a mixed-paper and electronic system may be more successful and allow time for health workers to adjust to new workflows and systems, while gradually phasing out data capture on paper.
- **The effectiveness of EIRs** on improving data use depends on how well EIRs are designed, developed, implemented, and used. The extent to which they are used to inform decision-making depends on the quality of the data entered in the EIR. Health workers are less likely to use data that they perceive to be incomplete or inaccurate.
- **There is low-certainty evidence** that tools used to digitize paper-based child health data may contribute to improved data quality and relieve the significant burden associated with manual data entry, thereby addressing opportunity cost barriers to EIRs.
- **In most low-resource settings,** achieving consistent EIR use is the greatest barrier to success. Consistent use is significantly undermined by challenges such as health workers' limited computer skills, parallel data entry and its associated administrative burden, limited Internet connectivity and frequent power outages in the most remote areas, and health worker motivations and perceptions about data quality.
- **Parallel paper and electronic reporting** will continue until there are few or no system malfunctions, power is constantly available, and a period of consistent data concordance between paper and electronic systems is demonstrated.
- **Point-of-service data entry** into electronic systems as an integrated part of health workers' workflow is assumed to be necessary to create a culture of data use but has yet to prove successful at producing complete, high-quality data in low-resource settings.
- **Although difficult to measure,** the observed effects of EIRs on data use and immunization outcomes are likely attributable to other components of multicomponent EIR interventions.
- **Evidence suggests** that the more that EIRs can alleviate staff workload (either through technological or staffing solutions) and support data use through additional training and on-the-job support, the more successful they will be.

2. Logistics Management Information Systems

A logistics management information system (LMIS) collects data on vaccine inventory and demand to support managing the vaccine supply chain. Like IIS and EIR interventions, computerized LMISs can overcome the challenges of paper-based systems by standardizing data collection, allowing for vaccine tracking in real time, transmitting data quickly throughout the system for accurate vaccine forecasting and stock management, reducing errors, and automating reporting[35]. WHO's classification of digital health interventions places LMIS within the system category because it can provide multiple functionalities, or digital health interventions, such as managing vaccine stock inventory and distribution or notifying vaccine stock levels[24].

We hypothesize that LMIS addresses barriers to data use related to access and availability and data quality in our TOC. Regarding access and availability, LMIS can potentially make data available in real time to users at multiple levels, therefore mitigating the risks of understocking (leading to stockouts and missed opportunities to vaccinate) or overstocking (leading to vaccine wastage). LMIS can also enhance data quality by streamlining data entry, providing secure storage of data, and improving the visibility of data inconsistencies so that corrective action can be taken.

We found computerized LMIS interventions for vaccine management as stand-alone interventions and as part of a multicomponent intervention. The USAID | DELIVER PROJECT, funded by the US Agency for International Development (USAID), is a multicomponent intervention for strengthening MCH programs. It introduced a vaccine logistics management information system (vLMIS) in Pakistan[50]. Also under the leadership of the USAID | DELIVER PROJECT, a VIMS was developed and piloted in Tanzania[51]. In Nigeria, eHealth Africa implemented LoMIS Stock, an offline-capable mobile and web application for reporting stock inventory[38]. Project Optimize, implemented by PATH and WHO in four countries, helped introduce computerized LMIS and other supply chain innovations, including the IIS in Albania, immunization modules in Guatemala's SIGSA Web, the Web-based Vaccination Supplies Stock Management (wVSSM) system in Tunisia, and VaxTrak in Vietnam[35,52–54]. In Mozambique, VillageReach is implementing the Dedicated Logistics System, a multicomponent intervention that includes dedicated logisticians, supportive supervision for facility health workers, data visualization features to support decision-making, and monthly data review meetings[55]. In India, the Immunization Technical Support Unit piloted a digital supply chain information system in Uttar Pradesh, which also involved introducing new district-level staff to reinforce cold chain and stock management capacities[56]. Compared with EIRs, which capture data at the service-delivery level, the LMIS interventions we reviewed were implemented at the district level and higher and were used to capture aggregated data that were then reported up the system. In some cases, the EIR and LMIS have been integrated, as with VIMS and the TImR in Tanzania and ZEIR in Zambia, which achieved end-to-end visibility for immunization data.

We found moderate-certainty evidence that computerized LMISs led to improved data use for vaccine stock management at the health-district level.

We identified two mixed-methods studies, one quasi-experimental study, and one report with emerging evidence from M&E project data that demonstrated that LMIS interventions contributed improved data use for vaccine management at the health-district level[50,35,52–55,57]. We did not find any studies that examined data use at either the health facility or national level, which was likely a result of the intervention's focus on the district level.

The 2016 mixed-methods evaluation of vLMIS in Pakistan found that 83% of provincial and district managers and data entry operators reported that vLMIS improved data-driven decision-making[50]. Evidence suggested that district and provincial managers used vLMIS to make decisions largely related to vaccine stocks. This finding was reinforced by data that showed lower wastage rates of measles vaccine in project provinces compared with nonintervention provinces. Qualitative data indicated strong and consistent responses regarding the use of data for decision-making related to monitoring and supervising facilities and resupply, as well as accuracy of reporting and forecasting. To validate self-reported

data use, evaluators observed provincial and district managers and data entry operators demonstrating their ability to use vLMIS. Results indicated that 67–81% of provincial and district managers and 66–97% of data entry operators could generate reports, calculate balances, extract tables and graphs, and assess months of supply. Provincial and district managers reported that timely, accurate, and accessible data (e.g., easy-to-understand graphs) were factors that facilitated their use of data for making decisions on the quantities of commodities to distribute to warehouses and stores. Final reports (from 2013) from the four countries where Project Optimize LMIS interventions were implemented showed varying results.

In Tunisia, results from baseline and endline Effective Vaccine Management (EVM) system assessments showed improvements in EVM indicators related to evidence-based vaccine forecasting and wastage reporting, which presumably resulted from an increase in data use[53,58]. Stock flows, on the other hand, worsened during the 2010–2012 period as a result of national-level stockouts that were not necessarily associated with the intervention. External factors, such as the Arab Spring and the corresponding state of flux of many elements of public service, likely influenced performance.

Four studies found improvements in vaccine stock management indicators, likely resulting from better use of data[50,52,56,57]. In Uttar Pradesh, India, the digital LMIS developed by Logistimo was piloted and examined in a 2017 study, which found that the replenishment time after stockout events was almost halved over the course of the 19-month pilot[56]. It dropped from an average of 4.93 days in months 1 through 13 to 2.35 days in months 14 through 19 ($p < .01$). In Albania, stockouts were mostly eliminated by the end of the project in 2012, compared with 2009 when pentavalent vaccine (Penta) was consistently overstocked and the measles, mumps, rubella vaccine was out of stock for a total of 67 days. In Nigeria, a quasi-experimental study of LoMIS found a quicker response to stockouts and cold chain equipment breakdown reports and a statistically significant decrease ($p < 0.00$) in the proportion of facilities reporting stockouts, which was also significantly lower ($p < 0.00$) than facilities with paper-based reporting[57]. All three interventions worked seamlessly across web and mobile software devices, which made real-time inventory data more available and accessible to decision-makers and contributed to improvements in data use. Emerging evidence from the implementation of the Dedicated Logistics System in Mozambique suggests that the package of interventions has improved understanding of distribution bottlenecks, with more attention placed on finding solutions[55]. An analysis of 2014 data showed an improvement in vaccine delivery intervals, although it was unclear to what extent improvements in data use contributed to this outcome. There were also examples of anecdotal evidence, including action taken following the identification of delays in vaccine delivery.

The Dedicated Logistics System intervention model in Mozambique was reinforced by:

- *recruitment of dedicated logisticians to work at health centers and be responsible for data collection, thus relieving the burden of data entry on facility health workers and providing supportive supervision and feedback on stock verification and consumption data;*
- *built-in data visualization and analytics designed to provide root cause analysis for support in identifying follow-up actions; and*
- *monthly data review meetings among logisticians and the provincial Expanded Program on Immunization (EPI) manager, medical chief, and Provincial Directorate of Health logistics supervisor to identify bottlenecks and ways to improve performance.*

In Tanzania, a quasi-experimental implementation research study of the VIMS pilot following one year of implementation found lower rates of understock of Penta in the intervention districts compared with the nonintervention (paper-based) districts; however, the difference was not statistically significant ($p = .41$)[51]. Likewise, the differences in data quality were not statistically significant. A few factors were thought to affect the intervention's effectiveness: duplicate data entry by the staff in paper and electronic systems, which may have negatively affected staff performance (in terms of accuracy and motivation, for example); unreliable Internet connectivity in some areas of the country; and outdated computer hardware at district, regional, or national levels, which may have been unable to run VIMS properly.

In Guatemala, the final report could not demonstrate that implementing two immunization modules, an immunization registry and a logistics and inventory module for vaccines and supplies, in SIGSA Web achieved any improvement over the legacy paper-based system because of the logistical challenges of unreliable Internet connectivity and failure to identify a satisfactory system for entering primary data in the EIR (discussed in Section 1. Electronic Immunization Registers).

We found moderate-certainty evidence that computerized LMISs led to improved intermediate outcomes in our TOC, including data quality, analysis, synthesis, interpretation, and review.

We identified five studies that found substantial improvements in the availability and quality of vaccine stock records at both regional and district levels and one quasi-experimental study in Tanzania that found better-quality data in districts that implemented a computerized LMIS compared with nonintervention (paper-based) districts, although these results were not statistically significant ($p = .20$)[52–54,50,56,51]. In Pakistan, the proportion of facilities that reported vaccine stocks in vLMIS increased over the intervention period; by

BOX B.

mHealth solutions can help simplify primary data capture and recording in LMIS, thereby making data more available and accessible in real time

We found examples of promising mHealth* solutions implemented in conjunction with LMISs. In India, data entered by facility health workers in a mobile application were uploaded to a digital bulletin board that continually streamed messages on abnormal events, such as stockouts, low stock, or user inactivity[59]. Displaying the digital bulletin board in district supervisors' offices contributed to an increase in availability across all vaccines; additionally, the average time to replenish vaccines after a stockout decreased from 14 days to 5 days per vaccine, an approximate 64% increase in responsiveness. Facility-level pharmacists and district-level supervisors reported that the digital bulletin board helped make actionable information available in real time, which led to more follow-up by district-level supervisors. The bulletin board created more frequent interaction between pharmacists and supervisors to solve problems, and text message alerts helped detect problems at an earlier stage; the redundancy in viewership was thought to create some social pressure to act. The EVM system, a mobile-based tool that electronically captures vaccine stock data[60], is another mHealth initiative implemented in India. An observational study of the EVM system's effectiveness in Bihar found improvements in EVM indicators and greater use of the information system at all levels.

** mHealth is defined by the mHealth Alliance as "mobile-based or mobile-enhanced solutions that deliver health." Reference: www.mhealthknowledge.org*

2016, rates were above 80% in the districts where vLMIS was implemented compared with around 40% in nonintervention districts. In Tunisia, inventory data recorded in wVSSM were shown to have greater accuracy at both regional and district levels. Accuracy of stock inventory, expressed as a ratio of the physical stock count to the actual stock records, was 100–102% in wVSSM in 2012, compared with the stock ledger system, which was 44–163% and 27–250% at regional and district levels in 2010. In Vietnam, the accuracy of stock records increased from 77% at baseline to 100% after one year of implementation of VaxTrax, suggesting strong adoption by district- and provincial-level staff. Conversely, VaxTrax included a function for tracking vaccine shipments that was not successfully operationalized in Vietnam because national-level users were not entering the shipments in the system, which caused the provincial staff to revert to using the paper-based system for confirming shipment receipts.

In India, data quality improved rapidly; data entry error rates averaged 77% in the first 3 months of the pilot and were reduced to 10% over the subsequent 16 months ($p < .01$). Meanwhile, adoption of the system was high from the beginning as a result of the pilot's strong political mandate, the relative simplicity of the inventory management process, and the low time burden for data entry.

Across all the LMIS interventions, success factors included the extent to which human resource requirements were considered, such as staff work burden associated with data entry. A barrier to the broader scale-up of LMIS in Pakistan, for example, was the shortage of dedicated staff, whereas interventions in India and Mozambique recruited dedicated staff to enter data and oversee supply chain management. Other interventions pointed to a normalization period required for staff to become competent using the new software (5 months in Vietnam) and for system performance to stabilize (3 months for data quality and 13 months for supply chain performance in India). Interventions that were based on strong formative research to define user requirements and learn from the advantages and disadvantages of legacy information systems were more likely to succeed.

In Malawi, health surveillance assistants at the community level used an SMS- and web-based reporting and resupply system called cStock to report stock data through their personal mobile phones[61]. An observational study evaluated the effect of the intervention on supply chain performance in two different study groups. Although the results showed improvements in both groups between baseline (in 2010) and endline (in 2013), the study group that benefited from district product availability teams (DPATs) had higher mean reporting rates

(94% compared with 79%; $p < .001$) and lower mean stockout rates (5–7% compared with 10–21%; $p < .001$). The findings showed that the multilevel quality improvement DPAT teams helped facilitate data use by health facility staff by connecting data producers with decision-makers at higher levels of the health system. The results suggest that pairing mHealth tools with health management systems and structures may be more effective at improving supply chain performance through greater data use.

We found other mHealth interventions that have yet to be evaluated. For example, in India nurses use the Vaccine and Logistics Evaluator (VALUE) handheld device, developed by the United Nations Development Programme and piloted in 2017, to record data on the names and numbers of vaccines used during vaccination sessions[62]. Similarly, county stock managers used LogiMobile, a mobile phone application developed by Logistimo, to record vaccine stock levels in Sudan from 2012 to 2013[63]. With these mHealth solutions, data entered into the mobile devices are fed directly into the HMIS or LMIS and made available in real time to data users at all levels. The mVacciNation application, piloted in Mozambique in 2015, captured data on individual child vaccination history along with vaccine stock levels and refrigerator temperatures for supply chain and cold chain management and decision-making[64]. Some applications come with additional mechanisms for placing and managing vaccine orders, scheduling vaccination appointments, and sending automatic text messages on the status of vaccine orders or to remind caregivers when children are due for their vaccinations.

Summary of Findings

- **There is moderate-certainty evidence** to suggest that computerized LMISs lead to improved data use at district levels and higher by making higher-quality data more available in real time for decision-makers, thus contributing to improvements in vaccine availability.
- **There is moderate-certainty evidence** that computerized LMISs likely lead to improvements in intermediate outcomes, such as data quality, analysis, synthesis, interpretation, and review.
- **LMIS interventions that were combined** with other data use activities, such as dashboards and platforms that connected data producers with data users (e.g., data improvement teams [DITs]), showed even greater improvements in data use and indicators of supply chain performance than LMIS interventions implemented in isolation.
- **Implementing LMIS** at higher levels of the supply chain (e.g., district, provincial, and national levels) was associated with fewer operational challenges because Internet connectivity tended to be more reliable and technology requirements were more easily addressed.
- **LMIS interventions were more likely to succeed** when the human resource requirements for supporting data entry and reinforcing data use with supportive supervision and training, as well as system functionalities supporting data analysis and visualization, were adequately considered.
- **LMIS interventions based on formative research** and designed to respond to the requirements and expectations of data users were more likely to be adopted and leveraged for data-informed decision-making.
- **The success of LMIS interventions** depended on the consistent use of the system by health workers at all levels and therefore must address the motivation-related barriers to use.

3. Health Management Information System

An HMIS records and stores aggregated health data and can facilitate converting data into useful information for decision-making. HMISs can link with systems that handle data records for individuals, such as EIRs, EMRs, and EHRs. Investments in HMISs have been prioritized as a necessary part of supporting the decentralization of health systems, based on the premise that an effective and efficient HMIS would provide district health managers with the information required to make informed decisions[8]. Per the WHO's classification of digital health interventions, HMIS is considered a system category serving multiple functionalities, or digital health interventions, such as data storage and aggregation, routine health indicator data collection and management, and data synthesis and visualization[24].

In this section, we focus on computerized HMISs. In other sections of the report, we discuss paper-based systems and approaches to strengthening HMISs. We expanded our review of HMIS interventions to include literature outside of immunization because most literature on HMISs is not specific to any one particular disease area. HMISs address data use barriers related to access and availability in our TOC by improving the collection and storage of health data and making data accessible to decision-makers in a timely fashion. HMISs can address issues of data quality with automatic validation features and by making data more accessible, enabling health workers to better identify and correct data errors.

DHIS is a computerized HMIS developed by the University of Oslo in 1994. It was designed to collect aggregated routine data from all public health facilities in a country and to support decentralized decision-making by enabling district and facility managers to make decisions about service delivery based on their data[65]. DHIS2 was introduced in 2006 with improvements that support the capacity to work in offline mode (although issues have been noted with this functionality), extend the use of data, and generate automated reports to enable decisions at local, district, and national levels[6]. DHIS2 was first implemented in India, and its first national rollout was in Kenya in 2010. It is presently used in over 60 countries worldwide at the time of this report[26].

We found moderate-certainty evidence that HMIS interventions led to data use at the district level and low-certainty evidence that HMIS interventions did not lead to data use at the service delivery level.

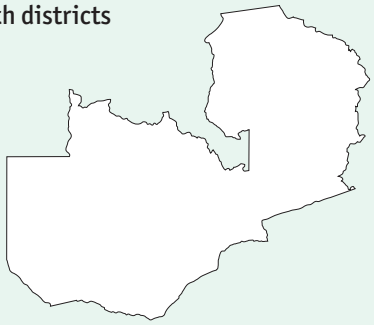
The evidence suggests that HMIS interventions are more likely to lead to data use at the district level, especially when combined with complementary activities to build capacity for data analysis and structured processes for data use. A multicountry case study of the outcomes of DHIS and DHIS2 use across seven African countries found that four countries were experiencing some level of success in using DHIS2 data for district-level decision-making[6]. In these countries, factors that contributed to the success included support to local health authorities, strong involvement of all relevant stakeholders in the process, and the integration and interoperability of data across systems. Improved data completeness and quality were reasons given for the successful use of DHIS in Sierra Leone. DHIS use was encouraged through wide dissemination of the districts' data. The use contributed to a process for performance ranking that was discussed during monthly district review meetings. In South Africa, a large effort was placed on standardized training, on-site mentoring, and extensive communication with information officers and managers at all levels of the health system. Three out of the seven countries at the time the report was published had yet to demonstrate evidence of DHIS and DHIS2 use in decision-making. Some of the challenges included lack of skills for data interpretation and use; lack of policy guidelines; inflexibility of the DHIS version implemented; lack of adequate financial, infrastructural, and human resources; and the need for extensive technical support. Many of the countries examined had also gone through multiple trials with different iterations of DHIS before establishing the right system.

A systematic review of district-level decision-making in LMICs found eight examples of tools that used HMIS data as part of a structured process for decision-making. These tools generally entailed a three-step decision-making process that included problem recognition, investigation, and solution development. The review found evidence of health districts using HMIS data for prioritization, development of action plans, and review and monitoring of the action plans. Authors concluded that for structured decision-making processes to be successful,

CASE STUDY

HMIS and decision-making in Zambia: rethinking information solutions for district health management[8]

In Zambia, researchers conducted a qualitative comparative case study in two health districts to examine the use of HMIS data in decision-making. They found evidence that HMIS data were used in all three levels of strategic decision-making (problem recognition, investigation, and solution development). While HMIS data were often a source of information, they were not the most common source. Examples of other information sources used included verbal and observational information. Among all the information sources evaluated, information based on experience was most commonly used for making decisions. The study suggests that data use interventions must consider the myriad sources of information that are brought to bear in district decision-making and their impact on managers' ability to make effective and sound decisions.



they must be accompanied by capacity-building and skills development for district-level decision-makers[66].

Although the evidence indicates that HMIS interventions may lead to data use at the district level, we found that the evidence does not support the same conclusion at the service-delivery level. We found two nonexperimental mixed-methods studies that suggested that DHIS and DHIS2 have not been effective at improving data use by frontline health workers. One study of DHIS implementation in South Africa found that at the ten health facilities evaluated, there was little understanding of the usefulness of data or its applicability to facility or program management, and clinic supervisors were not aware of their clinic's performance in relation to national targets[65]. While several facilities had developed operational plans, they did not use data to inform targets or monitor plans. Another study conducted in Kenya found that only 15 out of 22 hospitals (68%) were using DHIS2's analysis and presentation functions and only 19.8% of senior managers in the hospitals visited had access rights to the DHIS2 hospital reporting system[67]. In both studies, low utilization was attributed to unreliable data (linked to absent data quality assurance mechanisms) and absence of feedback on data and supervisory support from the district level. In South Africa, despite facility-level training on DHIS, health workers and managers were unable to make effective use of the data. The shortage of human resources with health informatics skills contributed to the lack of feedback, which was a root cause of poor-quality data and weak awareness of the importance of data. Garrib et al. suggested ensuring that health facility supervisors are trained to interpret and use facility data and assigning a dedicated information clerk to each facility who is responsible for data collection and validation, thus freeing up time for health facility staff to discuss, interpret, and take action on data[65].

We found moderate-certainty evidence that HMIS interventions contributed to intermediate outcomes in our TOC—including demand for and motivation to use data and data access, availability, and quality—at district levels but less so at the service-delivery level.

We found one systematic review that examined the strengths and operational challenges of using DHIS2 and reported on findings from 20 articles and reports from 11 countries[26]. The review found evidence that DHIS2 has contributed to encouraging a culture of information use for decision-making. The review identified three studies that reported improvements in the quality, timeliness, and completeness of data, while other studies found an increase in access to information. The review also found that the timely access to data afforded by DHIS2 contributed to a sense of ownership, which in turn generated a sense of responsibility to produce high-quality data[26]. This finding is reinforced by Karuri et al., who reviewed DHIS2 implementation in seven countries in Africa[6]. They found that despite challenges with data quality and health workers' capacity to analyze data, users tend to demand more and higher-quality data as DHIS2 data get more use.

Garrib et al. found that at the facility level, DHIS had not improved intermediate outcomes in our TOC, such as data quality, analysis, and interpretation[65]. In each of the ten health facilities evaluated, data validation focused on ensuring that data submitted were complete. Checking the quality and accuracy of the data was rarely done because of lack of time. There was also little analysis of the data and no discussion during staff meetings.

Some of the operational challenges of using DHIS2 included the inadequacy and poor quality of data in the system, insufficient human resource capacity (both in numbers of personnel and their ability, knowledge, and experience), lack of education and training, and lack of motivation or reluctance to use new systems.

There is growing recognition that building HMISs and investing in the quality of the data that go into the system are not sufficient to guarantee that data will be used but that HMIS interventions need to be coordinated with activities that build health workers' capacity to analyze, interpret, and use the data for decision-making. There are examples of promising strategies, such as a data interpretations feed, a feature in DHIS2 that allows users to share their interpretations of dashboards and other visualizations, which prompts discussions about observed trends in the data. Population Services International (PSI) worked with the University of Oslo to create more dynamic DHIS2 dashboard functionalities and data interpretations features. PSI uses these enhanced features, along with project-specific DHIS2 user groups, in over 30 country programs to trigger more conversations about data[68]. The effectiveness of these types of interventions, which are intended to reinforce the use of routine data captured in HMISs, are reviewed in greater detail in the following sections.

Summary of Findings

- **We found moderate-certainty evidence** that HMIS interventions may lead to data use at the district level, especially when coordinated with tools and activities to support the use of data, such as data dashboards, feedback, and supervision from higher-level managers.
- **At the service-delivery level,** there is limited evidence on the effect of HMIS interventions on data use. Low-certainty evidence suggests that HMIS interventions, implemented in isolation, may not lead to data use by frontline health workers.
- **We found a greater emphasis** on improving the quality of data at the facility level than on improving data use; however, we found moderate-certainty evidence that improvements in data use likely lead to improvements in data quality by generating greater demand for high-quality data.
- **HMIS interventions are less likely** to lead to improved data use when they fail to adequately account for the administrative burden of data entry and validation that are tasked to health facilities.

4. Decision Support Systems

Decision support systems consist of tools that help data users interpret and make sense of data and transform data into information that can be used for decision-making. Tools can include paper and electronic data dashboards, health summary bulletins, health status report cards, and color-coded data presentations[68]. Electronic decision support systems, per the WHO digital health intervention classifications, are considered in the system category[24].

They can adapt to the data use needs of users at various levels of the health system and serve multiple functionalities, including:

- *clinical decision-making involving patient care at the facility level;*
- *performance management at the district level; and*
- *population-based decision-making at the national level.*

Our TOC suggests that greater availability of high-quality data, on its own, is insufficient to ensure the use of the data[14]. The overwhelming quantity of data available to decision-makers can make it difficult to decipher the data and extract meaningful information[2,55]. Health workers and managers must therefore possess the skills and knowledge to analyze, interpret, and translate data—often from various sources and across multiple data elements—into information that is useful for decision-making. Decision support systems can address multiple intermediate outcomes in our TOC by linking key data sources, helping data users navigate large data sets, and synthesizing and displaying data according to need. These systems address structure and process mechanisms by strengthening and institutionalizing decision-making processes. They also strengthen data use skills by supporting data analysis and helping users transform data into actionable information.

Given their fundamental differences, we chose to distinguish among (a) computerized decision support systems (CDSSs) that employ rule- or algorithm-based software to automate the analysis and interpretation of data; (b) decision support tools, such as dashboards, that help organize and visually synthesize data for easier interpretation and use; and (c) HBRs such as child immunization cards. The evidence for these three different types of decision support systems is summarized in the following sections.

Computerized Decision Support Systems

In the immunization literature, we found one example of a CDSS intervention that employed a rule- or algorithm-based software to read the data and make interpretations for the data user for operational decision support, as well as a review of issues related to the use of CDSSs in childhood immunization programs. Two other similar interventions were for supply chain modeling for strategic decision support at the national level. The knowledge-based system (KBS) was a type of CDSS implemented in Papua New Guinea to help health service managers interpret immunization coverage rates and provide suggestions on how to improve them[69]. The supply chain modeling interventions included a software application implemented by VillageReach in the Democratic Republic of the Congo, Mozambique, and Zambia, and a supply chain simulation model in Nigeria that identified ways of maximizing supply chain performance[70,71]. To our knowledge, only the KBS has been evaluated. A case study of the supply chain modeling software implemented in the Democratic Republic of the Congo showed that the intervention proved to be a promising tool for helping stakeholders identify solutions to increase the availability of vaccines in hard-to-reach areas.

We also broadened our search outside of the immunization literature. We found one systematic review of 28 randomized control trials (RCTs) in high-income countries on the impact of CDSSs linked to EHRs and a feasibility study for a tablet-based Decision Support and Integrated Record-keeping (DESIRE) tool in Kenya to assist with clinical care of hypertension patients[72,73].

We found very low-certainty evidence that CDSSs had an effect on data use.

A mixed-methods evaluation of the KBS found that district health staff in one of the provinces reported using the system to interpret immunization data, recognize problems, and give more effective feedback[69]. The same province also noted a rise in the immunization rate over the four months following installation of the KBS, suggesting that corrective actions were taken to address the problems identified. The extent to which district health staff adopted the KBS and considered it useful was divided between the two provinces assessed. The evaluation suggested that the KBS was less effective in the province that was already meeting its immunization targets. Because of high performance, users did not perceive a need to review data and take action. Conversely, the province with lower performance reported using the KBS to identify and take action on declines in immunization coverage, high dropout rates, missing immunization reports, and supply shortages.

In the United States, the CDC has a clinical decision support for immunization program, which is an automated system that assesses patient immunization needs and provides recommendations to the health care provider[74]. Although we did not find evaluations of effectiveness, one paper described the process and challenges involved in developing IMM/Serve, an operational CDSS designed by the Yale Center for Medical Informatics[75]. The paper emphasized the complexity of creating CDSSs and the significant commitment of both time and resources required. The design phase alone required determining how to structure and encode the knowledge, deciding on the system's desired functionality, and thorough testing and validating by experts. Guidelines were also necessary on how to resolve conflicts of opinion regarding the correctness of the conclusions produced by the software. Once operational, maintaining the knowledge and functionality over time can be challenging and requires ongoing support and commitment from engineers and software builders.

The systematic review of 28 RCTs on the impact of CDSSs linked to EHRs in high-income countries found little evidence of a difference in clinical outcomes, such as patient mortality and morbidity. The results suggest that CDSSs did not result in notable changes in clinical decision-making in these settings[72]. While the feasibility study of the tablet-based DESIRE tool in Kenya did not evaluate whether it was effective at improving data use or clinical outcomes, qualitative data suggested that nurses perceived that the tool made patient encounters easier and helped them to provide better quality of care[73].

Monitoring Charts and Data Dashboards

We found five interventions that implemented monitoring charts or data dashboards as key components within a multicomponent intervention, including complementary activities such as data review meetings and supportive supervision. Each of the interventions provided an example of how these types of decision support tools have been tailored to data users at different levels of the health system. For data users at the national level, Poy et al. reported on the process of establishing a routine immunization data dashboard across six countries to monitor performance of the immunization system in the context of the Polio Eradication and Endgame Strategic Plan[76]. The dashboard, developed in Microsoft Excel, included a combination of both vaccination outcome and process indicators from routinely collected data. National data managers entered data manually in the dashboard quarterly. The intervention has not been evaluated to determine whether the data were used to manage district performance. That said, developing a dashboard for process monitoring was considered valuable given the emphasis generally placed on outcome indicators, which are less useful for spotting and addressing system bottlenecks in real time. In addition, Colombia's national information system, Sistema Integral de Información de la Protección Social, included a dashboard for immunization in 2012; however, it has not been evaluated[77].

We found moderate-certainty evidence that monitoring charts and dashboards improved data use among health workers at district and facility levels.

In Nigeria, the CDC piloted a routine immunization module within DHIS2 with a data dashboard configured for health workers at facility, district, state, and national levels[37,78]. The multicomponent intervention included state-level and local government area (LGA) DHIS2 training, deployment of DHIS2 field support staff, and supportive supervision. An evaluation of the project is currently under way, but M&E results from 2016 and 2017 project reports show that the intervention package, which included a routine-data dashboard, increased use of routine immunization data at all levels in Kano State. Data use actions at the health-facility level included responding to data that showed high dropout rates or low vaccine coverage, compiling lists of defaulters, convening meetings with communities to help with defaulter tracking, and exploring why mothers were not following the immunization schedule. At the district level, there was widespread use of the dashboard to track facility performance, target facilities for training or supportive supervision, and monitor immunization coverage

trends. M&E results also suggested that the use of data has led to improvements in its quality. The use of data dashboards to identify inconsistencies in immunization data was observed and documented in state and LGA monthly review meetings. This, in turn, led to analysis and identification of the issues, supportive supervision, and corrective actions to improve data quality. Several factors facilitated data use, including user-specific training modules for national, state, and LGA levels; deployment of DHIS2 implementation officers to provide hands-on learning and support to state and LGA immunization teams; and monthly meetings to review and analyze data in performance reports generated by the dashboard.

The Reaching Every District (RED) strategy, for example, uses immunization monitoring charts as part of the monitoring for action component of the strategy in conjunction with supportive supervision from district staff to health facilities, with a focus on using data to guide decisions[79]. The strategy was evaluated (nonexperimental study design) in countries from each of the WHO Africa subregions. Although the evaluation did not assess specific ways in which districts or facilities used data for decision-making, there were improvements in systematic monitoring that likely contributed to the observed improvements in delivery of immunization services[80]. In the nine countries assessed, DPT1 coverage for children under 1 year of age increased from 69% in 2002 to 87% in 2006. DPT3 coverage also increased from 57% to 79% over the same period. The multicomponent nature of the intervention suggests that decision support tools are more successful when paired with activities that ensure that they are mainstreamed as part of decision-making processes (e.g., through data review meetings) and that their application is reinforced (e.g., through supportive supervision).

We found moderate-certainty evidence that immunization monitoring charts and dashboards improved intermediate outcomes in our TOC, such as data quality, analysis, synthesis, interpretation, and review.

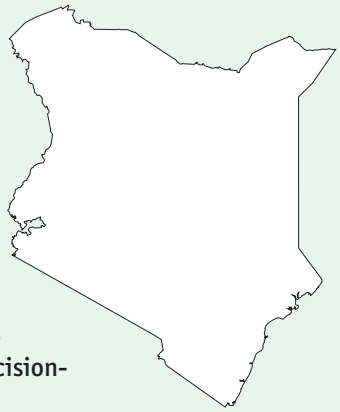
The evaluation of the RED strategy found that monitoring charts helped health workers understand their facility's performance: 70% of health workers in facilities with monitoring charts were able to explain their facility's performance. Across the countries assessed, most districts (95%) were conducting review meetings at which immunization data were discussed. This reinforced that the process of analyzing, synthesizing, and reviewing data appears to be an important intermediate outcome to improving data use. Supportive supervision from district staff to health facilities with a focus on using data to guide decisions complemented these activities.

Similarly, a case study in Kyrgyzstan found that providing health workers with simple paper-based tools, such as worksheets to help them compile data, perform indicator calculations, and plot graphs, led to improvements in data quality and health workers' ability to detect and react to problems [81]. The intervention also emphasized improved supervision at all levels of the health system. Supervision checklists were developed with information system indicators, a move that was found to contribute to improvements in data quality and motivation among health workers, since each facility was given a score based on the supervision checklist.

In India and Timor-Leste, the My Village My Home tool was piloted and evaluated. The poster-sized tool included a record on which community-based health workers and community members entered and tracked each child's vaccinations. The tool was posted in a public place, such as a community center or government office, which created social pressure and motivation among health care staff and caregivers to keep children up to date on vaccinations. While the tool was primarily implemented as an intervention to strengthen community participation in immunization, a 2015 evaluation with a nonexperimental study design found that the tool helped increase awareness among health workers of vaccination status, which in turn motivated them to improve coverage[82]. Before the tool was piloted in Timor-Leste, only the most accessible infants were in the system; the intervention appeared to help capture harder-to-reach children who were not counted previously but it also caused a drop in immunization coverage after the children previously left out were added to the coverage denominator. Timeliness of vaccinations given to children was also noted to have improved. The direct impact of the tool on data use and immunization coverage, however, remains inconclusive because both countries implemented the tool along with other initiatives aimed at improving services and demand for immunization. In Nigeria, project M&E results suggested that the routine immunization data dashboard, when packaged with other support activities, improved intermediate outcomes in our TOC, including data availability, analysis, and review[37,78]. In particular, the project reports noted increases in the number of health facilities that reported immunization data, which led to greater data availability. At the district and state levels, data were being used in monthly review meetings to identify issues in data quality and target field visits to take corrective actions.

CASE STUDY

District Health Profile tool for decision-making at the district level in Kenya for HIV prevention and treatment



The District Health Profile tool is a Microsoft Excel–based decision support tool that integrates data from various health programs to enable district health managers to review and monitor program progress[87]. The tool is designed to meet specific and targeted information needs by answering ten high-priority health questions and one data quality question. The tool links to existing Ministry of Health Excel spreadsheets, therefore requiring minimal data entry. Data are aggregated quarterly, and all calculations are automated using Visual Basic for Applications (VBA). The tool then produces quarterly reports with graphs and responses to the 11 questions, which alert program managers to potential problems in the delivery of HIV prevention and treatment services. By focusing on 11 questions instead of a long list of independent indicators, decision-makers can target their review and access data from multiple fragmented data sources.

The District Health Profile tool was qualitatively evaluated six months after its launch to determine its effect on data-informed decision-making. The results indicated that the tool was being used to identify problems and implement programmatic changes. The evaluation found that the tool helped:

- improve collaboration and data sharing among districts, facilities, and national-level managers;
- facilitate reporting, analyzing, tracking trends, and drawing conclusions about program progress;
- improve data quality by making it easier to identify and fix discrepancies;
- facilitate identifying poorly performing facilities and problem-solving; and
- increase demand for additional data.

A key factor in the tool's acceptability was the fact that the tool used technology that was already available and familiar to district staff. Some of the reported barriers to using the tool included the need for more training and support from supervisors, the lack of value placed on data to improve programs, and the lack of hardware, such as computers and printers.

Home-Based Records

An HBR is a health document used to record the history of health services received by an individual[83]. HBRs are generally kept by the individual or caregiver, either in paper or electronic format. The child immunization card is a type of HBR that contains a complete record of the child's vaccination history. Although most of the data use literature relates to how caregivers may use HBRs to make decisions about the health care of their children, the WHO recommendations on HBRs recognized that program managers can use information collected in HBRs for routine reporting, monitoring, and planning of health information, but the recommendations did not present any evidence of HBR use for this purpose[83].

We found no evidence that HBRs led to improved data use by health workers.

We found one RCT conducted in Pakistan and a final project report on an immunization card redesign intervention in Madagascar and Ethiopia[84,85]. The interventions in Madagascar and Ethiopia theorized that a redesigned immunization card may be easier for health workers (and caregivers) to use, and that by making vaccination data more available, it would be easier for health workers to determine whether and when a child was due for a vaccine. Despite this hypothesis, neither intervention measured if or how the redesigned HBRs improved data use by health workers. All three countries

showed improvements in immunization coverage associated with the HBR redesign. The RCT in Pakistan found a higher rate of DPT3 completion, 90 days after follow-up, in the study group that received the redesigned card (69%), and even higher in the study group that received the redesigned card and center-based education (74%), compared with the standard-care-only group (55%)[84]. The report from the HBR redesign in Madagascar and Ethiopia cited a finding in an unpublished manuscript that children in the intervention areas who possessed an HBR were 2.5 times more likely to be fully vaccinated by 1 year of age than those who did not possess an HBR. While these improvements more likely indicated that caretakers were using the HBRs to inform their care-seeking behavior, it is unknown to what extent the HBR was used as a decision-making tool for health workers.

In terms of promising strategies, we found a digital health intervention in Argentina that to our knowledge has not been evaluated[86]. The intervention, called Vaxeen, is a digital personal immunization assistant that enables individuals to record immunization data. Its applications provide a broad range of functionalities to both patients and health workers, but these have yet to be formally evaluated.

Summary of Findings

- **We found limited evidence** on the effectiveness of CDSSs on data use, particularly in the context of routine immunization; the evidence that does exist shows mixed results.
- **We found moderate-certainty evidence** that decision support tools, such as monitoring charts and dashboards, may improve data use. We also found moderate-certainty evidence that they may improve intermediate outcomes of data use, such as analysis, synthesis, interpretation, and review, by helping data users synthesize disparate pieces of data and translate them into information that is useful for decision-making.
- **Decision support systems** appear most relevant when they focus on specific programmatic questions and are tailored to the ways in which particular users employ data in their everyday work.
- **We found no studies** that examined whether HBRs, as a decision support tool, lead to improved data use by health workers. Rather, most evidence on HBR data use is related to decision-making by caregivers. This represents an evidence gap that should be examined in future research.
- **Decision support tools,** such as monitoring charts and dashboards, appear most effective when they are integrated within established data review and decision-making processes (such as monthly review meetings) and when they are reinforced through supportive supervision and other forms of feedback.
- **Decision support tools are only useful** when data users are motivated to use them. Improving attitudes toward data and data use is essential for improving acceptance and adoption of the tools. Likewise, decision support tools can provide a deeper understanding of the value of data in decision-making, leading to improved attitudes about the usefulness of data.
- **The underlying data** must be sufficiently complete and accurate for the effective use of decision support tools.
- **Building CDSSs is a time-consuming,** iterative process that requires validation by experts, along with guidelines for how to resolve conflicts of opinion regarding the correctness of the conclusions produced by the software. In addition, a high level of ongoing commitment and experienced knowledge engineers are needed to maintain the system over time.

5. Data Quality Assessments

Data quality assessment approaches range from interventions that train program managers how to conduct routine audits of data quality to external audits of data quality[88]. There are also various methodologies for examining data quality. WHO developed the data quality audit (DQA) methodology in 2001 for assessing the quality of administrative vaccination coverage data in LMICs[89]. It was the first instance that a standard method was applied to assess data consistency and quality quantitatively. It was subsequently adapted for countries to use as a self-assessment tool, the data quality self-assessment (DQS).

Ronveaux et al. identified limitations with the DQA methodology, such as its narrow focus on data validation, which often missed underlying systemic issues and thus led to recommendations that were not always actionable or that had little impact[90,91]. Other methodologies have been designed to overcome these limitations. For example, WHO and CDC developed the Immunization Information System Assessment (IISA), a more comprehensive tool that considers other relevant system components affecting data quality and is used to generate data quality improvement plans (DQIPs)[89]. A collaborative effort of WHO, the Global Fund, MEASURE Evaluation, and Gavi, the Vaccine Alliance led to the development of the DQR toolkit, a framework and toolkit meant to support routine, annual, and periodic independent assessments of facility-reported data, which include a module for immunization[16]. MEASURE Evaluation also developed the Performance of Routine Information System Management (PRISM) framework for evaluating broader routine health information system (RHIS) performance[19].

Within the scheme of WHO's digital health interventions classifications, data quality assessments relate most closely to the data collection, management, and use intervention area[24]. Recognizing that health workers are less likely to use data if they cannot trust the data's completeness or accuracy, data quality assessments address the data quality mechanism within our TOC.

Most literature we reviewed presented the results of external DQAs that were used to provide a diagnostic of immunization data quality at a single point in time. In some cases, improvements in data quality were measured after implementation of a follow-up DQA a few years later. Another smaller set of literature reported on the effectiveness of DQAs when implemented routinely by health workers. In this section, we review the findings from interventions in which DQAs were the primary intervention, but we found that DQAs were also implemented as part of a comprehensive intervention package in 11 other interventions. We also broadened our search to include evidence on DQA interventions outside of immunization.

We found moderate- to high-certainty evidence that data quality assessments improved intermediate outcomes in our TOC, including data quality.

We found five studies that showed an improvement in immunization data quality and two studies that showed an improvement in HIV data quality. These included a review of DQAs conducted in 41 countries, a time series observational study on the effect of a three-year national-level HIS data quality intervention in Mozambique[92], a report on two cross-sectional DQSs implemented by Agence de Médecine Préventive in Côte d'Ivoire[93], and evidence from repeat DQSs in El Salvador and Paraguay. Among the literature on HIV data quality outcomes, we found one nonexperimental study on Routine Data Quality Assessments in Kenya[94] and one experimental study that examined factors associated with DQA results in Malawi[95].

In the review by Bosch-Capblanch et al. of DQAs conducted between 2002 and 2005 in 41 countries, 21 countries failed the first DQA; among them, 6 countries undertook a second DQA two to three years later[96]. The verification factor, a measure of the proportion of DPT3 immunizations that can be traced through the reporting system, improved in all six countries; however, the 95% confidence intervals overlapped between the first and second DQAs, so authors could not be certain that the verification factors were actually different. The Quality Score, which was based on a number of process indicators, increased across all six countries at the national, district, and health unit levels. At the health unit level, the increases were statistically significant ($p < .001$). Even though the quality improvements could not be attributed to the DQA alone, the results suggest that the DQAs brought greater visibility and awareness to issues with data quality so that they could be addressed.

In Côte d'Ivoire, the percentage of facilities with a satisfactory verification factor increased from 74% to 82% between the first and second DQS. In Mozambique, data concordance improved by an average of 1.56% per month (95% CI: 0.89, 2.22) from 2011 to 2012, when the DQA intervention was implemented. Data quality then plateaued during the following years. Other activities aimed at boosting data quality and use complemented the DQA intervention, including supportive supervision to low-performing clinics, feedback from district and provincial levels, data trainings, and district performance meetings focused on improving data use for decision-making. It is likely that the continued implementation of the complementary activities helped sustain the gains in data quality that the DQA exercises had achieved. The study also found that higher numbers of human resources for health were associated with larger gains in data concordance. Facilities with fewer human resources for health or a heavy patient volume had comparatively smaller improvements in data quality, suggesting that the ratio of human resources to patients is an important factor for a successful data quality intervention.

Several repeated DQS exercises in El Salvador and Paraguay provided evidence that recommendations from an initial DQS were implemented and led to data quality improvements in a subsequent DQS. In 2006, El Salvador conducted a DQS that provided baseline information and resulted in recommendations for improving use and quality of vaccination data in the country. A subsequent DQS conducted in 2009 found that some of the recommendations from the 2006 DQS had been implemented and that the average quality index had increased from 57% in 2006 to 75% in 2009[97]. In Paraguay, data quality improved between the 2009 and the 2011 DQS (integrated into an international EPI review) as well[98]. In both instances, a formal evaluation of the specific recommendations implemented was not conducted, but country teams attributed measurable improvements in data quality to the DQS implementation and recommendations.

Among the evidence from the HIV sector, Routine Data Quality Assessments of facility-level EMRs in Kenya were associated with improvements in data quality, including a decline in missing data (from 31% to 13%) and an increase in data concordance (from 59% to 68%) between baseline and follow-up[94]. In Malawi, the WHO DQR tools and additional questions from MEASURE Evaluation's PRISM tools were used in an experimental study of facility-level data quality and its association with different functional areas of the health system. The study found that data use by the facilities to track performance was associated with improved data availability ($p = .04$) and data completeness ($p = .02$) but not with higher-accuracy data. This was likely because only a small fraction of facilities reported conducting regular accuracy checks and fewer than 60% of health workers had been trained to assess data quality properly[95].

A mixed-methods study of the effectiveness of strategies to improve data quality in Mozambique, Rwanda, and Zambia found that it was important for DQA interventions to be carried out alongside activities that provided additional feedback loops[88]. Across all three countries, activities that both assessed and worked to improve data quality, through supportive supervision, mentorship, and EHR system strengthening, were rated most effective among study participants.

We found no studies that directly evaluated the effect of DQA interventions on data use for decision-making; however, there was moderate-certainty evidence that data from DQAs were used to make improvements in data quality.

Although no studies directly evaluated the effect of DQA interventions on data use for decision-making, we found six studies that showed that DQA interventions led to improvements in data quality. We interpret this finding to suggest that by bringing more awareness and visibility to problems with data quality, DQA interventions prompted health workers to use data to address problems with the quality of their data.

In terms of promising strategies that have not undergone formal evaluation, we found examples from the application of the IISA/DQS Plus methodology in Grenada in 2018, which allowed for a comprehensive assessment of data flows and data quality, as well as the acceptability and quality of the EIR[99]. In Kenya and Ghana, where the IISA methodology was first implemented, Scott et al. reported anecdotal evidence of some concrete actions taken based on the IISA results and the corresponding DQIP[89]. In Kenya, national and county target-setting workshops were convened, and the DQIP was integrated into health systems strengthening support from Gavi, the Vaccine Alliance. In Ghana, action was taken to improve the managerial and supervisory skills of subdistrict staff, and data quality content was incorporated into coursework and continuing education curricula for health professionals.

In 2014, PAHO convened a working group that developed additional questions for the DQS to describe an existing EIR based on observation, review of the software, norms, and manuals. The working group also developed a specific set of questions added to the DQS quality checklists for the national, subnational, and local levels regarding hardware and software, infrastructure, human resources, Internet access, data entry,

and users' perceptions at the local level (EPI nurses and data entry clerks). This new version of the DQS, referred to as "DQS-Plus," was piloted in Panama in 2014 and in Honduras in 2015. Results from the two pilots indicate that the additional components make the DQS-Plus more effective at making recommendations for improving data use and data quality and assessing the acceptance and functionality of EIRs[99,100].

DQS-plus interventions could presumably contribute to improving the use of data for decision-making because better assessments of EIR data quality and functionality can help advance the development of standards and guidance for EIR implementation in LMICs. They can also help predict the probability of successful EIR adoption before countries embark on costly development and implementation.

Summary of Findings

- **There is moderate- to high-certainty evidence** that DQA interventions lead to improved data quality by providing greater visibility into issues with data quality so that health workers can act to improve the quality of data. However, activities to measure data quality are not sufficient to improve data use for decision-making.
- **DQA interventions appear most successful** when they are carried out alongside feedback loops so that in addition to bringing visibility to issues with data quality, health workers build the necessary skills, through supervision, mentorship, and training, to address those issues.
- **Assessments of data quality and use** have the potential to lead to improved data quality and use when they are accompanied by DQIPs that specify activities to address the root causes of suboptimal data quality and use.
- **Implementation of these plans** and activities depend, in part, on the existence of adequate resources and political will. Facilities with human resource constraints are less likely to fully implement activities to improve data quality and use.

6. Data Review Meetings

Meetings are one of the main ways that health workers at all levels of the health system access and share knowledge and information[10]. Program review meetings are common practice in many health and immunization programs[101]. WHO's EPI guidance documents promote regular review meetings as an opportunity to discuss data trends, share achievements, and promote peer exchange and problem-solving[102]. The RED approach lists the percentage of districts that conduct at least one review meeting per quarter as a core indicator within the RED strategy[103]. Review meetings promote data use by addressing many mechanisms in our TOC, such as demand, skills, structure and process, and motivation.

In terms of demand, a weak culture of knowledge seeking and sharing is a barrier to data-informed decision-making[10]. Review meetings help overcome this barrier by fostering a culture of data use through building awareness and positive attitudes toward data use. Such meetings employ adult-learning techniques like peer learning and knowledge sharing to build skills in data analysis. In terms of structure and process, they help institutionalize data use as part of the decision-making process. They can build motivation to use data by demonstrating the value of data and how data can be used to improve performance of immunization programs, in addition to fostering friendly competition and engendering a collective accountability for improving routine immunization.

Program review meetings can include quarterly review meetings (QRMs) held at the district level[101,104]; monthly meetings at district and state levels[37]; and monthly meetings of health workers, local government, and communities[105]. They can also include data discussions with facility workers and local leaders during routine technical support visits to facilities[85]. At district-level meetings, participants include health facility representatives and district-level authorities. Facility staff share and discuss locally generated immunization administrative data for self-analysis of performance and achievement[101]. Interventions implementing decision support tools, such as dashboards and monitoring charts, often leverage review meetings as a platform for presenting and discussing data analyses[37]. In Ethiopia, the Reaching Every District Using Quality Improvement Methods (RED-QI) intervention uses quality improvement methodologies such as Plan-Do-Study-Act (PDSA) for structured problem-solving during QRMs[101].

We found that at least 13 interventions in this review included data review meetings as a component. Only two articles specifically assessed the effectiveness of data review meetings in the context of routine immunization.

We found limited evidence that data review meetings led to data use outcomes in our TOC.

One longitudinal observational study analyzed qualitative data that had been collected on more than 200 review meetings conducted in four countries (Ethiopia, Kenya, Tanzania, and Uganda) from 2011 to 2016[101]. The only data use action reported was anecdotal: a case in which the QRM led to identifying a facility that had not vaccinated a single child in six months, despite having all necessary resources. This prompted follow-up from the district chairperson. The facility subsequently increased the number of children vaccinated through regular static and outreach sessions and demonstrated improved performance in later QRMs.

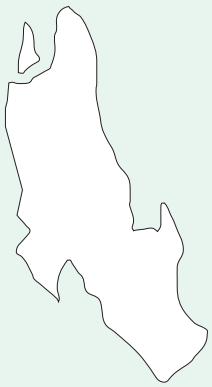
We found moderate-certainty evidence that data review meetings contributed to the achievement of impact indicators in our TOC, such as improved immunization coverage.

In our TOC, we hypothesize that improved immunization coverage is an outcome of improved data use; we therefore suggest that data use interventions that had an impact on immunization coverage likely involved, among other things, an improvement in data use. The same longitudinal case study and one other mixed-method multiple case study across three countries found that data review meetings contributed to

CASE STUDY

Improvements in data use in Zanzibar lead to improvements in data quality

One intervention in Zanzibar, Tanzania, set out to test the hypothesis that improvements in data use—in this case, through implementing quarterly data use workshops at the district level—would lead to improvements in data quality. The intervention benefited from contextual facilitators—namely, strong political commitment to improving the quality and use of HMIS data—and the rollout of DHIS2 software. The intervention reported achieving intermediate outcomes such as the availability of high-quality data and the analysis, interpretation, and review of data. Furthermore, a number of examples of improved use of data were reported, such as developing and applying improved indicators; this included some in immunization, like investigating high dropout rates and overage over 100% and identifying double counting[107].



reducing the number of undervaccinated children[101,105]. In the mixed-methods case study, quarterly district-level program review meetings were one of four key drivers of improved DPT3/third dose of pentavalent vaccine (Penta3) coverage in all three countries examined (Cameroon, Ethiopia, and Ghana). Other drivers and enablers included political and social commitment to routine immunization, actions of development partners, a cadre of community-centered health workers, health system and community partnership, and immunization services tailored to community needs. Nonetheless, the improvements could not be attributed to a single driver but rather stemmed from the synergy of the drivers.

We found low-certainty evidence that data review meetings contributed to improved intermediate outcomes in our TOC, including data quality and data interpretation and review.

The longitudinal case study reported a reduction in the proportion of health facilities with data disparities between oral polio vaccine, Penta, and pneumococcal conjugate vaccine coverage and data disparities for measles and Penta3 coverage over the course of five QRMs in Kenya[101]. It also reported that after multiple rounds of review meetings, health workers could better interpret immunization data and correctly complete monitoring charts. Each review meeting built on the recommendations and discussions from previous meetings to reinforce and supplement learning and practices. Adherence to RED methodology—including data verification, interpretation of facility immunization performance, identification of access and utilization problems, and peer review and feedback with a focus on performance drivers—was likely another success factor of the QRMs reviewed by Shimp et al. An assessment of immunization data quality in Mozambique by Mavimbe et al. supports the idea that the content of data review meetings and their approach to feedback are important success factors[101,106]. They found that data review meetings were predominantly used to discuss progress on meeting immunization coverage targets and that any criticism generally focused on why a facility was not reaching its targets, rather than on data completeness or validation. They found that such a singular focus on target achievement, although common in immunization programs, can reinforce negative perceptions of data serving the purpose of upward reporting through the system rather than supporting program implementation.

One factor for the success of data review meetings was their natural fit within existing processes in immunization programs, which enhanced both the adoption and sustainability of such meetings, since they were budgeted for in national immunization program annual plans. Another aspect of data review meetings that strengthened data use (even though it could not be quantified) was adapting the approach as culturally appropriate. In Mozambique, review meetings based on criticism without adequate support mechanisms were ineffective[106], whereas in Ghana, staff were motivated through

"name and shame" if performance was below expectations[105]. In most countries, however, a focus on team-oriented problem-solving with nonthreatening, learning-focused management techniques was highly motivating. Other success factors included documenting discussions through meeting minutes and conducting facility-level follow-up, on-site correction, and coaching by district staff to reinforce data use and action.

Incorporating quality improvement approaches, such as Rapid Appraisal of Program Implementation in Districts (RAPID) and PDSA cycles, with data review meetings can help provide a more structured approach to problem-solving and data use for decision-making.

Summary of Findings

- **Although few studies** have evaluated the impact of data review meetings on data use, there is low-certainty evidence that data review meetings lead to intermediate outcomes of data use such as data quality, analysis, synthesis, interpretation, and review.
- **Data review meetings are likely an effective tool** for improving health workers' data analysis skills and motivation for using data, and for facilitating the review and interpretation of data. However, if implemented in isolation, data review meetings are not likely to lead to data use. Rather, data review meetings are probably most successful when paired with complementary interventions that support data analysis (e.g., dashboards) and that provide follow-up or feedback loops (e.g., supportive supervision and learning networks).
- **Data use meetings that employ a structured approach** to problem-solving, drawing from continuous quality improvement methodologies such as RAPID and PDSA cycles, are more likely to lead to stronger data use outcomes.
- **Data review meetings that remain focused on learning** and team-oriented problem-solving are more likely to succeed in fostering a positive culture of data use.
- **Data review meetings have high plausibility** for contributing to sustainable improvements in data use by helping to standardize the processes for data use within already existing processes in the immunization program.

7. Peer Learning Networks

Peer learning involves gaining knowledge and skills through active help and support from people who have similar responsibilities and objectives[104]. Peer learning networks can connect health workers and allow them to interact, share information and feedback, and review and discuss data. By establishing connections across multiple levels of the health system, peer learning networks can help bridge the gap between data producers and data users. Increasingly, peer learning may take place on social network platforms like WhatsApp. Peer learning interventions align with the health care provider communication category of the WHO digital health intervention classifications, offering functionalities such as "communication and performance feedback to health care provider(s)" (2.5.2), "peer group for health care providers" (2.5.5), and so on.

We hypothesize that peer learning interventions may improve data use by addressing demand, skills, and motivation mechanisms in our TOC. Peer learning networks can increase demand for data use by building a culture of data use and empowering health workers to analyze and use data for decision-making. By facilitating the exchange of information and knowledge, peer learning networks can reinforce the development of skills in data analysis and in how to use data for problem-solving. They can bolster health worker motivation to use data by offering support from peers, as well as examples of their success using data to improve program performance.

Peer learning networks can include structured teams with a common goal. John Snow, Inc. (JSI) has a variety of initiatives to improve supply chain performance—initiatives that include peer learning. Quality improvement teams (QITs) have been formed in Kenya, Malawi, Myanmar, Pakistan, Rwanda, and Tanzania[108]. The network consists of teams at the facility and district levels that meet regularly and use a quality improvement approach to interpret data, prioritize problems, find solutions, and take actions to improve performance. In Ethiopia, the RED-QI approach implements QITs at three levels: community/health provider, Woreda Health Office, and primary health care unit[104]. Social networks are another type of network that provide an electronic platform for users to create a personal profile and build a network of connections with other users[109]; one example is the WhatsApp group peer network for health workers in Tanzania and Zambia under the BID Initiative[110]. At the national level, the BLN connects stakeholders like EPI managers and electronic health, or eHealth, specialists across more than 20 participating countries in Africa[111]. Network activities include design collaboratives, targeted discussions on topics like designing patient registries and increasing health worker motivation, webinars, and study visits. A promising strategy in Bogota, Colombia, is NOTI-PAI, an electronic messaging system that allows immunization officials to send news and immunization-related updates to vaccinators. Vaccinators report that the system allows them to follow up on undervaccinated children and defaulters[112].

Although we found no evidence that peer learning networks led to data use outcomes in our TOC, we found moderate-certainty evidence that peer learning networks led to improved vaccine availability.

Among the peer learning network interventions, none specifically evaluated the interventions' effect on data use. A survey completed by BLN participants in 14 of the 29 countries revealed perceptions about what participants have gained through their involvement with the network. The results indicated that the BLN has increased participants' knowledge and skills on immunization registries, change management, data use, and data quality[110]. Most participants also reported sharing information learned from the BLN with colleagues in their countries. In a few anecdotal examples, participants indicated that their participation in the BLN has helped them to be more data oriented in their work and to make decisions based on data. An Information Mobilized for Performance Analysis and Continuous Transformation (IMPACT) Team Network project report cited project M&E data results that indicated that the districts with IMPACT teams had

considerably lower stockout rates compared to non-IMPACT team districts. Although the report did not measure the effect on data use, it is reasonable to suggest that an increase in data use could explain the observed improvements in supply chain management[113]. The report provided anecdotal evidence from IMPACT team participants that the intervention improved relationships and communication among health workers and that actions were taken following team discussions. A likely success factor was the application of quality improvement approaches, which provided a structured approach to interpreting data, prioritizing problems, finding solutions, and taking action to improve performance. In Ethiopia, the effectiveness of the RED-QI approach, which included QITs along with other data use activities, was reportedly evaluated, but we were unable to obtain a copy of the study for this review.

In Malawi (as discussed in Section 2), the cStock mHealth tool for reporting stock data had a significantly stronger effect on supply chain performance indicators when implemented with multilevel QITs (DPATs). Shieshia et al. found higher mean reporting rates (94% compared with 79%; $p < .001$) and lower mean stockout rates (5–7% compared with 10–21%; $p < .001$) in the study group that benefited from the DPATs[61]. These findings suggest that interventions that address data availability barriers to data use, such as cStock, are more likely to improve data use when they are combined with health management systems and structures, such as QITs. In particular, the evaluation found that DPATs facilitated better data use by connecting data producers with decision-makers at higher levels of the health system[61].

In Myanmar and Pakistan, regions and districts implementing QITs demonstrated improvements in stock availability and decreased stockouts[108,114]. In Pakistan, decreased vaccine wastage was also attributed to the QITs. In Myanmar, stockouts were consistently lower in QIT sites than in non-QIT sites over a seven-month period (24% in QIT sites and 38% in non-QIT sites).

A peer training intervention in Indonesia found that DPT, polio, and measles vaccinations rose by about 39% following the intervention, which was targeted to poorly performing immunization nurses. Nurses with poor performance were selected based on their record of poorly reported immunization data or data indicating low immunization coverage. The intervention involved on-the-job training provided by experienced immunization nurses and covered topics such as how to operate the information system and how to use the record book to identify defaulters[115].

BOX C.

Literature review of how social network platforms can improve the use of data

MEASURE Evaluation conducted a literature review related to social network platforms and data use. It found that, of the six included platforms, most focused primarily on improving data reporting and quality (e.g., completeness) and on troubleshooting issues related to introducing new data collection or analysis tools. This finding was attributed to the early stages of the intervention and the recognition that data quality is an important precursor to data use. Participants in the network tended to be reluctant to share their data if they perceived the data to be incomplete or of low-quality. The review did not find evidence of a contribution to increased use of data, suggesting that the existence of platforms for data review and discussion alone do not guarantee data use[68].

We found low-certainty evidence that peer learning networks led to intermediate outcomes in our TOC, such as improved data review, analysis, and interpretation.

Although we found no evidence of the data use actions in our TOC, we found evidence of peer learning networks leading to improvements in knowledge, motivation, and skills related to data use. The BID project surveyed participants in the WhatsApp group peer networks as part of the PATH internal midline assessment in Tanzania and Zambia. It found that health workers self-reported an increased awareness and knowledge of peer facilities' vaccine coverage and stock[116]. There were mixed results on the extent to which the WhatsApp groups increased health workers' knowledge of how peer facilities were overcoming their immunization challenges. While increased knowledge was reported in Tanzania, it remained relatively unchanged in Zambia, suggesting that

health workers in Zambia may not have used the network to discuss challenges. Health workers in Zambia, however, affirmed that communication with peer facilities had increased their overall knowledge, motivation, and skills related to data use[116].

Peer learning networks were found to work best when they included the right people. The IMPACT teams, for example, brought together staff from across departments and levels of the supply chain to ensure a systemwide view when problem-solving[113]. This approach involved actors at lower levels as much as possible, given their proximity to service delivery. Strategies that incorporated one-to-one learning from a more experienced peer, as in the peer training intervention in Indonesia, were more effective than classroom-based training because they provide a non-threatening atmosphere in which trainees were more comfortable admitting to peers about training topics they did not understand. Another success factor was adopting structured approaches to continuous quality improvement (e.g., analyze, prioritize, identify root causes, develop practical solutions, implement, and monitor).

Summary of Findings

- **There are no studies** that have evaluated the impact of peer learning networks on data use or intermediate outcomes of data use, but there is emerging evidence of peer learning networks leading to improvements in knowledge, motivation, and skills related to data use.
- **Peer learning networks** are likely most effective at problem-solving when they bring together individuals from across departments and levels of the health system and when they adopt structured approaches for continuous quality improvement.

8. Supportive Supervision, Mentorship, and On-the-Job Learning

Many terms are used to describe supervisory activities in the health sector. Vasan et al. define supervision broadly as an activity where "a more senior professional, or a supervisor from a higher level in the health system, audits and/or directly observes the work of a primary HCW [health care worker] to ensure that the correct activities are being performed, and that they are done effectively"[117]. The concept of supportive supervision has even broader meaning and emphasizes quality at all levels of the health system, stronger relationships, and a focus on identifying and resolving problems[117]. Interventions involving supportive supervision respond to the lack of adequate feedback and support mechanisms at all levels of the health system. Within our TOC, supportive supervision, mentorship, and on-the-job learning seek to address skills and capability mechanisms by offering ways to build health workers' skills while fostering performance and motivation.

Among the WHO digital health intervention classifications, we found that "monitor performance of healthcare provider(s)" within the human resource management intervention category (3.1) was the most closely aligned intervention function. Although the literature we reviewed did not position supervisory activities as digital health interventions, we recognize the potential for digital health applications for this category of data use intervention.

Approaches we found in the immunization literature included strategies that:

- *reinforced routine supervision, such as a supportive supervision strategy targeting increased use of EHRs among village doctors in China*[118]*;*
- *periodically deployed cross-disciplinary, multilevel teams to work with health facilities and districts, such as the immunization DITs in Uganda*[119]*; and*
- *involved either recruiting new staff or identifying existing staff to fit specialized supervisory and mentorship roles, such as district data use mentors within the BID Initiative or immunization and surveillance data specialists (ISDS), as piloted by CDC's Stop Transmission of Polio program*[120].

In Uganda, DITs are composed of district, subdistrict, and health facility staff working in immunization, surveillance, and data management. During weeklong deployments, DITs spend five to six days at the district office and visit health facilities. Activities include data quality assessments, identification of data quality improvement activities, mentorship, and support to district-level staff. Similarly, CDC's ISDS strategy involves repeated short-term deployments (five and a-half months) of ISDS experts from around the world to provide technical assistance on EPI and issues related to vaccine-preventable disease surveillance data at the subnational level. As part of the BID Initiative's strategy, district data use mentors are government district staff who receive comprehensive training to provide ongoing support and mentoring to facility staff on data quality and use interventions.

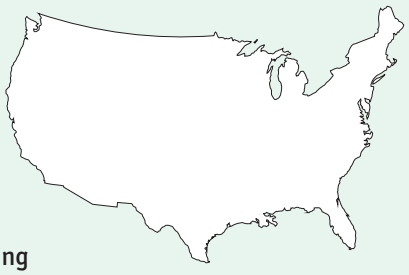
We found that some form of supportive supervision was included as a component in 28 interventions in this review. Only four articles specifically assessed implementing supportive supervision interventions in the context of routine immunization.

We found mixed evidence that supportive supervision intervention strategies led to data use outcomes in our TOC but high-certainty evidence that they contributed to improvements in immunization coverage.

There was mixed evidence of the effectiveness of DITs in Uganda. Results from routine monitoring showed improvements in data use at district and facility levels between the first and second round of DIT deployments[119]. These results showed an increase in the proportion of health facilities and districts with documented evidence that routine immunization data were used for action. They also showed an increase in the proportion of health facilities that knew their target population of children under 1 year of age. However, a rapid organizational-level survey assessed initial results after the second round of DIT deployments in a sample of districts and health facilities and found limited evidence that recommendations around data analysis and use had led to any improvements after the first DIT deployment[121]. The survey found at both district and

CASE STUDY

Effect of a national data quality assessment and feedback system on HIV testing data implemented in the United States



In the United States, the CDC implemented a national data quality assessment and feedback system intended to improve the quality of HIV-testing data. The intervention included routine conference calls with health departments, during which feedback was provided on data integrity, timeliness, and completeness. The results of the study showed improved completeness in four of the eight variables studied, which were also the same variables that did not already have high levels of completeness. The results suggest that providing remote supervision via mHealth interventions may improve data quality and could provide an alternative approach to on-site supervision, which is costlier and more resource intensive. We are cautious, however, to interpret the generalizability of these findings for LMICs, given important contextual differences[126].

facility levels that the recommendations issued by the DIT related to data management and collection were more fully implemented than those related to analysis and use. Among the five health facilities visited, none had taken action on the DIT recommendations to improve data use. Reasons for inaction included insufficient availability of required materials, inadequate human resource capacity (e.g., new staff, untrained staff, and low motivation), and a poor management structure with a lack of clarity around roles related to data analysis and use. Methodological differences may explain the contradictory results from routine monitoring compared with the rapid organizational-level survey. The survey was based on a small sample of health districts and facilities and used different data collection methods than routine monitoring. Also, the survey results may have been influenced by selection bias due to purposive selection of sites.

The other studies we reviewed reported only on data completeness. The RCT in China reported that the supportive supervision intervention helped increase the proportion of complete child vaccination records in the EHR from 15.4% to 33.3% ($p = .05$) after six months of implementation and there was no noticeable improvement in the control group. Although the intervention was deemed successful at improving the use of EHRs by village doctors, the study did not provide evidence of how EHRs were used; the only outcome measured was completeness of EHR records. Nonetheless, the strength of the study design provides compelling evidence of the effectiveness of supervision strategies. In particular, elements thought to have contributed to the intervention's success were the tailored nature of the supervision, on-site coaching, and technical support that doctors received, including hands-on help in how to use the EHR in a way that fit the doctors' particular circumstances and needs.

Despite the mixed evidence on the effect of supportive supervision interventions on data use, after expanding the review to include literature outside of immunization, we found three systematic literature reviews on health worker performance in LMICs[117,122,123]. Although the reviews did not specifically examine data use outcomes, they did find that multifaceted approaches, including supervisory activities, were effective at building general capacity of health workers. Rowe et al. found that supervision with audit-and-feedback techniques was an effective strategy to supplement in-service training[124]. We found similar strategies employed in the United States under the CDC's Assessment, Feedback, Incentives, and eXchange (AFIX) program for increasing quality improvement in immunization service delivery. The program begins with an assessment of health care providers' immunization delivery practices, which is followed by tailored feedback and follow-up[125].

Vasan et al. examined the literature on supervision, mentoring, and coaching. They found that the evidence on supervision activities was the most extensive and provided the strongest likelihood of having a positive effect on health worker performance and quality improvement[117]. Among the 23 studies on supportive supervision identified in the review, 3 reported on immunization outcomes: an RCT in the Philippines that found a 75% increase in correct antenatal care record keeping; a pre-post study in Georgia that found a statistically

significant increase in DPT3, polio, and hepatitis B coverage and a significant reduction in vaccine wastage; and a systematic review and meta-analysis of Integrated Management of Childhood Illness training and supervision, which found worsening vaccination rates, although not statistically significant. The authors found limited evidence on the roles of mentoring and coaching; they cited a need for more research on these types of approaches.

We found moderate- to high-certainty evidence that supportive supervision intervention strategies led to improvements in data availability and quality. We also found low-certainty evidence that they led to improvements in data analysis, synthesis, and interpretation.

We found three studies and two reports with M&E data that showed measurable improvements in data use intermediate outcomes. As already discussed, the RCT conducted in China showed evidence of increased data availability due to improved completeness of child vaccination records.

In Kenya, results from the CDC ISDS pilot found that, between the first and second deployments, health facility staff's knowledge and skills improved (e.g., an increased proportion of health facilities could correctly calculate a dropout rate, keep monitoring charts up to date, and properly archive EPI and vaccine-preventable disease data). Data quality also improved in terms of congruence between tools (e.g., register, tally sheet, summary sheet, and DHIS2), and between the target population for a health facility and the corresponding target population for the same health facility at the subcounty. Specific elements of the supportive supervision intervention strategies that appeared to have facilitated these improvements included identifying site-specific problems, followed immediately by conducting on-the-job training, which helped reinforce health workers' knowledge and skills, and conducting most of the on-the-job training at the health facility.

We previously reported on the results from a case study in Kyrgyzstan where the primary intervention was paper-based monitoring tools such as monitoring charts and dashboards. The intervention, which also included supportive supervision activities, found that including indicators concerning the information system in routine supervision checklists led to enhanced data quality in routine immunization reports. In addition, the supervision checklists were used to score health facility performance, which was found to motivate health workers to improve data quality[81].

Summary of Findings

- **Few studies examine** the impact of supportive supervision strategies on immunization data use specifically; generally, the evaluations of such strategies tend to examine other elements of health worker performance.
- **The specific stand-alone models** of supportive supervision strategies that have been studied within the context of immunization programs (e.g., team deployments to health districts and facilities) show mixed evidence of having an effect on data use but provide moderate- to high-certainty evidence that they lead to improved data quality and availability and low-certainty evidence that they lead to improved data analysis, synthesis, and review.
- **Some form of supportive supervision** was included as a component in 28 interventions in this review, suggesting that supportive supervision is a widely used strategy to reinforce feedback mechanisms that support data use.
- **Supportive supervision is likely most effective** when it applies audit-and-feedback techniques, such as site-specific problem identification, followed by coaching and on-the-job training tailored to the identified gaps.
- **Supportive supervision is also likely most effective** when it involves a two-way flow of information between the supervisor and health worker and when the feedback is provided through both oral and written means on a routine basis.

9. Training

Inadequate capacity of health workers, managers, and decision-makers to collect, analyze, synthesize, and interpret data is a barrier to data use at all levels of the health system. One of the most common approaches to strengthening capacity is training. For the purposes of this review, training refers to any intervention to strengthen the capacity of those individuals responsible for the collection, analysis, synthesis, and use of data at all levels of the health system through workshops, classroom-based learning, and other more hands-on approaches. This could include formal education (also known as pre-service training) or on-the-job training (known as in-service training). Training has the potential to improve the use of data through multiple mechanisms by improving the demand for, access and availability of, and quality of data and improving the skills of health workers to collect and use data.

Although there is a substantial literature on training, this review found limited literature on training as a primary intervention type intended to lead to the data use actions in our TOC, even outside of immunization. However, it is worth noting that training in varying forms and intensities is included as a secondary component in at least 17 of the other interventions covered in this review.

All of the training interventions we reviewed (where training was the primary intervention type) involved in-service training for health workers, managers, and other personnel. We did not find evidence from interventions intended to improve the effectiveness of pre-service training to increase capacity to use data. However, some interventions included in this review, such as an intervention in Côte d'Ivoire to increase the use of data in decision-making[87] (discussed more fully in Section 10 as an example of a multicomponent intervention), included both in-service and pre-service training components to cultivate skills in the analysis, synthesis, presentation, and interpretation of data, along with more traditional M&E techniques. These remained part of the national training curricula even after the intervention ended.

Trainings vary in length and style. A systematic review of strategies to improve the performance of health care providers in LMICs found that training alone yielded just modest improvements in health worker performance, but when combined with other interventions, such as strengthened infrastructure, financing supervision, and management techniques, training was more effective[124]. Group problem-solving was also found to increase the effectiveness of training. Increasing the length of training was not found to lead to a commensurate increase in the effectiveness of the training, unless the training included more than one topic area.

We found moderate-certainty evidence that training contributed to improvements in the data use skills and capabilities of participants.

For instance, CDC collaborated with a local university in Ethiopia to offer a Leadership in Strategic Information course, which included modules to equip participants to use data to improve the assessment, planning, surveillance, and M&E of HIV and other diseases. Pre- and post-training assessments indicated that participants' self-reported skill levels had increased. Furthermore, participants were required to apply the knowledge gained through the training by conducting a needs assessment to identify a key public health challenge in their region. The teams then gave a presentation, which was evaluated to determine improvement in skills. Scores from the presentation indicated that participants had developed critical skills in program planning, data collection, and data analysis, though there was need for improvement, particularly

in generalizing qualitative findings and developing actionable recommendations. Following a five-country training to improve data-driven decision-making in HIV-testing programs (implemented in South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe), participants noted increased confidence in interpreting data and assessing target achievements[127].

However, we found low-certainty evidence that training contributed to data use outcomes in our TOC.

This can be attributed at least in part to the evaluation design, typically pre- and post-training assessments based on self-reported experiences of participants, rather than formal evaluations or longitudinal studies of behavior change. The Data for Decision Making (DDM) intervention in Cameroon included an interdisciplinary training package focused on epidemic preparedness for bacterial meningitis, cholera, and yellow fever at the district, provincial, and national levels[128]. Following the trainings, DDM-trained health officers detected an impending epidemic in two health divisions and implemented a vaccination program within two weeks, preventing a potentially large epidemic[129]. There is a need for more longitudinal studies to assess the extent to which training contributes to sustained improvements in data use. At present, there is anecdotal evidence of training participants using data to inform actions. For instance, in one example of capacity built through the DDM interventions in Cameroon, a charge nurse identified an outbreak and notified provincial officials, and an immunization campaign was quickly organized.

The WHO Immunization Academy "aims to improve the capabilities of immunization staff to ensure that data that is fit-for-purpose is available in the right place at the right time to allow for timely decision-making and improvements in planning implementation and monitoring to result in better program outcomes"[130]. The Academy has used the WHO Scholar Programme, a distance learning program implemented by WHO since 2016. The Scholar approach was designed based on evidence-based action and applied learning, leadership acceleration, mentoring, and collaborative methodologies. Courses include how to develop a data improvement plan, key topics for immunization monitoring, and coverage surveys. After successfully completing the course, participants become part of the WHO Scholar Alumni network, and are invited to support new scholars. This approach has not yet been evaluated but represents a promising training strategy.

We found moderate-certainty evidence that training may be more effective as part of a multicomponent intervention and/or when reinforced by other supportive activities—most commonly, supportive supervision.

All but one of the training interventions reviewed implemented supervision following the training; this was viewed as essential to reinforcing and applying the skills gained through training. Other supportive activities included peer learning, where opportunities were created for training participants to meet, share experiences, and engage in group problem-solving[131,132]. Furthermore, the DDM intervention implemented by CDC in Bolivia, Cameroon, Mexico, and the Philippines included improvements to HMISs through streamlining indicators to make them more relevant and thereby promote use.

One intervention in Botswana aimed to increase the number of health information personnel by creating district M&E officers, an entirely new cadre of health worker. University graduates were hired and provided with on-the-job training in health informatics and M&E. Trainings were conducted 2-3 times per year and included a combination of didactic sessions and more hands-on skills building approaches. Skills developed through trainings were reinforced with mentoring from I-Tech and the Ministry of Local Government. Knowledge in skills related to computer literacy, checking data validity, data quality procedures, developing indicators were reported by participants to have improved significantly over the year[133].

This was supported by evidence from the systematic review of interventions to improve health provider performance[134], which found that training was more effective when combined with other interventions, such as supervision and group problem-solving. Incorporating exercises in which training participants could apply their knowledge to real-world situations was also found to be important to reinforce key capacities strengthened through training.

Summary of Findings

- **Post-intervention assessments** found that training contributed to improvements in the skills and capabilities of participants.
- **We found only limited anecdotal evidence** of training contributing to data use outcomes in our TOC. This is attributable at least in part to the design of included evaluations, many of which only included pre- or post-training assessments that were based on the self-reported experiences and skills of participants. There is a need for more thorough evaluation of specific trainings and the extent to which they contribute to improvements in data use on a longer-term basis. For instance, the WHO Scholar Programme contains material that is very relevant to data use, but it has yet to be evaluated.
- **We found that training may be more effective** as part of a multicomponent intervention or when reinforced by other supportive activities—most commonly, supportive supervision. All but one of the training interventions included complementary activities such as supportive supervision, which was identified as crucial in reinforcing training materials.

10. Other Data Use Interventions: Multicomponent Interventions

Although many of the interventions we reviewed comprised activities that addressed various mechanisms of data use, the literature reviewed in previous sections tended to showcase a specific component more prominently (although many of them could still be considered multicomponent). For instance, the BID Initiative included a suite of interventions aimed at improving the use of immunization data. However, EIRs were the most prominent intervention type; therefore, it was included in the EIR section. In this section, we discuss a number of multicomponent interventions that leveraged many or, in some cases, nearly all of the intervention categories that we previously discussed, but which lacked a clearly identifiable primary intervention type.

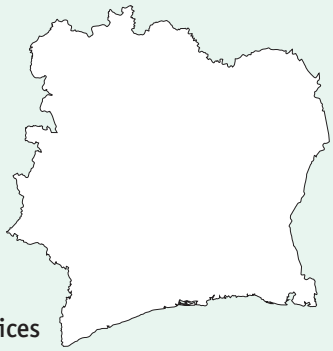
These multicomponent interventions included JSI's Building Routine Immunization Capacity, Knowledge and Skills (BRICKS) framework for strengthening immunization program competencies, leadership, and management. BRICKS includes situational assessment to identify needs and prioritize support, supportive supervision, review meetings, and applied training (on-the-job and coaching)[135]. The same framework has influenced other interventions, such as RED-QI[104]. The RED-QI project applies practical quality improvement models and tools to strengthen routine immunization. Intervention components include QITs that meet regularly to identify and analyze areas that need improvement, tools to facilitate analysis of bottlenecks, PDSA cycles for a structured approach to problem-solving, peer learning and coaching to reinforce skills and knowledge, review meetings, and supportive supervision. In Ethiopia, a qualitative case study of the implementation of the RED-QI methodology at the health-post level found evidence that QITs were using simple tools, such as the EPI monitoring chart, to identify and track defaulters[136]. Despite promising practices, there were still challenges with the quality of data, such as insufficient skills and knowledge for proper reporting among health workers and poor motivation given the multitude of reports.

We found low-certainty evidence from a multicomponent intervention in Punjab, Pakistan, that multicomponent interventions could contribute to intermediate outcomes, data use actions, and even impact (increased immunization coverage) in our TOC.

In 2014, implementation of the Punjab Health Roadmap, a broad effort to improve MCH outcomes, commenced[137]. Low immunization coverage (49% at baseline in 2014) was identified as a key barrier to improving child mortality. The intervention included tracking vaccination coverage rates in real time with an mHealth application, regular data review meetings where districts compared progress and discussed challenges, and frequent "stocktakes" with the chief minister of Punjab province. By 2016, coverage had increased to 82%. Key factors driving this dramatic improvement were commitment and hands-on leadership from the chief minister via stocktake meetings to review progress and enforce accountability for outcomes. Concurrently, efforts were undertaken to improve access to delivery centers and to improve health facilities, with similarly positive results.

CASE STUDY

Experimental study of a comprehensive multicomponent data use intervention in Côte d'Ivoire



The government's efforts to strengthen data-informed decision-making in Côte d'Ivoire was the only data use intervention we found that was evaluated with a quasi-experimental study design (pre-post study using a combination of purposeful and random sampling, but not random assignment)[7]. It was also one of few evaluated multicomponent theory-based interventions designed to explicitly address all three domains (behavioral, technical, and organizational) of the PRISM framework that also influenced our TOC[19]. Implemented from 2008 to 2012, the intervention worked on developing the country's HMIS infrastructure and strengthening its human resource capacity, both in quantity and skills. Training in data analysis and traditional M&E practices was added to both in-service and pre-service curricula for government health workers, data managers, and clinicians. To address the staffing shortages, new leadership positions and regional M&E units were created to oversee data management, conduct regular M&E supervision, transmit data to the central level, and lead data-informed decision-making. The Ministry of Health developed national guidelines with clearly defined processes and procedures for frontline staff with data use responsibilities, including national supervision guidelines, a data management procedures manual, a national DQA protocol, and terms of reference for routine data quality assessments. At the district level, the study found an increase in the data use score between baseline and endline (from 44% to 70%). The study developed the data use score, a composite, continuous index of three dichotomous data use indicators established by the PRISM framework (whether RHIS information was discussed in staff meetings, whether decisions were taken from the discussions, and whether the decisions were referred to upper management for action) to measure quantifiable changes in data use. The data use score remained unchanged at the facility level, but measures of data quality and availability increased at both facility and district levels. Authors posited that the emphasis on data quality, which was not combined with other complementary data use activities, likely explained the lack of an increase in data use by health facilities. This finding suggests that improvements in data quality alone do not lead to an increase in data use.

We reviewed other multicomponent interventions that fall into the category of promising strategies, namely Shifo Foundation's MyChild Solution and MyChild Outreach interventions, implemented in various forms in several countries. Both sets of interventions involve digitizing paper records on Smart Paper Technology. MyChild Solution includes the MyChild Card (an HBR), MyChild Birth Record, MyChild Health Record, and TT Vaccination Card (another HBR). MyChild Outreach is a related intervention to strengthen efforts to provide services to marginalized communities through outreach. This includes the MyChild Card, a text message reminder system, a defaulter list, an Outreach performance card, and a session performance dashboard. While evaluations of the MyChild Card have been conducted in Afghanistan, Uganda, and The Gambia (discussed more fully in Section 1), implementation of these multicomponent interventions have yet to be evaluated, but they have the potential to address many of the intermediate outcomes in our TOC and to lead to data use actions at all levels.

We found mixed evidence to suggest that the use of data to monitor stock levels at the community level and to determine when to request additional supply (as part of a broader intervention to improve availability of medicines and commodities) contributed to improved stock availability.

JSI implemented the Strengthening Supply Chains at the Community Level intervention in Ethiopia, Malawi, and Rwanda to improve the availability of key medicines and commodities at the community level. The intervention included developing simplified resupply procedures, training on the resupply procedures, and forming multilevel QITs to support implementing these new procedures.

Although there was evidence of more consistent stock of some medicines and commodities at the community level, inconsistent stock levels at the resupply point (often resulting from inadequate national stock levels) and inadequate data use at higher levels were identified as barriers to impact.

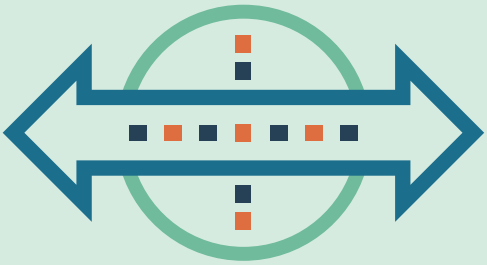
BOX D.

Applying user-centered design to data use challenges in South Africa and Tanzania

We found one promising strategy that employed a user-centered design and did not fall neatly into any of the intervention categories previously discussed and is not a multicomponent intervention. Using a user-centered design approach, MEASURE Evaluation implemented a series of workshops in four districts in South Africa and Tanzania to develop prototype interventions to improve data use. The workshops involved discussions about a successful HIS, during which participants identified and ranked barriers to data use and brainstormed prototype interventions to address those challenges and achieve improved use. Prototypes ranged from the relatively simple to the more complex and resource intensive. These prototypes included use of social media platforms like WhatsApp to improve interaction between data users and data producers and provide support in solving technical computer-related issues, enhanced supportive supervision (including identifying best practices in supportive supervision), programs to reward facilities that submit their data in a timely fashion, and portals to improve visualization of real-time data, among many others. Although this initiative ended with the design of prototypes and did not include implementation, participants committed to taking some of the ideas forward. The user-centered approach is significant for its attention to the human factors that facilitate data use and could be considered in the context of other projects[138].

Summary of Findings

- **We found low-certainty evidence** from a multicomponent intervention in Punjab, Pakistan, that multicomponent interventions could contribute to intermediate outcomes, data use actions, and even impact (increased immunization coverage) in our TOC.
- **Outside of immunization,** we found high-certainty evidence from a comprehensive multicomponent intervention in Côte d'Ivoire of intermediate outcomes in our TOC, namely the availability of timely, high-quality data.
- **We found mixed evidence** to suggest that the use of data to monitor stock levels at the community level and to determine when to request additional supply (as part of a broader intervention to improve the availability of medicines and commodities) may contribute to improved stock availability.



Recommendations

for Improved Monitoring and Evaluation

We found numerous published and grey literature on interventions to improve data quality and use but few examples of rigorously evaluated data use interventions. In this section, we describe and recommend best practices for M&E of interventions to improve data use. Both endeavors could be strengthened: monitoring primarily through better indicator definitions and evaluation primarily through more appropriate evaluation designs. There is a need to develop better measures for assessing data use in decision-making to better understand the effectiveness of these interventions. In this section, we review existing methods that have been applied to measuring data use and propose a set of indicators that are adapted for measuring routine immunization data use. We then propose guidance for evaluators seeking to measure whether, why, and how these interventions work.

Monitoring

Routine monitoring data can provide important insights into whether and why a data use intervention is working. As the data use field has matured, implementers and funders have increasingly developed and applied sound M&E plans, including measurable indicators. As a general principle, we recommend that data use interventions' M&E frameworks should:

- *align with an intervention TOC (e.g., the IDEA TOC);*
- *include process, output, outcome, and (if possible) impact indicators; and*
- *enable real-time data collection to facilitate continuous learning and adaptation.*

Process and output indicators

Process indicators should monitor the implementation process, including its fidelity and quality, its activities, and potentially even its outputs. Process indicators will differ according to the interventions or programs but should be used to help inform whether the assumptions in the intervention TOC are being met. Process indicators should pay attention to individual, organizational, technical, and behavioral levels. Table 3 gives examples of indicators that we adapted from the PRISM RHIS performance diagnostic tool[139] to use for monitoring routine immunization data use. These evaluators assume that taking action on data requires these other inputs.

TABLE 3.

PRISM RHIS performance diagnostic tool adapted for immunization

Health facilities

01.	**Does the facility chart and display data (in a table, graph/chart, or map) on immunization coverage rates?**
02.	**Has the facility had a routine meeting to review immunization data in the last month?**
03.	**Has the facility in charge participated in meetings at the district level to discuss routine immunization performance in the last three months?**
04.	**In the last three months, did the facility receive any feedback from the district office on its EPI program performance?**
05.	**Has the facility received any guidelines or recommendations for action (based on routine immunization data) from the district office in the last three months?**
06.	**Has the facility received a visit from a district supervisor to discuss EPI program performance and/or help make a decision based on immunization data?**
07.	**Does the facility have a procedure manual for data collection and/or data use?**

Health districts

01.	**Does the district display data (in a table, graph/chart, or map) on immunization coverage rates?**
02.	**Has the district had a routine meeting to review immunization data in the last month?**
03.	**Did the district publish a newsletter or report in the last three months showing examples of use of immunization data?**
04.	**Has the district sent a feedback report using immunization data to facilities during the last three months?**
05.	**Does the district have an up-to-date district health management organizational chart showing functions related to HMIS and immunization information?**
06.	**Does the district have a procedure manual for data collection and/or data use?**

As identified through this review, behavior change is often necessary for intervention adoption leading to data use and should be tracked as a process indicator. Recent updates to the Consolidated Standards of Reporting Trials Statement for Social and Psychological Interventions (CONSORT-SPI) guidelines and other guidelines stress the importance of reporting on change processes and mechanisms underpinning behavior changes.

TABLE 4.

Example outcome indicators

Type of indicator	Indicator	Data source
Intermediate outcome	Health worker logged into EIR.	EIR system data
Intermediate outcome	Health worker ran a report of defaulters.	EIR system data
Data use action (outcome)	Health worker made successful contact (by telephone or text message, for example) with the families of children on the defaulter list and delivered validated key messages.	EIR data (e.g., option in child's record to indicate when contact was made)

Outcome indicators

The outcome of most data use interventions is likely to be some type of data use. Data use can be measured simply and at low cost if it is well defined and particularly if it is linked to an intervention TOC. In this review, we observed two main issues with existing indicators to measure intermediate outcomes or data use: a general lack of specificity (e.g., "data were used") and measurement of intermediate outcomes (e.g., "data were analyzed") but not data use actions (Table 5).

For example, the following indicator was used to measure data use: "HCW [health care worker] took action on their data to identify defaulters."[31,32]. While this indicator at least focuses on action, it could be more specific. The data source for this indicator is self-reports during interviews, which have a number of limitations. We propose the indicators listed in Table 4 instead.

Tracking trends in these indicators over time and identifying gaps between them would help implementers and supervisors determine where to focus assistance. Another benefit of more specific indicators is their ability to guide actual practice. Additionally, if indicators are presented in a checklist format, they will more likely be viewed as a job aid as opposed to an audit function.

On the other hand, certain data use interventions may be agnostic to specific data use actions, such as if the intervention aims to improve mechanisms like demand, capability, and motivation to use data for any decision. In these cases, outcome indicators may need to be generic. Another option is the use of contribution tracing to measure the relative influence of data or information on a decision that was made, starting with the decision as opposed to the data[140].

Finally, indicators and their measurement should be considered during intervention design and built in to the intervention itself as much as possible. The example in Table 4 uses the EIR system to track these indicators, but similar steps can be taken for non-digital interventions. Building on the findings that data review meetings were more likely to be effective if they followed a quality improvement structure, we propose adapting such a structure to suggest or prompt data use actions (e.g., "Did meeting attendees identify facilities or districts in need of a supportive supervision district?") and track the implementation and outcomes of those actions.

Taking into account these considerations, we propose a set of indicators for monitoring immunization data use interventions with a focus on the intermediate outcome and data use action levels of our TOC. The indicators are adapted from PRISM tools and draw from the data use literature in this review. To allow for triangulation between data sources, we include both self-reported (perceived) and verified (observed) indicators of data use skills and practices (Table 6) and a checklist of process indicators, adapted from the PRISM RHIS performance diagnostic tool and designed to assess the organizational facilitators of data use (Table 3).

TABLE 5.

Summary of indicators used in this report's reviewed documents

Measurement approach identified through this review	Benefits	Challenges
To measure data use, Nutley et al. generated a data use score based on three indicators of RHIS use: ► *whether RHIS information was discussed in staff meetings,* ► *whether decisions were taken from the discussions, and* ► *whether the decisions were referred to upper management for action*[7]. The score was determined based on a review of monthly data review meeting minutes.	The approach measures multiple steps in the causal chain. There is minimal or no respondent burden.	Meeting minutes alone may not be detailed enough to glean meaningful information.
The BID Initiative measures health workers' ability to use data according to three data use scenarios: ► *ability to identify defaulters,* ► *ability to identify areas with low DPT3 coverage, and* ► *ability to identify vaccine stock levels.* Health workers' data use practices are measured by asking whether they took action on their data in these three scenarios. The external evaluation included direct observation of data use practices[29,141].	Indicators are directly tied to specific data use actions Direct observation may be more reliable than self-reporting but still risks the Hawthorne effect. The approach may be more reliable than self-reported data use.	The outcome of the data use action could be more specific (e.g., "Health worker phoned families of defaulters to schedule an appointment"). Self-reporting is potentially inaccurate (as demonstrated in PRISM study in Uganda)[19]. There is a respondent burden related to self-reports and the cost of direct observation; automating the collection of similar indicators through the EIR system could reduce these costs.
The immunization DITs intervention in Uganda used a combination of indicators, which included the percentage of health facilities charting and displaying Penta3 and measles coverage and the percentage of districts and health facilities with documented evidence that routine immunization data were used for action.	Intermediate outcomes related to displaying data align with the DIT TOC and are a necessary condition for data use in this intervention.	Other key assumptions in the intervention causal chain are unmeasured, including whether health workers have the skills to interpret and discuss charted data. It was not clear what constituted "documented evidence" and how the data for this indicator were collected.

TABLE 6.

Indicators for monitoring immunization data use interventions

Indicator category	Facility level	District level	National level	Data source
Data use skills *perceived*	Ability to identify problems with data quality*	Ability to identify facilities with poor data quality*	Ability to identify districts with poor data quality*	Self-assessment of confidence in each area on a scale of 1–4
	Ability to identify defaulters and unvaccinated in facility catchment area			
	Ability to identify areas with low DPT3 coverage	Ability to identify facilities with low DPT3 coverage	Ability to identify districts with low DPT3 coverage	
	Ability to identify current vaccine stock levels in their facility	Ability to identify facilities with low stock levels	Ability to identify districts with low stock levels	
Data use skills *observed*	Ability to detect inconsistencies in data quality			Problem-based test
	Ability to calculate DPT3 coverage rate accurately			
	Ability to calculate dropout rate			
	Ability to develop a bar chart for full immunization coverage			
	Ability to find and interpret a trend in a visualization of immunization coverage data			
Data use practices *perceived*	**Data-informed action score (composite of the following indicators)**			
	Whether immunization data were used to take action in any of the following areas:			Self-reported data use over last three months
	- performance monitoring			
	- performance improvement			
	- management and routine supervision			
	- data quality improvement			
	- implementation planning			
	- vaccine stock management			
	- action plan development			
	- national program strategy and policy development			
Data use practices *observed*	**Data use score (composite of the following indicators)**			
	Whether routine immunization information was discussed in staff meetings			Meeting records over last three months
	Whether decisions were taken from the discussions			
	Whether the decisions were referred to upper management for action			
	Whether action was taken on the decisions			

* *For immunization coverage indicators, the ability to identify problems with data quality includes the identification of data quality issues in both numerators and denominators.*

Evaluation

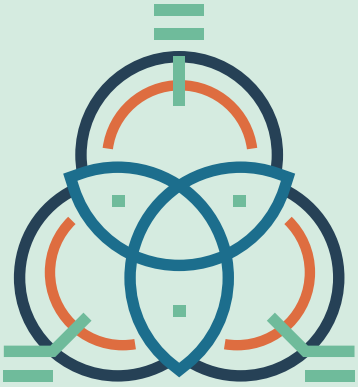
There are benefits and drawbacks to all evaluation approaches and designs. Ultimately, evaluations must be designed to optimize their informational value against the cost of imperfect information. Evaluating complex interventions, which encompasses most of the interventions reported here, requires a different prioritization of the design elements of evaluation. For example, while experimental study designs are considered the gold standard for evaluating biomedical interventions, as they reduce the risk of bias due to confounding by randomly allocating the intervention across a population, the traditional approach to experimental studies does not often leave room for investigating why and how the intervention works and, accordingly, how to transfer it to other settings[142].

Drawing from the evolving principles and guidance for the evaluation of complex interventions[142–145], we propose the following questions to consider when designing an evaluation of data use interventions.

01. ***Is an evaluation needed?***
    - *What is the level of confidence in the existing evidence?*
    - *What are the costs of making the wrong decision based on the existing evidence?*
    - *How transferable is the existing evidence to my context? How context dependent is the intervention, and did existing evaluations consider context adequately?*
    - *Is enough known about the cost-effectiveness of the intervention, including associated transaction costs in terms of time and human resources, to make an informed decision about whether to introduce the intervention?*
    - *Is it clear why and how the intervention works and how the effects vary by implementation quality, beneficiary groups, or other important dimensions?*
    - *If existing evidence suggests limited effectiveness, did this evidence adequately measure implementation fidelity?*
02. ***If an evaluation is needed, what type of evaluation is needed?***
    - *Considering the TOC for how the intervention works, what is the saturation of evidence and level of confidence in that evidence that data use is attributed to the intervention?*
    - *What are the most appropriate approaches and methods for generating or strengthening evidence for each causal link? How do these approaches weave together?*
    - *What is the feasibility and cost of various evaluation approaches? What are the trade-offs between internal validity and pragmatic considerations?*
    - *Consider whether more iterative approaches for real-time diagnosis and solutions, such as PDSA cycles and rapid quality improvement strategies, to drive ongoing engagement and faster impact, are feasible?*

In general, the evaluation of complex interventions often requires multiple approaches, where the priority is not to select the most rigorous approach (i.e., an RCT), but rather to select an approach "fit-for-purpose" to the question. Following the guidance of the British Medical Research Council and others, we recommend a component of process evaluation to uncover why and how the intervention works and its relationship to context[142]. Process evaluation need not be overly resource intensive; we can imagine a model of using routine monitoring data alongside document review and occasional observation and interviews. This could be embedded in a quasi-experimental outcome evaluation, such as an interrupted time series (again drawing from routinely collected data). Approaches that measure only changes in outcomes may be helpful for the setting in question, but they are not helpful for policymakers in other settings who must decide whether to implement that intervention. Evaluations must aim to make the conditions for success explicit. Further, robust process evaluation can help identify the full range of intended and unintended consequences of a data use intervention.

Basing evaluation on a robust TOC helps to narrow in on specific causal mechanisms to explore, which may be less costly or more feasible than evaluating certain outcomes. It can also help focus evaluation on the most costly components of an intervention to assess their contribution to change or to accelerate the evaluation timeline. For example, if we are reasonably confident that LMIS improves vaccine availability when supply chain managers log in and consult the reports multiple times per week, an evaluation of a new LMIS may focus solely on evaluating intervention components that aim to ensure that supply chain managers have the skills and motivation to log in and review reports. Such an evaluation could be low cost and rapid, but we also flag the importance of some type of long-term follow-up to measure the sustainment of these intermediate outcomes. Systems dynamics modeling may also be possible if parameter values along the causal chain are known or can be inferred[146].



Discussion

This review is the first of its kind that we are aware of to focus on the use of routine immunization data to inform immunization program decisions. The topic of data use is itself relatively new. Although much of the published literature on the topic provides insights into the barriers related to data use[9–13], we found few rigorous studies or evaluations of data use interventions on explicit data use actions. Considering the complexity of the phenomenon of data use for decision-making, we do not necessarily recommend investment only in RCTs or other experimental design studies to establish effectiveness; rather, we found that the most useful and richest evidence came from mixed-methods studies and evaluations that described why and how the intervention worked and for whom and where it worked. Few of the reviewed studies reported on the persistence of outcomes over time through an implementation science lens. Additionally, few studies measured unintended consequences of these interventions.

Although our primary focus was on what works to improve immunization data quality and use, we later broadened our search to include literature on data use interventions in other health sectors. Although not exhaustive, our search for evidence outside of immunization identified additional evidence that further corroborated and deepened our findings. We found a decent amount of research evidence on improving the quality and use of HIV data, owing in large part to the strategic focus on and investment in data use by PEPFAR. In previous reviews, multiple intersecting barriers to the use of routine health data in decision-making were identified as fitting within technical, organizational, and behavioral categories[19]. Our review considered these factors, along with other literature, and proposed a TOC for data use that guided our analysis. This review helps fill a critical gap in what is known about the state of the evidence on interventions to improve routine health data. By employing a structured, theory-based approach to synthesizing the available evidence on data use interventions, this review adds to the knowledge about what interventions work, why they work, under what circumstances, for whom, and at what levels of the health system. Our conclusions agree with other literature on the topic. For example, the finding that multicomponent interventions are likely more effective than single-component interventions was echoed by a literature review conducted by MEASURE Evaluation and a systematic review of strategies to improve health care provider performance[124]. The review suggested that a comprehensive and integrated approach to improving data use is necessary for sustained results, considering the complex array of barriers to data use[11].

On the topic of data quality, there is a strong notion in the literature and among global health practitioners that improvements in data quality will lead to data use. The assumption follows that if investments are made in improving

data quality, then heath workers will use that data for making decisions to improve program performance. Although results of this review confirm that data quality is an important barrier and necessary precursor to data use, we found evidence to suggest that data quality interventions alone are likely not enough to lead to improvements in data use. This is because health workers may lack the necessary skills to analyze and translate data into information that is useful for making decisions on program implementation. They may also lack the motivation or awareness of how data can lead to improved program performance, or the structures and processes that help create an enabling environment for data use may be lacking. Rather, there is more compelling evidence to suggest that data use interventions are more likely to lead to improvements in data quality. The evidence suggested that as health workers began using their data more, they were able to identify inconsistencies with data quality and take corrective action. Data use also appeared to generate demand for higher quality data, which in turn drove actions to improve data quality; as data quality improved, users were able to better trust the data, thus reinforcing data use.

Selecting an appropriate package of interventions requires that stakeholders weigh considerations about an intervention's effectiveness, sustainability, and overall cost, including both monetary and transaction costs. However, we found limited studies and evaluations that included cost-effectiveness analyses and therefore were unable to examine the cost-effectiveness of interventions included in this review. Likewise, we did not find any examination of the outcomes of data use interventions over the long term, which makes it challenging to determine how to successfully ingrain data use in the health system and ensure lasting results. Many of the HIS interventions including EIRs, LMISs, and HMISs pointed to challenges, especially at the service-delivery level, with operational barriers, such as frequent power outages leading to data entry backlogs, and administrative burdens on health workers, such as parallel paper and electronic data entry. HCWs' doubts about system sustainability in light of past failed attempts and concerns about data loss also tended to limit the acceptability of these systems among frontline HCWs. We propose additional research on the topic and suggest additional consideration of the human transaction costs associated with the intervention, as well as any potential unintended consequences for service delivery.

The state of the evidence around what works to improve data use is still nascent. Few data use interventions have been rigorously studied or evaluated. We found more evidence on intermediate outcomes within our TOC, such as improvements in data quality, availability, analysis, synthesis, interpretation, and review, but less evidence on what works to support action and decision-making informed by data. The lack of consensus around how to define data use and what actions constitute data use makes it challenging to establish agreed-upon measures of data use and poses a barrier to generating evidence on the effectiveness of data use interventions[15]. Nonetheless, the information and evidence we collected permitted us to develop stronger evidence-informed theories on what works to improve the quality and use of data, for whom, and under what circumstances.

We also noted particular gaps in the evidence on what works to improve data use at the facility level. Our findings suggest that more emphasis has been placed on data use at the district level than at the facility level, where the focus has tended to center more on data quality than on data use, likely given that the facility level is the point at which data are generated. Also, HMIS strengthening in support of decentralized health systems has emphasized making data available to district health managers so that they have the information required to make informed decisions about service delivery. However, our review of the evidence suggests that data use interventions are more likely to lead to improvements in data quality than data quality interventions alone. More emphasis on building data use skills and a culture of data use at the facility level may have a greater effect on strengthening data quality and use, but this should be tested in future research.

As illustrated in the evidence gap map, there are also gaps in the evidence on routine health data use and action at the national level by EPI programs, National Immunization Technical Advisory Groups, and other national-level stakeholders. Additionally, we found no evaluations that examined whether or how data use interventions led to improvements in immunization equity. More research is needed to understand how to improve equity through the use of data, for example by designing data use interventions that enable equity analyses by all levels and types of data users (e.g., how vaccination rates differ by dimensions such as gender and ethnicity).

Our findings, although presented primarily through the lens of data use for immunization program decisions, remain relevant for other health sectors. This review provides stronger, more evidence-based theories that can inform the development, implementation, and evaluation of subsequent research on data use interventions.

Strengths and Weaknesses of the Review

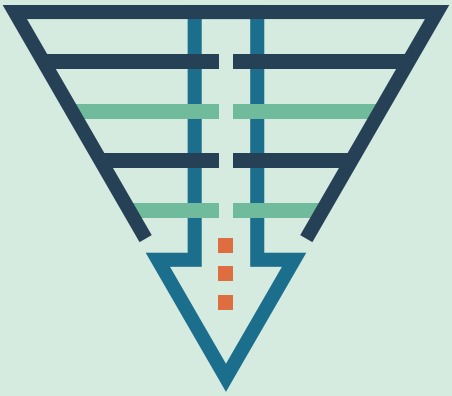
This review contributes to our understanding of what does and does not work to improve the quality and use of routine immunization data by providing a synthesis of the evidence and learnings from 69 studies and evaluations and emerging

examples of promising strategies from 34 papers. Strengths of this review were its inclusiveness and methodological flexibility, afforded by the realist review approach, and the emphasis on understanding how the interventions functioned, what made them successful, for whom, and under what conditions. A majority of the evidence we reviewed was from the non-peer-reviewed literature; although of lesser quality, it provided important evidence and learnings that otherwise would be overlooked in more traditional systematic reviews.

Although the review was exhaustive and we went to lengths to contact implementers who may have documents describing data use interventions and implementation research, we likely missed some interventions. The team from PAHO was able to reach extensively into the PAHO region, improving our ability to also include Spanish-language documents. However, we did not have this same reach for other regions where English is not the dominant language.

Most data use interventions were composed of multiple strategies. Although we attempted to segment the findings according to the primary intervention type, it was not possible to fully disentangle the effects of individual strategies and activities. For this reason, we cannot recommend which interventions or packages of interventions are most effective, but we can provide stronger theories about what may work and why. Another limitation was our reliance on what was reported in the literature that provided the basis for our findings. Not all the literature adequately described how the intervention functioned or identified the contextual factors that may have contributed to its success or failure. Because we did not have the opportunity to interview the stakeholders responsible for implementing the interventions, we may have missed important contextual considerations.

Finally, the focus on routine immunization data alone was helpful in constraining the review timeline and process but risks further siloing immunization programs. We expanded the review to include literature from other health sectors (specifically, HIV and MCH); however, these efforts were not as comprehensive and likely failed to capture all of the available evidence on the topic. Many promising reviews of data use more broadly are also under way. The entire body of work should be considered together to inform strategic and cross-programmatic investments in interventions to improve data use.



Conclusion

We reviewed 549 records of research evidence and promising strategies intended to increase the use of data to improve immunization decision-making. Our gap map illustrates the relatively small number of records that pertain to each intermediate outcome and data use action. Summarizing across all evidence and promising strategies, and informed by our TOC, we reached the following conclusions.

Multicomponent interventions were the most prevalent and often more effective.

Nearly all the interventions we reviewed leveraged more than one data use strategy. The more comprehensive the set of strategies, and the more they addressed barriers at various stages of data use (e.g., data availability, data quality, and data use skills) and touched upon multiple mechanisms driving data use behaviors and actions, the more likely they were to achieve results. By addressing different facilitators of data use, the multicomponent interventions employed interconnected, mutually reinforcing strategies that appeared to have a greater collective effect than a single intervention. Notably, successful intervention packages included strategies that addressed:

- *skill sets and capacity of data users;*
- *gaps in feedback mechanisms;*
- *data use within existing systems, workflows, and workloads;*
- *user-centered design principles;*
- *interaction between data producers and data users, and structured problem-solving;*
- *data use culture and motivation to use data; and*
- *long-term commitment of financial and human resources.*

Interventions that took a health systems approach to institutionalizing data use were more likely to be successful and sustainable.

Interventions were more successful over the long term when they focused on systematizing data use at all levels of the health system and as part of decision-making processes. This occurred by routinely conducting data review meetings at all levels, making national guidelines and protocols on data use available to frontline staff, creating dedicated staff positions at all levels of the health system to oversee data management and use activities, and incorporating training in data use in national in-service and pre-service training curricula.

We found limited or mixed evidence on the effectiveness of health management information systems, including electronic immunization registries, on data use, but they remain promising interventions for improving data use when accompanied by complementary activities.

Transitioning from paper to computerized health management information systems across all levels of the health system seems to have made higher-quality data more available to decision-makers and may have contributed to better data

use at the district level when complemented by activities that reinforce data use. The effect on data use at the facility level, however, remains less conclusive. In many countries, the significant operational challenges, extended time required for a return on investment, and absence of complementary data use activities have contributed to the mixed results presented in the research literature. Full transition to computerized systems may be more successful when they are incrementally phased in only once a reliable foundation of data use infrastructure, human resource capacity, and skill base has been established.

Moderate- to high-certainty evidence exists to suggest that computerized logistics management information systems (LMISs) have made higher-quality data more available to decision-makers to improve management of supply chains.

Computerized LMISs that were implemented at district levels and higher seem to have had more success than similar efforts to digitize routine service-delivery data at a facility level. There were often fewer operational challenges when they were implemented at district and higher levels, where Internet connectivity, electricity, and information technology support were more reliable. In addition, we hypothesize that data users may have greater knowledge of how to use supply chain data to take action directly compared with routine service delivery data, which are more commonly collected for reporting by frontline health workers who feel little connection to or agency over the data. Although implementing computerized LMISs as a single intervention improves data quality and use, there were even greater gains in data use and supply chain performance when LMISs was complemented by other data use activities.

There is a dynamic, cyclical relationship between data quality and data use.

Although poor data quality was an important barrier to data use, we found limited evidence that single-component interventions to improve data quality led to improvements in data use. Conversely, we found stronger evidence that data quality improved through the use of data. As decision-makers started using their data more and identifying inconsistencies with data quality, they took more corrective actions to improve data quality.

The state of the evidence does not lend itself to recommendations on which interventions or package of interventions are most effective. Improving immunization data use greatly depends on designing a package of interventions that is theoretically sound and contextually driven, addresses technical and behavioral barriers, and can be sustained outside a project setting. With a more robust understanding of the theory behind how interventions could work to improve data use, we are able to recommend improved approaches to monitoring and evaluating interventions. Measuring data use is possible, but it relies on a firm understanding of the mechanisms that drive data use behaviors and actions and how the use of data may change health outcomes. With the growth in digital technologies playing a role in data use, there is opportunity to automate much of the measurement.

This review targets various audiences and intends to provide relevant information and evidence on the most effective practices so that policy and program decision-makers, as well as funders and implementers, may choose and implement the highest-impact approaches to improving the use of data for expanded vaccine coverage and equity, and ultimately the reduction, or even elimination, of vaccine-preventable diseases. We anticipate that these findings will also be of interest to researchers and evaluators to prioritize gaps in the existing knowledge. Our recommendations are segmented by audience group to encourage action.

CHECKLIST OF ACTIONS TO SUPPORT DATA USE

Theory of Change Data Use Actions	How to improve data use at the **HEALTH FACILITY LEVEL?**	How to improve data use at the **HEALTH DISTRICT LEVEL?**	How to improve data use at the **NATIONAL LEVEL?**
Implementers (and national level actors)	***Cross-cutting actions*** ☐ The data use intervention's design is based on an assessment of current data quality and use challenges and their root causes, including assessing the mechanisms, behavioral drivers, and contextual factors that may act as barriers or facilitators to specific data use actions.[1] ☐ The intervention specifies the data use actions (from the TOC) it aims to support. ☐ The data use actions are actionable by the intervention's intended users and are of significance to the program itself. ☐ All parties are clear which data use action the intervention will reinforce and strengthen. ☐ The intervention has a clear theory for how it will work. ☐ It is clear how the intervention will use multiple mechanisms and behavioral drivers to achieve its intended data use actions. ☐ The intervention clearly targets specific bottlenecks known to constrain data use in the intervention setting. ☐ The intervention aligns with national guidelines on processes and procedures for data collection, analysis, and use by health care workers. ☐ During the design and conception phase of the intervention, an M&E strategy was developed to measure whether data are being used as intended and as defined by the data use actions it is intended to address.		
	☐ The intervention establishes or strengthens feedback loops between data collectors (e.g., health care workers in a facility) and decision-makers at higher levels. ☐ Implementers support harmonization across projects and alignment with local policies and guidelines on health care workers' roles and responsibilities in relation to data analysis and use.	☐ District level health workers have the needed tools and training to deliver effective supportive supervision, including ways to provide proper feedback to facility health care workers and ways to support the intended data use actions. ☐ District level staff have clarity on their roles and responsibilities in relation to data analysis and use.	☐ Data use strategies focus efforts on increasing use of evidence in policy decision-making. ☐ Data Improvement Plans (DIPs) include actionable recommendations. ☐ DIPs are monitored to ensure facilities and districts take action on the recommendations.

1 *Refer to the IDEA TOC which outlines the potential mechanisms (demand, access/availability, quality, skills, structure & process, communication), behavioral drivers (capability, motivation, opportunity), and contextual factors..*

Theory of Change Data Use Actions	How to improve data use at the **HEALTH FACILITY LEVEL?**	How to improve data use at the **HEALTH DISTRICT LEVEL?**	How to improve data use at the **NATIONAL LEVEL?**
Policymakers and Multilaterals	***Cross-cutting actions*** ☐ The intervention aligns with national guidelines on processes and procedures for data collection, analysis, and use by health care workers.		
	☐ Health facilities are equipped with sufficient human resources—including dedicated staff where feasible—to perform tasks associated with data collection, management, and analysis. ☐ Front-line health worker training curricula focuses on training staff to use routine service delivery data for decision-making and problem solving and shifts perceptions away from data serving the sole purpose of reporting up through the system.	☐ Tools that organize data into meaningful information are implemented with complementary strategies for discussing data analyses and determining actions to be taken. ☐ Strategies are implemented to improve the quality of supportive supervision to focus on improving data use skills and practices.	☐ National guidelines contain well-defined processes and procedures for data collection, analysis, and use by health care workers across all levels of the health system. ☐ National guidelines include clear guidance on various types of decision-making informed by data, as well as guidelines for how health workers are expected to use data in various scenarios.

Theory of Change Data Use Actions	How to improve data use at the **HEALTH FACILITY LEVEL?**	How to improve data use at the **HEALTH DISTRICT LEVEL?**	How to improve data use at the **NATIONAL LEVEL?**
Funders	***Cross-cutting actions*** ☐ Investments address documented bottlenecks to data use and use multi-component and theory-driven approaches to resolving those challenges. ☐ Investments are funded based on what is known to work, or has high likelihood of success in a given context. ☐ Investments are aligned with national policies and strategies for data use or ehealth and with other investments. ☐ Investments are accompanied with a robust M&E plan that will contribute to filling existing evidence gaps, including cost-effectiveness.		
	☐ Data quality investments have been equally balanced with strategies to improve data use.	☐ Investments include components of quality improvement methodologies to provide structured approaches to interpret data, prioritize problems, and find solutions.	☐ Investments are geared towards data use strategies end efforts to increase use of evidence in policy decision-making.

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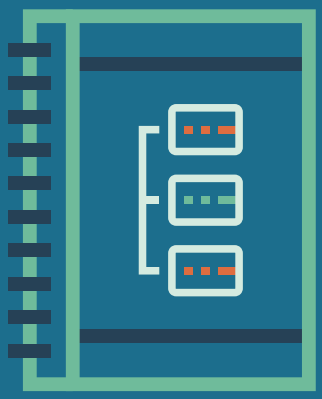

Annexes

Annex 1. Search Terms

PubMed

Vaccine (Mesh) + Data use/quality (title/abstract)

Searching strategy	Result
((((((((Vaccin*[Title/Abstract] OR Immunis*[Title/Abstract] OR Immuniz*[Title/Abstract])))))) OR (((Immunization or Immunisation or Vaccine[MeSH Terms]))))))) AND ((“Data quality”[Title/Abstract] OR “Data use”[Title/Abstract] OR “Data-use”[Title/Abstract]))	131

POPLINE

Vaccine (Keyword) + Data use/quality (Title)

Searching strategy	Result
(((Data use) OR (Data-use) OR (Data quality))) and (((Keyword:VACCINES OR Keyword:IMMUNIZATION)))	28

CABI Global Health

Vaccine + data use

Searching strategy	Result
(ab:((((Data use) OR (Data-use) OR (Data quality)))) OR title:((((Data use) OR (Data\-use) OR (Data quality))))) AND (((sc:ft) OR (sc:sr) OR (sc:AO))) AND (ab:((((Health management information system) OR (Electronic medical record) OR (Immunization register) OR (Home\-based record) OR (Logistic management information system) OR (Supply chain data) OR (Medical record system) OR (Electronic health record) OR (Electronic patient record) OR (Health information system)))) OR title:((((Health management information system) OR (Electronic medical record) OR (Immunization register) OR (Home\-based record) OR (Logistic management information system) OR (Supply chain data) OR (Medical record system) OR (Electronic health record) OR (Electronic patient record) OR (Health information system))))) AND (((sc:ft) OR (sc:sr) OR (sc:AO))) AND (ab:(Vaccin* or Immuniz* or Immunis*) OR title:(Vaccin* or Immuniz* or Immunis*)) AND (((sc:ft) OR (sc:sr) OR (sc:AO)))	138

Annex 2. Theory of Change Definitions

	Definition	Reference
Mechanisms		
Demand	Building demand for and positive attitudes toward data-informed and information-informed decision-making This mechanism emphasizes the importance of health workers, managers, and decision-makers valuing the concept of data-informed decision-making, as well as the intermediate steps needed to achieve that goal.	Langer (2016)
Access and availability	Ensuring availability of data and then ensuring that potential users are able to access data This mechanism emphasizes our assumption that data must be available and accessible if they are to be used.	Langer (2016), Nutley (2013)
Quality	Ensuring that data is of appropriate quality for the decisions or actions to be informed This mechanism emphasizes the fact that poor data quality is often cited as a barrier to data use and that improvements in data quality may lead to improved data use.	Nutley (2013)
Skills	Ensuring data users have the skills to access data and to turn data into actionable information through data management, analysis, synthesis, interpretation, and discussion Users must be able to apply these skills to the workplace. Health workers, managers, and decision-makers should be able to integrate data and information with other drivers of decision-making.	Langer (2016), Nutley (2013)
Structure and process	Influencing organizational, technological, and institutional structures and processes that facilitate or block data-informed decision-making This could include how data management infrastructure is structured, how health workers spend their time, professional norms related to collecting, analyzing, and discussing data, and what latitude health workers have to take action on data.	Langer (2016), Nutley (2013)
Communication	Influencing the timely and effective communication of data to potential users or those in a position to take action Unlike access and availability, this mechanism acknowledges that some decisions or actions will be based on data and information that are "pushed" to potential users and that simply making data and information available and accessible is often not sufficient.	Langer (2016), Nutley (2013)
Behavior change components		
Capability	"Capability is defined as the individual's psychological and physical capacity to engage in the activity concerned. It includes having the necessary knowledge and skills."	Michie (2011)
Motivation	"Motivation is defined as all those brain processes that energize and direct behaviour, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making."	Michie (2011)
Opportunity	"Opportunity is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it."	Michie (2011)

Annex 3. Included Documents Organized by Primary Intervention Type

	Document name	Year	Geography	Electronic Immunization Registries	Logistics management information systems	HMIS and DHIS	Decision support systems	Monitoring charts and dashboards	Home-based records	Data quality assessments	Data review meetings	Peer learning networks	Supportive supervision, mentorship, and on-the-job learning	Training	mHealth	Other / Multicomponent interventions
				Intervention components included												
Electronic Immunization Registries	Adequacy and Quality of Immunization Data in a Comprehensive Electronic Health Record System	2013	Kenya	◆												
	BID Initiative Tanzania Mid-term external evaluation	2018	Tanzania	◆	◆			◆				◆	◆	◆		
	BID Initiative Tanzania, PATH internal midline evaluation	2017	Tanzania	◆	◆			◆				◆	◆	◆		
	BID Initiative Zambia, PATH internal midline evaluation	2018	Zambia	◆	◆			◆				◆	◆	◆		
	Digitizing Paper Forms with Mobile Imaging Technologies (mScan)	2012	Mozam-bique	◆												
	Immunization Information Systems to Increase Vaccination Rates: A Community Guide Systematic Review	2015	High-income countries	◆												
	Improving immunization data quality in Peru and Mexico: two case studies highlighting challenges and lessons learned	2018	Peru, Mexico	◆												
	Improving immunization registration, coverage and monitoring (ImmReg) in Viet Nam	2017	Vietnam	◆											◆	
	MyChild Card External Evaluation in Afghanistan	2018	Afghanistan	◆												
	MyChild Card External Evaluation in the Gambia	2018	The Gambia	◆												
	MyChild Card External Evaluation in Uganda	2018	Uganda	◆												
	Project Optimize, Guatemala (SIGSA Web)	2013	Guatemala	◆												
	UW START Health Registers, Uruguay case study	2014	Uruguay	△												
	Zambia Smart Care Project Final Report	2016	Zambia	◆												

Evidence includes studies and evaluations that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

◆ Evidence △ Promising strategy

	Document name	Year	Geography	Electronic Immunization Registries	Logistics management information systems	HMIS and DHIS	Decision support systems	Monitoring charts and dashboards	Home-based records	Data quality assessments	Data review meetings	Peer learning networks	Supportive supervision, mentorship, and on-the-job learning	Training	mHealth	Other / Multicomponent interventions
				Intervention components included												
Logistics management information systems	Assessing stability and performance of a digitally enabled supply chain: Retrospective of a pilot in Uttar Pradesh, India.	2017	India		◆											
	Assessing the effectiveness of a web-based vaccine information management system on immunization-related data fucntions	2018	Tanzania		◆			◆								
	Deliver Logistic Management Information System (vLMIS) Final Evaluation Report	2016	Pakistan		◆			◆						◆		
	LoMIS stock Impact Evaluation report	2017	Nigeria		◆			◆							◆	
	Project Optimize, Albania (IIS)	2013	Albania		◆									◆		
	Project Optimize, Tunisia (wVSSM)	2013	Tunisia		◆											
	Project Optimize, Vietnam (VaxTrak)	2013	Vietnam		◆											
	Village Reach Dedicated Logistics System (DLS)	2015	Mozam-bique		△		△	△					△			
HMIS and DHIS	An evaluation of the District Health Information System in rural South Africa	2008	South Africa			◆										
	Assessing the ability of health information systems in hospitals to support evidence-informed decisions in Kenya.	2014	Kenya			◆										
	DHIS2: The Tool to Improve Health Data Demand and Use in Kenya	2014	Multiple			◆										
	District decision-making for health in low-income settings: a systematic literature review	2016	Ethiopia, India, Nigeria			◆										
	HMIS and decision-making in Zambia: re-thinking information solutions for district health management in decentralized health systems	2006	Zambia			◆										
	The District Health Information System (DHIS2): A literature review and meta-synthesis of its strengths and operational challenges based on the experiences of 11 countries	2018	Multiple			◆										

Evidence includes studies and evaluations that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

◆ Evidence △ Promising strategy

	Document name	Year	Geography	Electronic Immunization Registries	Logistics management information systems	HMIS and DHIS	Decision support systems	Monitoring charts and dashboards	Home-based records	Data quality assessments	Data review meetings	Peer learning networks	Supportive supervision, mentorship, and on-the-job learning	Training	mHealth	Other / Multicomponent interventions
				Intervention components included												
Decision Support Systems	Effectiveness of Computerized Decision Support Systems Linked to Electronic Health Records: A Systematic Review and Meta-Analysis	2014	Multiple				◆	◆								
	Informed Design: How Modeling Can Provide Insights to Improve Vaccine Supply Chains	2017	N/A				△	◆						△		
	Initial experience of using a knowledge based system for monitoring immunization services in Papua New Guinea	1995	Papua New Guinea				◆	◆								
	Usability and feasibility of a tablet-based Decision-Support and Integrated Record-keeping (DESIRE) tool in the nurse management of hypertension in rural western Kenya	2015	Kenya	◆			◆	◆							◆	
Monitoring Charts and Dashboards	AFRO RED Evaluation Report 2007	2007	Multiple					◆			◆		◆			
	Impact of a Decision-support Tool on Decision Making at the District Level in Kenya	2013	Kenya					◆						◆		
	Improving the monitoring of immunization services in Kyrgyzstan	2000	Kyrgyzstan			◆	◆	◆					◆	◆		
	Monitoring Results in Routine Immunization: Development of Routine Immunization Dashboard in Selected African Countries in the Context of the Polio Eradication Endgame Strategic Plan	2017	Angola, Chad, DRC, Ethiopia, Nigeria, South Sudan				△	△								
	My Village My Home: Engaging Communities with a Simple Tool to Help Increase Immunization Coverage	2015	India, Timor-Leste					◆								
	Nigeria RI DHIS2 Project Progress Report	2016	Nigeria			△		△		△	△		△	△	△	
Home-Based Records	Home-based Record Redesigns that Worked, Lessons from Madagascar & Ethiopia	2017	Madagascar and Ethiopia						◆							
	Vaxeen: a Digital and Intelligent Immunization Assistant	2016	Argentina						△							
	WHO Recommendations on home-based records for Maternal, Newborn, and Child Health	2018							◆							

Evidence includes studies and evaluations that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

◆ Evidence △ Promising strategy

	Document name	Year	Geography	Electronic Immunization Registries	Logistics management information systems	HMIS and DHIS	Decision support systems	Monitoring charts and dashboards	Home-based records	Data quality assessments	Data review meetings	Peer learning networks	Supportive supervision, mentorship, and on-the-job learning	Training	mHealth	Other / Multicomponent interventions
				Intervention components included												
Data Quality Assessments	Accuracy and quality of immunization information systems in forty-one low income countries	2009	Multiple							◆						
	Country Immunization Information System Assessments	2017	Ghana, Kenya							△						
	Effects of a health information system data quality intervention on concordance in Mozambique: time-series analyses from 2009-2012	2015	Mozam-bique					◆		◆	◆		◆	◆		
	Evaluacion Internacional del Programa Ampliado de Inmunizaciones de Paraguay	2000	Paraguay							△						
	Grenada Immunization Information System Assessment	2018	Grenada							△						
	Improving data quality across 3 sub-Saharan African countries using the Consolidated Framework for Implementation Research (CFIR): Results from the African Health Initiative	2017	Mozam-bique, Rwanda, Zambia					◆		◆	◆		◆			
	Informe final Evaluación Internacional Vacunas El Salvador	2009	El Salvador							△						
	National Assessment of Data Quality and Associated Systems-Level Factors in Malawi	2017	Malawi							◆			◆			
	PAHO, Panama DQS Final Report	2014	Panama							△						
	PRISM Case Studies: Strengthening and Evaluating RHIS	2008	Multiple							△						
	Rapport de mise en oeuvre du DQS et du LQAS dans les 83 Districts sanitaires de la Côte d'Ivoire	2017	Côte d'Ivoire							◆						
	The impact of routine data quality assessments on electronic medical record data quality in Kenya	2018	Kenya							◆						
Data Review Meetings	Drivers of Routine Immunization system performance at the district level	2012	Cameroon, Ethiopia, Ghana								◆		◆	◆		
	Immunization Review Meetings - Low Hanging fruit for capacity building and data quality improvement	2017	Ethiopia, Kenya, Tanzania, and Uganda								◆		◆			
	Improving quality and use of data through data-use workshops: Zanzibar, United Republic of Tanzania	2012	Tanzania								◆					

Evidence includes studies and evaluations that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

◆ Evidence △ Promising strategy

	Document name	Year	Geography	Electronic Immunization Registries	Logistics management information systems	HMIS and DHIS	Decision support systems	Monitoring charts and dashboards	Home-based records	Data quality assessments	Data review meetings	Peer learning networks	Supportive supervision, mentorship, and on-the-job learning	Training	mHealth	Other / Multicomponent interventions
				Intervention components included												
Peer Learning Networks	BID Learning Network (BLN) results	2018	Multiple									△				
	How Mobile Electronic Devices are Connecting Health Workers to Improve Data Quality and Data Use for Better Health Decisions: Experience from BID Initiative in Tanzania	2015	Tanzania, Zambia		△			△				△	△	△		
	How social network platforms can improve the use of data	2017	Multiple									◆				
	IMPACT Team Network - Empowering people with data	2016	Malawi, Rwanda, Myanmar					△			△	△				
	Myanmar Supply Chain Quality Improvement Teams Pilot Results	2016	Myanmar		◆						◆	◆				
	NOTI-PAI: An Innovative Feature of Bogotá's Immunization Registry	2012	Colombia	△			△					△				
	Pakistan visibility and analyics network project		Pakistan								△	△	△			
	Quality improvement practices to institutionalize supply chain best practices for iCCM: Evidence from Rwanda and Malawi	2016	Rwanda, Malawi									◆				
	Reaping the fruits of IMPACT Team work in Kirinyaga County		Kenya									△				
	Strengthening community health supply chain performance through an integrated approach: Using mHealth technology and multilevel teams in Malawi	2014	Malawi									◆			◆	
Supportive supervision, mentorship, and on-the-job learning	An evaluation of a tailored intervention on village doctors use of electronic health records	2014	China										◆			
	Enhancing Workforce Capacity to Improve Vaccination Data Quality, Uganda	2017	Uganda							◆			◆	◆		
	How can we achieve and maintain high-quality performance of health workers in low-resource settings?	2005	LMICs										◆			
	Primary health care supervision in developing countries	2008	LMICs										◆			
	Quality of HIV Testing Data Before and After the Implementation of a National Data Quality Assessment and Feedback System	2017	U.S.							◆			◆			
	STOP Immunization and Surveillance Data Specialist (ISDS) Strategy	2018	Kenya, Laos							◆			◆	◆		
	Support and performance improvement for primary health care workers in LMICs: a scoping review of intervention design and methods	2017	Multiple										◆			
	Uganda DIT Summary	2018	Uganda							△			△	△		

Evidence includes studies and evaluations that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

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	Document name	Year	Geography	Electronic Immunization Registries	Logistics management information systems	HMIS and DHIS	Decision support systems	Monitoring charts and dashboards	Home-based records	Data quality assessments	Data review meetings	Peer learning networks	Supportive supervision, mentorship, and on-the-job learning	Training	mHealth	Other / Multicomponent interventions
				Intervention components included												
Training	Building Capacity for Data-Driven Decision Making in African HIV Testing Programs: Field Perspectives on Data Use Workshops	2016	South Africa, Swaziland, Tanzania, Zambia, Zimbabwe				◆				◆			◆		
	Data for Decision Making (DDM) Project Evaluation	1994	Multiple			◆	◆	◆				◆	◆	◆		
	Data for Decision-Making (DDM): Strengthening capacity in developing countries for evidence-based public health	2003	Bolivia, Cameroon, Mexico, Philippines			◆	◆	◆				◆	◆	◆		
	DDM Training Program Best Practices		Bolivia, Brazil, Costa Rica, El Salvador, Guatemala, Jordan, Mexico, Nicaragua, Philippines, South Africa											◆		
	Establishing a health information workforce: innovation for low- and middle-income countries	2013	Botswana										◆	◆		
	Health Care Provider Performance Systematic Review	2014	LMICs										◆	◆		
	Leadership in strategic information (LSI) building skilled public health capacity in Ethiopia	2011	Ethiopia									△	△	△		
mHealth	Effectiveness of Using Mobile Phone Image Capture for Collecting Secondary Data: A Case Study on Immunization History Data Among Children in Remote Areas of Thailand	2016	Thailand	△										△	△	△
	Improving Performance of Rural Supply Chains Using Mobile Phones	2014	India												◆	◆
	Mobile-based effective vaccine management tool: an m-health initiative implemented by UNICEF in Bihar	2016	India										◆		◆	
	Project Optimize, South Sudan (LogiMobile)	2013	South Sudan		△										△	
	Stregnthening Peruvian Immunization Records through Mobile Data Collection Using the ODK App	2016	Peru	△											△	
	Strengthening community health supply chain performance through an integrated approach: Using mHelath technology and multilevel teams in Malawi	2014	Malawi		◆			◆				◆			◆	
	The power of partnerships: transforming vaccine coverage in Mozambique	2016	Mozam-bique												△	
	Vaccine and Logistics Evaluator (VALUE) device	2017	India												△	

Evidence includes studies and evaluations that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

◆ Evidence △ Promising strategy

	Document name	Year	Geography	Electronic Immunization Registries	Logistics management information systems	HMIS and DHIS	Decision support systems	Monitoring charts and dashboards	Home-based records	Data quality assessments	Data review meetings	Peer learning networks	Supportive supervision, mentorship, and on-the-job learning	Training	mHealth	Other / Multicomponent interventions
				Intervention components included												
Other / Multicomponent interventions	Applying User-Centered Design to Data Use Challenges: What We Learned	2017	Tanzania, South Africa									△				△
	Back to basics: Routine Immunization Tools Used for Analysis and Decision Making at the Toga Health Post (UI-FHS)	2015	Ethiopia					△				△				△
	Building Routine Immunization capacity, knowledge and skills (BRICKS)	2016									△	△	△	△		△
	Local use of geographic information systems to improve datautilisation and health services: mapping caesarean sectioncoverage in rural Rwanda	2013	Rwanda					△			△					△
	Moving data off the shelf and into action: an intervention to improve data-informed decision making in Côte d'Ivoire	2014	Côte d'Ivoire	◆			◆			◆	◆			◆		◆
	Reaching every district using quality improvement methods (RED-QI)	2015	Ethiopia							△	△	△	△			△
	Setting a new pace: How Punjab, Pakistan, achieved unprecedented improvemebts in public health outcomes	2018	Pakistan				△	△			△		△		△	△
	Shifo, MyChild Infosheet	2018	Gambia, Afghanistan, Uganda	△	△			△	△							△
	Shifo, MyChild Outreach	2018					△		△						△	△
	Strengthening Supply Chains at the Community Level	2014	Malawi, Rwanda, Ethiopia									◆	◆	◆	◆	△
	The integration of barcode scanning technology into Canadian public health immunization settings	2014	Canada	△											△	△

Evidence includes studies and evaluations that applied scientific research methods or evaluation design, as well as literature that did not qualify as a study or evaluation but had strong theoretical plausibility of improving data use, as judged by our TOC. We referred to these records as promising strategies, which we define as strategies that have not yet proven successful, but have potential for future success.

◆ Evidence △ Promising strategy

Annex 4. IDEA Workshop Meeting Agenda and List of Participants

Meeting Agenda: Wednesday, May 16

Timing	Activity
8:30 am	*Arrive: Continental Breakfast*
9:00 am	**Opening Session** ► Welcome ► Workshop Process Review ► Introductions
9:45 am	**Review of Key Background Information** ► Overview and clarifying discussion on the Theory of Change: supporting information-informed decision-making for immunization programs ► Overview and clarification of common terminology (e.g., data quality and use)
10:30 am	*Break*
10:45 am	**Why Do I Take Action? (A review of target audiences)** ► Review of target audiences ► Clarify the target audience role in the Theory of Change: interests and motivations, messages, and potential mechanisms used to reach those audiences
11:30 am	**Identify and Categorize Research Evidence Findings & Promising Strategies** ► Identify interesting evidence findings and promising strategies ► Categorize evidence findings and promising strategies by mechanisms (e.g., Demand, Access & Availability, Quality, Skills, Structure & Process, Communication, Behavior Change Drivers)
12:30 pm	*Lunch Break*
1:30 pm	**Identify and Categorize Research Evidence Findings & Promising Strategies (continued)** ► Finalize collection of interesting evidence findings and promising strategies ► Categorize by mechanisms (e.g., Demand, Access & Availability, Quality, Skills, Structure & Process, Communication, Behavior Change Drivers)
2:45 pm	*Break*
3:00 pm	**Target Research Evidence Findings & Promising Strategies** ► Map target audiences to the research evidence
4:00 pm	**Close Out**
4:30 pm	**Adjourn**

Meeting Agenda: Thursday, May 17

Timing	Activity
8:30 am	*Arrive: Continental Breakfast*
9:00 am	**Welcome Back**
9:15 am	**Identify Implementation Considerations for Interventions** ▸ Introduce interventions types and their relation to the Theory of Change ▸ Identify implementation considerations for interventions (in breakout groups)
10:15 am	*Break ; breakout groups transition back to main room*
10:30 am	**Report Out and Discuss Implementation Considerations for Interventions**
11:45 am	**Prioritize Findings (from Day 1) by Target Audiences**
11:50 am	*Lunch Break*
12:45 pm	**Review Prioritized Findings**
1:00 pm	**Overview of Gap Map**
1:15 pm	▸ **Identify Gaps in Evidence or Knowledge** ▸ Populate the gap map ▸ Prioritize gaps
2:45 pm	*Break*
3:00 pm	**Identify Action for Advancing Knowledge or Filling Gaps**
4:00 pm	**Close Out and Next Steps** ▸ Next steps ▸ Your personal commitment
4:30 pm	**Adjourn**

IDEA Workshop Participant List

Peter Bloland, CDC

David Brown, Brown Consulting

Sara Cerrell, Global Change Network

Kendra Chappell, Nexight Group

Marcela Contreras, PAHO

Carolina Danovaro, WHO, Geneva

Mamadou Diallo, UNICEF

Elsy Dumit Bechara, PAHO

Daniella Figueroa-Downing, Gavi

Emma Stewart, PATH Advocacy & Public Policy team

Hallie Goertz, PATH

Jack Holmes, Nexight Group

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Kendall Krause, Bill & Melinda Gates Foundation

Ana Morice, SAGE Working Group on Quality and Use of Global Immunization and Surveillance Data

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Jennie (Audrey) Lyons, Ministry of Health, Grenada

Lee Hampton, Gavi

Andrea Fletcher, Cooper/Smith

Annex 5. IDEA Evidence Synthesis Table

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Electronic immunization registries			
Access and availability data are easier to extract and more accessible to the user **Data quality** enhanced by built-in data validation features and the ability to track children across multiple facilities **Opportunity** workflow processes are simplified and streamlined, and the need for numerous paper records is eliminated	**Capability factors** ‣ Computer literacy of health workers ‣ Knowledge of how to use data for action **Motivation factors** ‣ Heath workers' perception of improved data quality ‣ The extent to which health workers must perform parallel data entry ‣ Simplification and streamlining of workflow and reporting processes ‣ Availability of support from mentors and higher-level management **Opportunity factors** ‣ Degree to which the burden of data entry from paper records is minimized ‣ Extent to which higher-level managers' expectations around data quality and use are clear ‣ Adequacy of human resources to manage associated administrative burden ‣ Stability of electricity and Internet connectivity ‣ Interoperability with the broader HIS and vaccine stock management system ‣ Extent to which country has a registry culture in which health workers already register children in a paper-book or card system **Intervention functionalities/components** ‣ Automatic generation of monthly immunization reports and lists of children due for vaccination ‣ Automatic text message vaccination reminders to caretakers ‣ Longitudinal tracking of vaccination history for individual children ‣ Data storage and aggregation ‣ Routine health indicator data collection and management ‣ Application of technological solutions to facilitate the digitization of paper records ‣ Leveraging of complementary activities to reinforce analytic capacity and data use	**Intermediate outcomes**	
		We are uncertain about the effect on data availability ‣ Four studies and one systematic review found that data were more available.[30,32,33,34] ‣ In three studies, data availability was undermined by inconsistent use of the EIR, which resulted from challenges with operationalizing electronic data entry.[35,36,29]	**Very low**
		Increases data quality ‣ Five studies found improvements in data quality, including reduced barriers to data use related to data quality, more accurate data entry, and a perception among health workers of higher-quality data in the EIR.[30,32,34,29,31] ‣ Two systematic reviews—one on electronic registries, or eRegistries, in MCH programs in LMICs and one on IIS in high-income countries—found improvements in data quality.[33,38] ‣ One case study found challenges with the quality of denominator data, which led to overestimating coverage.[40]	**Moderate**
		Increases data synthesis, review, analysis, and interpretation ‣ Two studies found self-reported increases in data synthesis and review by health workers and increases in their ability to analyze and interpret data, such as identifying defaulters, areas of low coverage, and vaccine stock levels.[32,31] ‣ Three studies found that nurses were confident with synthesizing data using the EIR.[32,29,31]	**Moderate**
		Tools used to digitize paper immunization records contribute to improved data quality ‣ One study found that digitized child immunization history records were more complete than manually entered records.[47] ‣ Three evaluations and one study found that scanning technology was able to accurately digitize data from paper forms and reduce the amount of time spent on manual data entry.[43,44,45,46,48] ‣ Two mixed-methods studies (one in a low-income country and one in a high-income country) found no difference in data quality, and improvements in the timeliness of data entry were mixed.[29, 42]	**Low**
		Data use by health facilities	
		We are uncertain about the effect on data use by health facilities ‣ Two studies found a self-reported increase in taking action in response to their data[32,31], and one study found no significant change between baseline and midline, although it may have been too early to detect significant changes in data use behavior[29]. ‣ In one study, facility health workers could express a plan for data use, but others could not identify ways to use data for action.[36]	**Very low**
		Data use by health districts	
		Improves data use and emphasis on data by health districts ‣ In one study, district staff reported using EIR data in data review meetings to make decisions.[31] ‣ In the same study and one other study, facility health workers reported an improved emphasis on data quality and use by higher-level health staff, but clarity regarding their roles around data quality and use could have been improved.[32,31]	**Low**
		Data use by national program	
		Uncertain ‣ No studies were identified that reported this outcome.	**No evidence**
		Impact on immunization coverage	
		Contributes to increases in immunization coverage ‣ One study found a statistically significant increase in full immunization coverage of children under 1 year old and a boost in on-time vaccination, which may have been influenced by text message immunization reminders to caretakers.[30] ‣ A systematic review of IIS in high-income countries found improvement in vaccination-related activities linked to increased vaccination rates.[33]	**Moderate**

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Logistics management information systems			
Access and availability data are available in real time to users at multiple levels for more timely action **Data quality** streamlined data entry and secure data storage **Structure and process** harness data management technology to systematize decision-making processes **Opportunity** workflow processes are simplified and streamlined	**Capability factors** ▸ Easy-to-understand visualizations **Motivation factors** ▸ Degree to which complementary platforms (e.g., data review meetings) are leveraged to support reviewing and interpreting data and problem-solving ▸ Communication between key supply chain collaborators (e.g., logisticians, EPI manager, facility staff, etc.) ▸ Extent to which design responds to data user requirements and expectations ▸ Timely, accurate, and accessible data **Opportunity factors** ▸ Degree to which the burden of data entry from paper records is minimized ▸ Extent to which human resource needs are met (e.g., dedicated logisticians) ▸ Interoperability with the broader HIS ▸ Stability of electricity and Internet connectivity ▸ Tool's ability to work seamlessly across web and mobile software devices **Intervention functionalities/components** ▸ Supply chain data available to decision-makers in real time ▸ Built-in data dashboard visualization and analytics ▸ Vaccine shipment tracking (successful operationalization was contingent on buy-in from national-level users) ▸ Vaccine stock management ▸ Automated monthly reporting on administered vaccines	**Intermediate outcomes**	
		Increases data quality and availability ▸ Five studies found substantial improvements in the availability and quality of vaccine stock records at both regional and district levels.[40, 42, 43, 44, 45, 46, 48, 56] ▸ One quasi-experimental implementation research study found higher data consistency in the intervention districts compared with nonintervention (paper-based) districts after one year of implementation; however, these differences were not statistically significant (p = .20).[51]	**Moderate**
		Increases data synthesis, review, analysis, and interpretation ▸ One study found self-reported data, confirmed by observational data, of improved skills and knowledge related to the analysis and interpretation of monthly supply chain data by provincial and district managers.[48]	**Low**
		mHealth solutions applied to LMIS interventions contribute to increases in data availability and accessibility ▸ Three studies found improvements in EVM indicators and supply chain performance due to greater availability of high-quality, real-time data for decision-making.[59,60,61]	**Low**
		Data use by health facilities	
		Uncertain ▸ No studies were identified that reported this outcome.	**No evidence**
		Data use by health districts	
		Improves data use for vaccine stock management by health districts ▸ Two mixed-methods studies found evidence of increased use of data for supply chain management, including improvements in EVM indicators related to data use in vaccine forecasting and wastage reporting; provincial and district managers self-reported that vLMIS improved their use of data to make decisions on vaccine stocking and decisions related to monitoring and supervising facilities.[42, 48] ▸ One quasi-experimental study found a quicker response to stockouts and cold chain equipment breakdown reports between baseline and endline (responses within 24 hours increased from 20% to 87% and from 10% to 59%, respectively).[57] ▸ Program data from one intervention showed an improvement in vaccine delivery intervals and reports of data influencing action taken to resolve vaccine delivery delays.[47]	**Moderate**
		Data use by national program	
		Uncertain ▸ No studies were identified that reported this outcome.	**No evidence**
		Impact on vaccine availability	
		Improves vaccine stock management, leading to more consistent stock availability ▸ Four studies found evidence of improved vaccine stock management, including lower vaccine wastage rates, reduced number of days of stockouts in intervention areas compared with nonintervention areas, and faster replenishment of stocks following stockouts.[40, 48, 56, 57] ▸ One quasi-experimental implementation research study found lower understock of pentavalent vaccine in the intervention districts compared with nonintervention (paper-based) districts after one year of implementation; however, the difference was not statistically significant (p = 0.41).[51] ▸ One study could not detect an impact on stock availability due to external factors unrelated to the intervention – factors that national-level stockouts.[42]	**Moderate**

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Health management information systems			
Access and availability data are available in real time to users at multiple levels for more timely action **Data quality** automatic data validation features and secure data storage	**Capability factors** ▸ Extent to which users are supported through training, on-site mentorship, supportive supervision, and so on ▸ Decision-makers' data analysis capacity ▸ Utilization of tools/ frameworks for structured decision-making **Motivation factors** ▸ Health workers' attitudes and interest in reporting in and using new systems ▸ Decision-maker autonomy ▸ Extent to which clinic staff receive feedback on the data they submit **Opportunity factors** ▸ Availability of appropriately skilled personnel ▸ Quality and availability of data in the system **Intervention functionalities/components** ▸ Computerized record keeping and data aggregation ▸ Data accessible to decision-makers in real time ▸ Embedded data validation checks ▸ Automated report generation	**Intermediate outcomes**	
		Contributes to improved data quality and availability ▸ One systematic review and a review of seven cases studies found improvements in data quality and completeness; greater visibility of facility performance appeared to incentivize improvements.[26,6]	Moderate
		Does not contribute to improvements in data analysis, interpretation, and review (as a stand-alone intervention) ▸ One nonexperimental, mixed-methods study found no evidence of improved data analysis, interpretation, and/or review at the facility level, owing to the absence of feedback and support mechanisms.[65]	Low
		Greater data use improves data quality ▸ One systematic review and a review of seven case studies found that greater data use led to greater ownership of and demand for high-quality data.[26,6]	Moderate
		Data use by health facilities	
		Does not lead to improved data use ▸ Two nonexperimental, mixed-methods studies found low utilization of HMIS data at the service-delivery level when feedback and other support mechanisms were absent from higher levels.[67,65]	Low
		Data use by health districts	
		Improves data use by health districts ▸ One systematic review found that health districts were using data for facility monitoring and performance improvement and for district implementation planning and prioritization.[66] ▸ One multi-country case study found evidence of data use in four out of seven countries examined.[6] ▸ One qualitative case study found evidence of HMIS data use for decision-making, in addition to verbal, observational, and experiential sources of information.[8]	Moderate
		Data use by national program	
		Uncertain ▸ No studies were identified that reported this outcome.	No evidence
		Impact on immunization coverage	
		Uncertain ▸ No studies were identified that reported this outcome.	No evidence

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Decision support systems (e.g., CDSS, monitoring charts, dashboards, and HBRs)			
Structure and process strengthen decision-making structures and processes **Skills** support data analysis, helping users to transform data into actionable information	**Capability factors** ▸ Utilization of user-specific DHIS2 training modules ▸ Mobilization of human resource support to provide hands-on learning and mentoring **Motivation factors** ▸ Degree to which data analysis and use are reinforced by consistent feedback through both training and supportive supervision ▸ Integration with existing systems and workflows (e.g., leveraged by data review meetings) **Opportunity factors** ▸ Completeness and accuracy of the underlying data **Intervention functionalities/components** ▸ Data aggregation from multiple sources ▸ Data synthesis and visualization ▸ Automated analysis of data for easy interpretation ▸ Automated report generation ▸ Tailored analysis in response to specific programmatic questions	**Intermediate outcomes**	
		Improves data quality, analysis, synthesis, interpretation, and review ▸ Two evaluations with nonexperimental study designs, one case study, and one project report found that simple, paper-based immunization monitoring charts and dashboards increased awareness and tracking of immunization coverage and led to improvements in data quality.[80, , 81, 82, 37, 78] ▸ One mixed-methods evaluation found that CDSSs were more likely to improve analysis and interpretation of data in low-performing regions.[69]	**Moderate**
		Data use by health facilities	
		Improves data use by communities and health facilities ▸ One evaluation with a nonexperimental study design and one project report found that facilities used monitoring charts to review whether they were meeting targets, respond to high dropout rates and low vaccine coverage, and follow up on defaulters.[82, 37, 78]	**Moderate**
		Data use by health districts	
		Monitoring charts and dashboards improve data use by health districts to bolster facility performance and data quality ▸ One project report found that data were used by health districts for facility performance tracking to prioritize facilities for supportive supervision. The same report also found that data use led to improvements in data quality.[37, 78] ▸ One qualitative evaluation found evidence that a Microsoft Excel–based data dashboard (for an HIV program), tailored to answer specific programmatic questions, was used by district health managers to monitor and address facility performance problems and to improve data quality.[26]	**Moderate**
		We are uncertain about the effect of CDSSs on data use ▸ One mixed-methods evaluation found that district health officers in low-performing regions were more likely to use CDSS to give feedback to health facilities.[69] ▸ One systematic review from 28 RCTs in high-income countries found little to no difference in clinical outcomes.[81] ▸ One feasibility study of a tablet-based CDSS for clinical care of patients with hypertension reported perceptions among nurses that the tool made patient encounters easier and improved the quality of care.[73]	**Very low**
		Data use by national program	
		Uncertain ▸ No studies were identified that reported this outcome.	**No evidence**
		Impact on immunization coverage	
		Contributes to improvements in immunization coverage ▸ Three evaluations and one project report found evidence of improved coverage in the countries and regions where the intervention was implemented, with greater effect in low-performing regions.[80, 82, 76, 69] ▸ In one country, coverage decreased, however only because once monitoring charts made it possible to capture harder-to-reach children who had previously been left, they were added to the coverage denominator.[82]	**Moderate**

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Data quality assessments			
Data quality complete and accurate data more likely to be used for sound decision-making	**Capability factors** ▸ Extent to which staff have the skills and training needed to assess data quality properly **Motivation factors** ▸ Extent to which the intervention is paired with feedback and skills reinforcement through targeted training, supervision, and feedback meetings **Opportunity factors** ▸ Ratio of human resources for health to patients at the facility level **Intervention functionalities/components** ▸ Standardized methodology for systematically assessing and quantifying data quality ▸ Support for self-assessment of data quality ▸ Expanded scope of DQS Plus methodologies for a more holistic assessment of IIS performance ▸ Production of actionable DQIPs facilitated by methodology	**Intermediate outcomes**	
		Leads to improvements in data quality ▸ One time-series observational study found statistically significant improvements in data concordance, and three reports on repeat DQS found an increase in the number of facilities with a satisfactory verification factor.[93, 92, 97, 98] ▸ One review of data quality in 41 countries found that data quality improved (verification factor and quality score) in 6 countries that conducted repeat DQAs.[96] *In the evidence from the HIV sector:* ▸ One nonexperimental study found improved data quality, including a decline in missing data (from 31% to 13%) and an increase in data concordance (from 59% to 68%) at the facility level between baseline and follow-up routine data quality assessments.[94] ▸ One experimental study found that data use by health facilities was associated with improved data availability (p = .04) and data completeness (p = .02) but not with higher data accuracy.[95]	**Moderate to high**
		Data use by health facilities	
		Improves health facilities' use of data to improve data quality ▸ Six studies, including five with a nonexperimental design and one with an experimental design that demonstrated improvements in data quality, suggest that DQAs prompted health facilities to use data to improve data quality.[93, 92, 97, 98, 94, 95]	**Moderate**
		Improvements in data quality lead to greater data use by health facilities ▸ One time-series observational study found that facilities with high-quality data were less likely to have stockouts.[92]	**Low**
		Data use by health districts	
		Uncertain ▸ No studies were identified that reported this outcome.	**No evidence**
		Data use by national program	
		Encourages data use by the national program to inform vaccine strategies and policies ▸ One study reported anecdotes that the DQIP led to concrete actions taken by the national program in two countries to improve data quality through changes in vaccination program strategies and policies.[89]	**Very low**
		Impact on immunization coverage	
		Uncertain ▸ No studies were identified that reported this outcome.	**No evidence**

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Data review meetings			
Demand foster a culture of data use by building knowledge-seeking and data-sharing behaviors **Skills** leverage peer learning and knowledge sharing to build skills and confidence in data analysis **Structure and process** support and reinforce country processes that build data use into the decision-making process **Motivation** demonstrate how data can be used to improve program performance	**Capability factors** ‣ Extent to which the intervention is paired with activities that further support data analysis and provide follow-up or feedback loops ‣ Leveraging quality improvement methodologies for a structured approach to data analysis and problem-solving ‣ Extent to which review meetings build progressively upon previous meeting recommendations and discussions to reinforce and supplement learning and practices **Motivation factors** ‣ Focus on team-oriented problem-solving and learning ‣ Extent to which data review examines data completeness, data verification, and interpretation of performance data ‣ Equal representation from data users and data producers **Opportunity factors** ‣ Likelihood of adoption and sustainability given the intervention's fit within existing immunization program processes and budget **Intervention functionalities/components** ‣ Convening immunization stakeholders at multiple levels ‣ Communication and performance feedback for health care providers ‣ Peer exchange and problem-solving ‣ Application of quality improvement methodologies	**Intermediate outcomes**	
		Improves data quality when combined with supportive activities in the context of broader efforts to improve health information infrastructure ‣ One longitudinal case study reported a reduction in the proportion of health facilities with disparities among vaccine coverage indicators.[95] ‣ One case study reported significant improvements in data quality due in part to quarterly data review meetings implemented in the context of broader efforts to strengthen quality and use of HMIS and DHIS2 data in Tanzania.[107]	**Low**
		Improves data interpretation and review ‣ One longitudinal case study reported that after multiple rounds of review meetings, health workers were better able to interpret immunization data and correctly complete monitoring charts.[95]	**Low**
		Data use by health facilities	
		Uncertain ‣ No studies were identified that reported this outcome.	**No evidence**
		Data use by health districts	
		Improves data use by health districts ‣ One longitudinal case study reported an anecdotal example of a health district using data to resolve a problem identified during the QRM.[95] ‣ One case study reported a number of instances of improved data use (and quality), such as follow-up on immunization defaulters, better understanding of denominator issues, and increased tracing of indicators and targets.[107]	**Low**
		Data use by national program	
		Uncertain ‣ No studies were identified that reported this outcome	**No evidence**
		Impact on immunization coverage	
		Contributes to increases in immunization coverage when combined with supportive activities ‣ One mixed-methods case study found that quarterly district-level program review meetings were one of four key drivers of improved DPT3/Penta3 coverage, and one longitudinal case study found improvements in immunization coverage rates.[94,95]	**Moderate**

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Peer learning networks			
Demand cultivate a culture of data use and empower health workers **Skills** reinforced through information and knowledge exchange **Motivation** offer support and peer examples of data use successes	**Capability factors** ‣ Leveraging quality improvement methodologies for a structured approach to data analysis and problem-solving ‣ Leveraging tools that facilitate data management, analysis, and visualization (e.g., data dashboards) **Motivation factors** ‣ Providing opportunities for working one-to-one, in a non-threatening atmosphere, with more experienced peers ‣ Willingness to share data based on concerns that poor quality data would reflect negatively on individual performance **Opportunity factors** ‣ Multidisciplinary nature of the network or team (e.g., involving immunization stakeholders across departments, functions, and levels) **Intervention functionalities/components** ‣ Information and knowledge exchange ‣ Collective problem-solving using structured approaches ‣ Increasing collaboration, communication, and coordination among immunization stakeholders at multiple levels and functions	**Intermediate outcomes**	
		Improves data review, analysis, and interpretation ‣ One mixed-methods study found a self-reported increase in health worker knowledge, motivation, and skills related to data use. Two other projects reported M&E results showing anecdotal evidence of health workers at facility and district levels working collaboratively to review, analyze, and interpret data.[32, 135, 31] ‣ Two observational studies found that QITs met regularly to review stock data, identify challenges, and determine solutions (such as moving stock between over- and understocked facilities).[114]	**Low**
		Data use by health facilities	
		Improves use of data to monitor vaccine supply and cold chain ‣ One observational study found that facilities that received the intervention had fewer stockouts.	**No evidence**
		Data use by health districts	
		Uncertain ‣ No studies were identified that reported this outcome.	**No evidence**
		Data use by national program	
		Improves data use in decision-making by the national program ‣ In one survey, national-level network participants reported becoming more data oriented in their work and making decisions based on data.[31]	**Low**
		Impact on vaccine availability	
		Improves vaccine stock management, leading to more consistent stock availability ‣ M&E results from three countries found that intervention districts had lower rates of stockouts compared to nonintervention districts.[135] ‣ An observational study from two countries found improved vaccine supply and cold chain management. In Pakistan, two out of three districts had a reduction in vaccine wastage, and three out of three districts had fewer stockouts.[114] In Myanmar, stockouts declined from 50% to 20–26% at the regional level, and the percentage of adequately stocked facilities rose from 4% to 33–39%.[108] ‣ One observational study found significantly higher mean reporting rates (94% compared with 79%; $p < .001$) and lower mean stock-out rates (5–7% compared with 10–21%; $p < .001$) in the intervention group.[62]	**Moderate**

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Supportive supervision, mentorship, and on-the-job training			
Skills build data analysis skills and knowledge **Capability** build ability to transform data into actionable information	**Capability factors** ▸ Extent to which supervision and mentorship are site specific (i.e., tailored to the specific gaps in skills and data management, analysis, and use practices identified in assessments) ▸ Application of audit-and-feedback techniques **Motivation factors** ▸ Extent to which supervision is individualized and open ▸ Two-way flow of information between supervisor and community health worker ▸ Extent to which expectations for data use are clear and feedback is consistent ▸ Frequency of routine follow-up (including both oral and written feedback) ▸ Extent to which health workers are empowered to engage in proactive problem-solving **Opportunity factors** ▸ Management and leadership clarity on roles and expectations related to data analysis and use ▸ Degree to which individuals across multiple levels of the health system are connected and engaged ▸ Integration of data quality and use indicators in supervision tools and job aids (e.g., checklists) **Intervention functionalities/components** ▸ Performance monitoring of health care provider(s) ▸ Site-specific problem identification ▸ On-the-job mentorship ▸ Tailored improvement strategies	**Intermediate outcomes**	
		Improves data analysis, synthesis, and interpretation ▸ Two reports with M&E data found that data management skills and practices of health facility staff improved between baseline and follow-up (e.g., ability to correctly calculate dropout rates, fill out monitoring charts, and properly archive data).[119, 120]	**Low**
		Improves data quality ▸ One organizational-level survey, one case study, and two reports with M&E data found improved data quality, congruency between data collection tools, and timelier reporting in HMIS.[119, 120, 121, 81]	**Moderate**
		Improves data availability ▸ One RCT found a statistically significant increase (from 15.4% to 33.3%; p = 0.05) in the completeness of child vaccination records and no change in the control group (from 18.6% to 17.5%; p = 0.69).[118]	**High**
		Data use by health facilities	
		We are uncertain about the effect on data use by health facilities ▸ One report with M&E data found an increase in the proportion of health facilities with documented evidence of data use (from 39% to 53% between rounds 1 and 2).[119] However, a rapid organizational-level survey of the same intervention found that no health facilities reported implementing data use recommendations; rather, recommendations related to data management were implemented more often.[121]	**Very low**
		Data use by health districts	
		We are uncertain about the effect on data use by health districts ▸ One report with M&E data found an increase in the proportion of districts with documented evidence of data use (from 68% to 77% between rounds 1 and 2).[119] However, a rapid organizational-level survey of the same intervention found minimal evidence of data use actions; instead, health districts were more likely to address recommendations related to data management and collection.[121]	**Very low**
		Data use by national program	
		Uncertain ▸ No studies were identified that reported this outcome.	**No evidence**
		Impact on immunization coverage	
		Contributes to improvements in immunization coverage and other immunization performance outcomes ▸ One systematic review found 23 studies on supervision and supportive supervision, including 3 that reported immunization outcomes: one RCT in the Philippines found a 75% increase in correct antenatal care record keeping; one pre-post study in Georgia found a statistically significant increase in DPT3, polio, and hepatitis B coverage and a significant reduction in vaccine wastage; and one systematic review and meta-analysis found worsening vaccination rates, although not statistically significant.[117]	**High**

Hypothesized mechanisms	Contextual factors that affected how the intervention worked and intervention functionalities/ components hypothesized to support data use	Evidence of the intervention's effect on data use and data quality	Certainty of the evidence*
Training			
Skills strengthens skills in data collection, analysis, and interpretation **Capability** builds capability to generate and use data to inform programmatic decisions **Demand** increases the demand for timely, high-quality data by improving data-related skills and demonstrating the value of data **Quality** increases data quality by improving capabilities surrounding data	**Capability factors** ▸ Extent to which training is designed to address gaps related to M&E, epidemiology, health informatics, surveillance, and so on ▸ Extent to which training is reinforced by strategies such as applied group problem-solving, peer learning, and supervision **Motivation factors** ▸ Extent to which training conveys the value of data, not just at higher levels of the health system but also at the facility level where data are produced **Opportunity factors** ▸ Creation of new cadres of health workers responsible for M&E **Intervention functionalities/components** ▸ Pretraining assessments to identify skill gaps ▸ Applied learning component to reinforce training concepts	**Intermediate outcomes**	
		Improves analysis, synthesis, interpretation, and review of data ▸ One post-training assessment found increased confidence and capability in interpreting data and assessing the achievement of indicator targets.[127] ▸ One longitudinal evaluation of an intervention to create a new cadre of district M&E officers showed an increase in activities to strengthen data management, quality, reporting, and utilization for evidence-based planning.[133]	**Low**
		Data use by health facilities	
		Improves the use of data at the health facility level ▸ The Data for Decision Making Project in Cameroon provided anecdotal evidence of health officers using data to monitor disease burden and implementing immunization campaigns in response to an epidemic.[128]	**Low**
		Data use by health districts	
		Improves the use of data at the district level ▸ Results from evaluation of the creation of a new cadre of district M&E personnel provided anecdotal, self-reported evidence of improved quality and use of data at the district level.[133]	**Low**
		Data use by national program	
		Contributes to improvements in the use of data at the national level ▸ Anecdotal evidence from the multicountry Data for Decision Making Project in Bolivia evaluation and subsequent strengthening of the cholera surveillance system throughout the country pointed to improvements in data use. In Mexico, data on the health burden of tobacco use were used to advocate for, develop, and implement a tobacco-prevention policy.[128]	**Low**
		Impact on immunization coverage	
		Uncertain ▸ No studies of training alone or of training as the primary intervention type were found that reported this outcome.	**No evidence**

* *The certainty of evidence rating of high, moderate, low, or very low was based on an assessment of the internal validity of the included studies (e.g., considering study design and assessing study quality using the Mixed-Methods Appraisal Tool), the number of studies and their agreement, and the context dependence of the evidence.*

IDEA

IMMUNIZATION DATA:
EVIDENCE FOR ACTION

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