Troubleshooting Guide for Common DHIS2 Tracker Issues

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Abbreviations

BPMN	Business Process Model and Notation
COVID-19	coronavirus disease 2019
CPU	central processing unit
DHIS2	District Health Information System 2
Global VAX	Global COVID-19 Vaccine Access
HISP	Health Information Systems Program
ICT	information and communications technology
MOH	ministry of health
TEI	tracker entity instance
USAID	United States Agency for International Development

DHIS2 Tracker troubleshooting guide

Digital systems, including the District Health Information System 2 (DHIS2), are integral to many countries' COVID-19 vaccine implementation; they are used to collect individual or aggregate data on vaccination, vaccine availability, and uptake of vaccines.

In 2022, the United States Agency for International Development (USAID) completed calls with Global COVID-19 Vaccine Access (Global VAX) surge countries, as well as a survey to 42 USAID Missions receiving funding for COVID-19 vaccines. From the responses received, USAID identified common issues with and challenges in timely data entry at the service delivery points and the quality of and access to data, as well as the use of data for decision-making, with a primary concern being around a backlog of unreported COVID-19 vaccination data.

Many of the countries under Global VAX were using DHIS2, as well as DHIS2 Tracker, for COVID-19 data reporting. While data was collected during vaccination sessions, the ability to input the data was constrained, leading to data entry backlogs. These backlogs resulted in fragmented and delayed reporting of immunization coverage, vaccine utilization and metrics needed for timely decision making.

This technical toolkit builds on those findings and presents guidance to resolve identified information and communication technology challenges by users with the use of the DHIS2 and DHIS2 Tracker. The tools provided, designed in consultation with users for actionable results, are designed to help countries quickly address identified challenges, respond to the current pandemic, and scale DHIS2 Tracker implementations into the future so that they do not repeat similar challenges experienced during the pandemic response.

Data entry may be overwhelming when the number of vaccinations grows at a facility. If the system is unresponsive, there is a tendency to capture data on paper and then transfer them to DHIS2 Tracker at a later date, thereby creating a more time-consuming and burdensome process in the long run, as well as data quality challenges. Further, reliable systems and tools to enter data are paramount for accurate data collection and reporting. Slow load times and limited responsiveness of DHIS2 and Tracker can lead to frustration and restrict the users ability to enter data, oftentimes demotivating the user. While there are other infrastructure related challenges that can contribute to these performance challenges, this guide is focused on the configuration of DHIS2 and Tracker. A related root cause analysis of COVID-19 data reporting backlogs was conducted that addresses the challenges focusing on technology, infrastructure, guidance/ processes, and human resources[1].

A system that is configured for high availability[2] is needed to avoid duplicative efforts to access and record data correctly the first time. A best practice is to begin by consulting with the DHIS2 teams and HISP [Health Information Systems Program] network and sizing the hosting and support environment according to current best practices for the population and vaccination events expected. Many countries are exploring using the DHIS2 Tracker for other challenges, such as routine immunization, where dozens of additional antigens need to be tracked, the expansion of immunization sites requiring devices and connectivity often doubles in a short period of time, and the number of vaccination events can grow by another 40 percent or more. (See Table 1 for an example of additional events for the Tanzania context.) Before those steps are taken, the burden of data collection with improperly sized and configured systems needs to be resolved to avoid the current data backlog challenge.

[1] USAID/PATH (2023). Multi-Country CN-18 COVID-19 Vaccination Data Backlog Root Cause Analysis - Kenya, Senegal, Tanzania.
[2] A high availability system is configured to deliver performance and handle the number of simultaneous users and data queries with minimal or zero downtime.

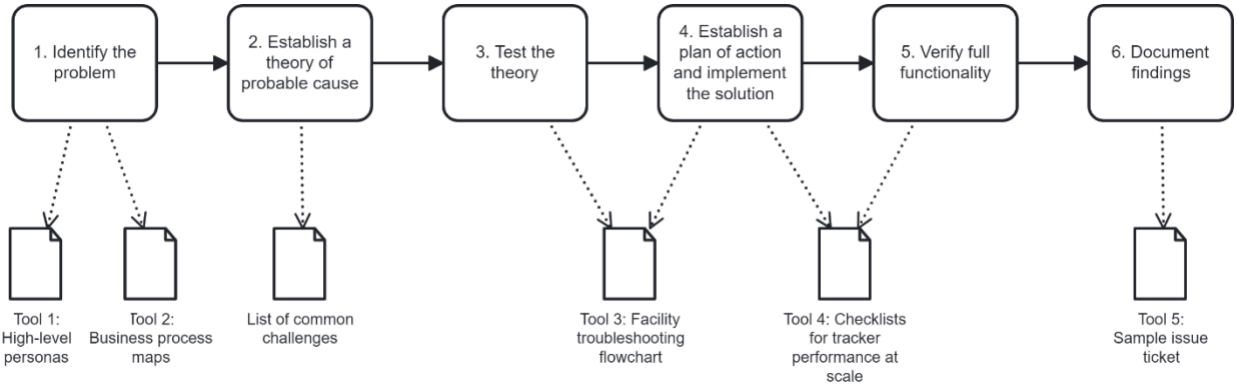
Table 1. Sizing Tracker for the Tanzania context	**COVID-19 vaccinations[3]**	**Routine immunization[4]**
Target population	43,000,000	2,866,084
Vaccines	1	9
Doses	2	17
Tracker entity instances (fully immunized)	86,100,000	34,030,620

It is our objective that the system administrators supporting ministries of health will use these tools and guidance to understand the needs of their users; optimize the processes for their country context; and ensure the recommended specifications are being met at all levels to track and troubleshoot local issues.

How to use the guide

With the computing demands of scale with multiple simultaneous immunization events being entered, users across DHIS2 Tracker implementations have reported numerous slowdowns and system freezes that have contributed to a data backlog. The following sections provide a guide and tools to lead to quick resolution through the common troubleshooting steps (Figure 1). The tools developed for this guide and referenced below can be applied across multiple steps and can be found in the section Troubleshooting guide. These tools are designed to be used to support the troubleshooting steps, or independently adapted to fit to each country's needs.

Figure 1. Troubleshooting steps mapped to tools found in this guide



Source: Adapted from: Cisco Networking Academy. Preventive maintenance and troubleshooting. In: *IT Essentials Companion Guide v7*. Hoboken, NJ: Cisco Press; 2020.

Step 1: Identify the problem

Depending on the country context, users described in the “High level personas” (Tool 1) section reported using their own devices, old or outdated application hardware, unstable Internet, etc. The root cause of an issue may not be what the user initially reported. For example, frustration with the slowness of the system may be due to local network issues, and sometimes the error messages reported by the system have another cause. It is important to gather as much information as possible from the user (see sample issue ticket, Tool 5), asking questions to identify symptoms, investigate recent changes, and if possible, gather information from the server log files. In Annex A we have provided interview guides used to help inform the common challenges experienced and development of the Tracker performance checklist. This guide can be adapted for interviews to help collect server hosting/storage and specifications.

[3] Source of data: https://data.covid19taskforce.com/data/countries/Tanzania.
[4] Source of data: https://immunizationdata.who.int/pages/schedule-by-country/tza.html and https://immunizationdata.who.int/listing.html?topic=coverage&location=TZA.

Step 2: Establish a theory of probable cause

Table 2 contains a summary of the top challenges reported to date, along with an initial set of probable causes. Initially, use the facility troubleshooting flowchart (Tool 3) to rule out obvious issues before advancing to more complex diagnosis of the hosted application. However, if multiple users are reporting issues concurrently, there is usually a systemic issue, and so the Checklists for Tracker Performance at Scale (Tool 4) should be applied.

Steps 3 through 5: Test and verify

Hold off on making changes until you are reasonably confident you have a solution ready to implement. Once the theory is confirmed, determine the steps to resolve the problem. Over time, problems often become familiar, enabling the support team to quickly predict the likely cause, mitigate the situation, and empower users to resolve the problem on their own.

After the cause has been identified, establish a plan to resolve the problem. If a quick fix corrects it, verify that the user has full functionality and, if applicable, implement preventive measures. If possible, have the user test the solution and try to reproduce the problem. When the user can verify that the problem has been resolved, you can proceed to Step 6. If the problem remains, return to Step 2 to establish a new theory of the probable cause and, if necessary, escalate the problem to the support team that has more experience (or reach out to the DHIS2 Community[5]). Before you escalate, document each test that has been tried.

Step 6. Document the findings

Being deliberate about documenting the findings can lead to faster and more efficient problem resolution for others on the support team. Over time you may see patterns, and by cataloging the issues and their resolutions, the team can quickly reference past occurrences and resolve them or see a greater pattern that can inform configuration, infrastructure, or training adjustments. Several users reported outdated manuals. Updating these materials and training can also reduce the number of issues reported.

Furthermore, documenting what has been tested so far can help when escalation is needed or if the change had unintended consequences and the changes need to be reversed. Tool 5 provides a sample issue ticket that can be used by the support team.

[5] See https://community.dhis2.org/c/support/8

List of common challenges

Through multiple interviews and observations (n=136) with management teams and facilities in Kenya, Tanzania, and Senegal, we diagnosed various problems for the data backlogs caused by DHIS2 and Tracker. Eleven common challenges were identified through structured interviews (Annex A) and ordered by the level of severity and prevalence, shown in Table 2. High-level recommendations are listed with further references for resolution. The first two challenges may be resolved at the facility level while others may require system administrator intervention.

Table 2. Common challenges summary

#	Description	Severity	Prevalence	Possible Resolution
1	Slow application [*validated by testing the overall network speed*]	High	High	Check for network issue. Close other running applications on the client. Restart client. Determine if server is having issues. Free up storage space for the client.
2	Freezing of application [*documented by client issue report*]	High	Medium	Check if network is still available. Close other running applications on the client. Restart client. Determine whether server is having issues. Free up storage space for the client.
3	Server issues: high CPU/load, low memory, disk I/O, disk space, network [*documented through server-monitoring software*]	High	High	Use multiple servers with load balancing, if possible, and increase resources allocated to the application instance. Check computer or web application firewall for dropped connections or system issues. Review DHIS2 recommendations.
4	Latency or other network issues between hosted instance and client [*validated by ping, tracert, or network-testing application*]	High	Medium	Check with cloud provider for options. Attempt alternative connection method if available (e.g., alternate mobile operator, use of Wi-Fi). [See challenge 7 re: concurrent usage]
5	Database misconfiguration [*documented through query monitoring*]	High	Low	Check server and table configuration to make sure the database is optimized for required performance. Ensure caching is enabled in the DHIS2 configuration so that repeated requests for the same analytics resources are served from the cache and database queries are skipped. If the database is on the same server as the application, split to a separate server.
6	Incorrect landing page configuration [*documented by long application load times*]	High	Low	Minimize use of program indicators in dashboards. Limit access to dashboards that use program indicators as the landing page upon logging into DHIS2.
7	Inability of server to handle concurrent usage during certain times of day [*documented by client issue report*]	Medium	High	See if data entry can be spread throughout the day instead of clustered.
8	Transaction and reporting on same server	Medium	High	Split reporting to a separate server.
9	Lack of option for off-line data entry	Medium	Medium	Add this as an option if network issues are insurmountable. Off-line data entry requires additional storage on the client device and may lead to a greater incidence of challenges 2 and 4.
10	Aggregate and Tracker data on same server	Medium	Low	Split applications to separate servers.
11	Lack of synchronization between Tracker and aggregate data	Low	Low	Run this process during low-usage times.

Abbreviations: CPU, central processing unit; DHIS2, District Health Information System 2.
Note: "Client" refers to a tablet or phone.

Tools overview

This guide is intended to help ICT and ministries identify and address DHIS2 Tracker challenges in a timely manner and help reduce software infrastructure causes of a data backlog. To address the common challenges the following troubleshooting tools were designed to provide templates and guidance.

Tool 1: High level personas.

Personas provide context for the different actors engaged in the data collection and entry. They may vary depending on the immunization activity or setting but the personas provided can help ICT administrators better understand the users facing the challenges.

Tool 2: Business process maps for COVID-19 vaccination.

Business process maps are included as a starting point to understand the interactions between the systems and the different personas.

Tool 3: Facility troubleshooting flowchart.

A troubleshooting flowchart has been created to help trace the flow and diagnose if the challenges are being caused by human interaction, infrastructure, device, or systems.

Tool 4: Checklists for Tracker performance at scale.

Performance checklists have been developed with HISP and DHIS2 to understand server configurations and limitations that impact performance for Tracker users.

Tool 5: Sample issue ticket.

Finally, a sample issue ticket has been drafted to help document the resolution of issues and support overall knowledge management.

The personas section provides a level of contextualization and an understanding of how DHIS2 Tracker is being used in countries and how it fits into existing workflows. Based upon their skills with communications and information technology, they (or support technicians) may use the other tools included to troubleshoot or inform administrators to quickly resolve challenges with data entry and use.

Planning for the future

At the time of writing, Java Development Kit version 11, PostgreSQL version 12 and 13, as well as DHIS2 version 2.35 was in use. As software continues to evolve and knowledge associated with addressing data entry is compiled, we recommend that this guide also evolves with major releases of the software with regression testing that optimizes performance.

Tool 1: High-level personas

The scale required for full-population vaccination involves several sets of users performing the data entry, those maintaining the mobile devices and data plans, a team overseeing the programmatic use to identify the data bottlenecks, and skilled hosting providers ensuring a high-availability environment.

Figures 2 through 6 below depict the end users and other related stakeholders who interact with the DHIS2 or are somehow involved in data entry and data use. This information is presented to better understand the general background, roles and responsibilities, motivations, challenges, and environmental factors involved so that we, in turn, can better understand the constraints as part of problem resolution. While data entry clerks are often deployed to enter data into the system, in lower-volume settings, nurses are tasked with the data entry process (even using their own phones and data bundles to complete the work).

Figure 2. Nurse (tech savvy)

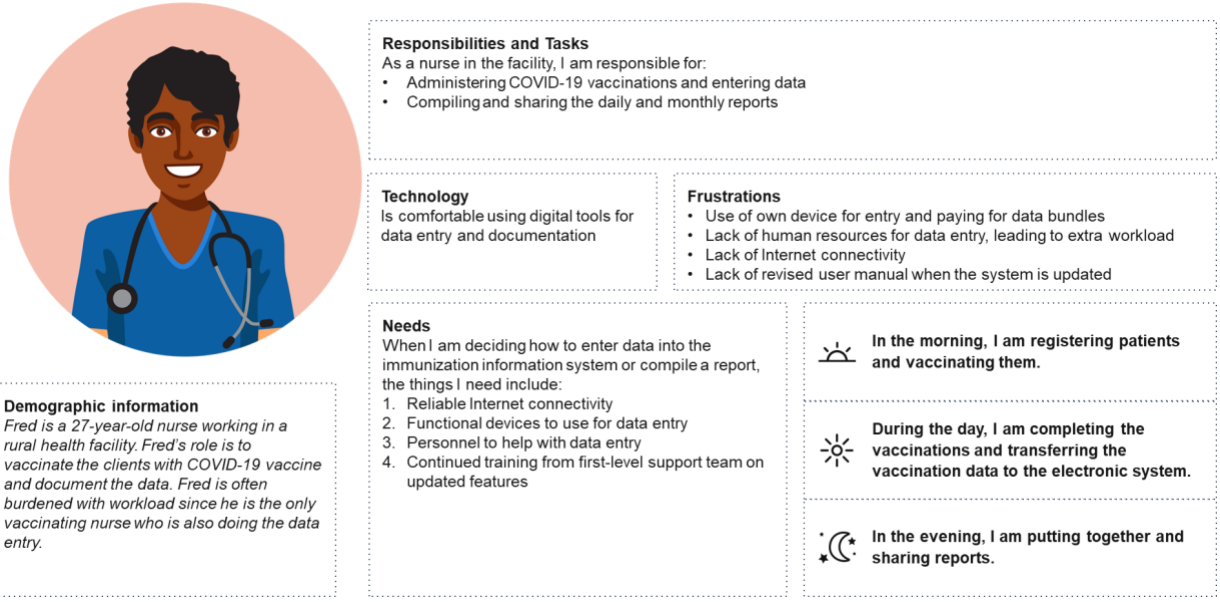


Figure 3. Nurse (first-time user of digital health application)

Demographic information
Joyce is a 45-year-old nurse from a rural facility. Joyce is responsible for administering routine and COVID-19 immunizations in her facility. She attends to many clients during the day and spends her afternoons working on reports. Joyce is not well versed with technology and relies on data clerks to transfer the COVID-19 vaccination data to the digital platform.

Responsibilities and Tasks
As a nurse in the facility, I am responsible for:
- Administering COVID-19 vaccinations and manual data entry
- Compiling and sharing the daily and monthly reports

Technology
The nurse is not well versed with electronic data entry and has challenges with understanding the user interface and updating the data.

Frustrations
- Having a new task requiring electronic data entry, something that is not part of her daily routine
- Has only attended one training on the vaccination system with limited support on its use

Needs
When I am deciding how to enter data into the electronic system or obtain a report, the things I need include:

1. Data entry personnel to help with entry
2. Standard manual tools for entering the COVID-19 vaccination data
3. Additional training on the use of the electronic system

In the morning, I am registering patients manually and vaccinating them.

During the day, I am completing the vaccination and transferring the vaccination data to the data clerk, who will rekey them into the electronic system.

In the evening, I am putting together and sharing reports.

Figure 4. Data clerk

Demographic information
Cheikh is a 25-year-old data clerk at a district hospital. He recently graduated from university and decided to take a role to develop his skills.

Responsibilities and Tasks
As a data clerk in the facility, I am responsible for:
- Entering COVID-19 vaccination data at the district hospital
- Traveling to outreach sessions to support data entry
- Reporting to the district records officer

Technology
Is comfortable using digital tools for data entry and reporting. This happens when airtime to buy data bundles and devices is provided.

Frustrations
- Lack of reliable Internet resources for data entry
- Lack of reliable electricity or backup power
- Digital system hanging and general slowdowns
- Lack of standard operating procedures for COVID-19 data entry
- Use of personal devices for data entry due to the devices provided being old and nonfunctional
- Limited functionality for editing data in the digital systems
- Late payments for outreach sessions and logistics by partners
- Heavy workload and lack of motivation

Needs
When I am deciding how to fill data into the immunization system or produce a report, the things I need include:

1. Airtime and data bundles to facilitate data entry and syncing
2. Functional devices to use for data entry
3. On-time payments and stipends
4. Facilitation of logistics for outreach sessions

In the morning, I am registering patients as they get vaccinated.

During the day, I am entering vaccination data into the patient immunization record system.

In the evening, I am putting together and sharing reports.

Figure 5. District Health Information Officer

Responsibilities and Tasks
As a district health information officer, I am in charge of regional cold chain and immunization systems:
- Receiving data on COVID-19 vaccinations from the facilities and performing supportive supervision
- Organizing data entry clerks for outreach and campaigns
- Delegating facility data backlog entry to clerks reporting to her

Technology
Uses digital tools for data entry and amends/edits the erroneous/incomplete data in the electronic register and logistic systems, as the facility personnel do not have rights to correct on their own.

Frustrations
- Late daily COVID-19 reports
- Growing backlog from some of the facilities
- Vaccine stockouts
- Lack of devices and data in the facilities, exacerbating the backlog

Demographic information
Judith is a 35-year-old district health information officer. She works at the district hospital and oversees routine and COVID-19 immunizations data in 25 facilities in the area.

Needs
When I am ensuring the facilities have the resources for data entry, the things I need include:
1. Airtime and data bundles across the facilities for data entry and syncing
2. Functional devices for the facilities
3. Data clerks to support clearing the backlog
4. Resources for transport, training, and supervision of facilities

In the morning, I review facility data for quality and completeness.

During the day, I am supporting facilities with clearing backlogs and conducting facility supervision.

In the evening, I receive reports from the facilities and share with my supervisors.

Figure 6. National Information and Communications Technology (ICT) Officer

Responsibilities and Tasks
As the national ICT officer, I am responsible for:
- Supporting different facilities to troubleshoot any challenges they have with digital systems
- Reviewing server log files and issues reported by different facilities
- Working with the data center service provider for troubleshooting
- Training teams on use of the electronic systems

Technology
Has great expertise in using the country health information systems and is able to retrain others.

Frustrations
- Use of own resources when troubleshooting
- Access to real-time data or visibility into service-level agreements at the data center
- Inadequate support with logistics during support

Demographic information
Jacky is an ICT officer overseeing the systems for the countries 8,000+ facilities. She has great expertise in digital health systems, and most of her data center operational knowledge has been learned on the job.

Needs
When I am supervising the overall system functionality, the things I need include:
1. Budget for rightsizing server environment
2. Software tools and equipment to troubleshoot issues
3. Data bundles
4. Logistics support

In the morning, I support facilities over the phone and troubleshoot any issues they have with digital systems that can be resolved remotely.

During the day, I am meeting with ministry staff and troubleshooting any issues with facilities and the hosting provider.

In the evening, I am reviewing reported issues and planning for the next day.

Tool 2: Business process maps

The following business processes highlight the client data entry interactions with the DHIS2 Tracker: (1) register client and (2) administer vaccine (both for facility-based delivery and in an outreach/off-line mode).

A business process is a set of related activities or tasks performed together to achieve the objectives of the health program—in this context, COVID-19 vaccine delivery. Using the Business Process Model and Notation (BPMN) standard,[6] workflows are presented visually as a "story" to enhance communication and collaboration among users, stakeholders, and engineers.

Register Client

For the client, an initial step is to create the client's immunization record. This will allow the client, providers, and MOH to identify which vaccinations have been given. Adult clients requiring a new vaccine (such as for COVID-19) typically will not be in the system, as it may not have been available when they received previous vaccines. Furthermore, many countries implementing the COVID-19 trackers did not previously have a client registry, which would shorten this initial step. Figure 7 provides a flowchart for this business process, and the annotations below provide additional information for various steps in the flowchart.[7] Note that, while the flow in Figure 8 includes steps for self-registration, the functionality has not been very successful due to several reasons, including the need for a unique identification number, cellphone number, and Internet access. This resulted in health workers having to register individuals on arrival and entering all individual data. During massive campaigns, this further overwhelmed health staff and created huge backlogs. Health staff turned to paper-based data entry, but there were no official paper forms, so staff recorded individual data on blank paper. These data, which were to be then transferred to the digital platform, can be incomplete and problematic.

"Register client" business process notes and annotations:

2. Different than child immunization, vaccines that target older age groups may require the client to register in an external scheduling or related system. These records may be automatically imported into the system or may need to be manually imported or entered. This external system often requires a smartphone and network connection, at a minimum.

5. This is a paper version of the electronic vaccine record providing additional documentation to the user for reminders and other information regarding the vaccines given.

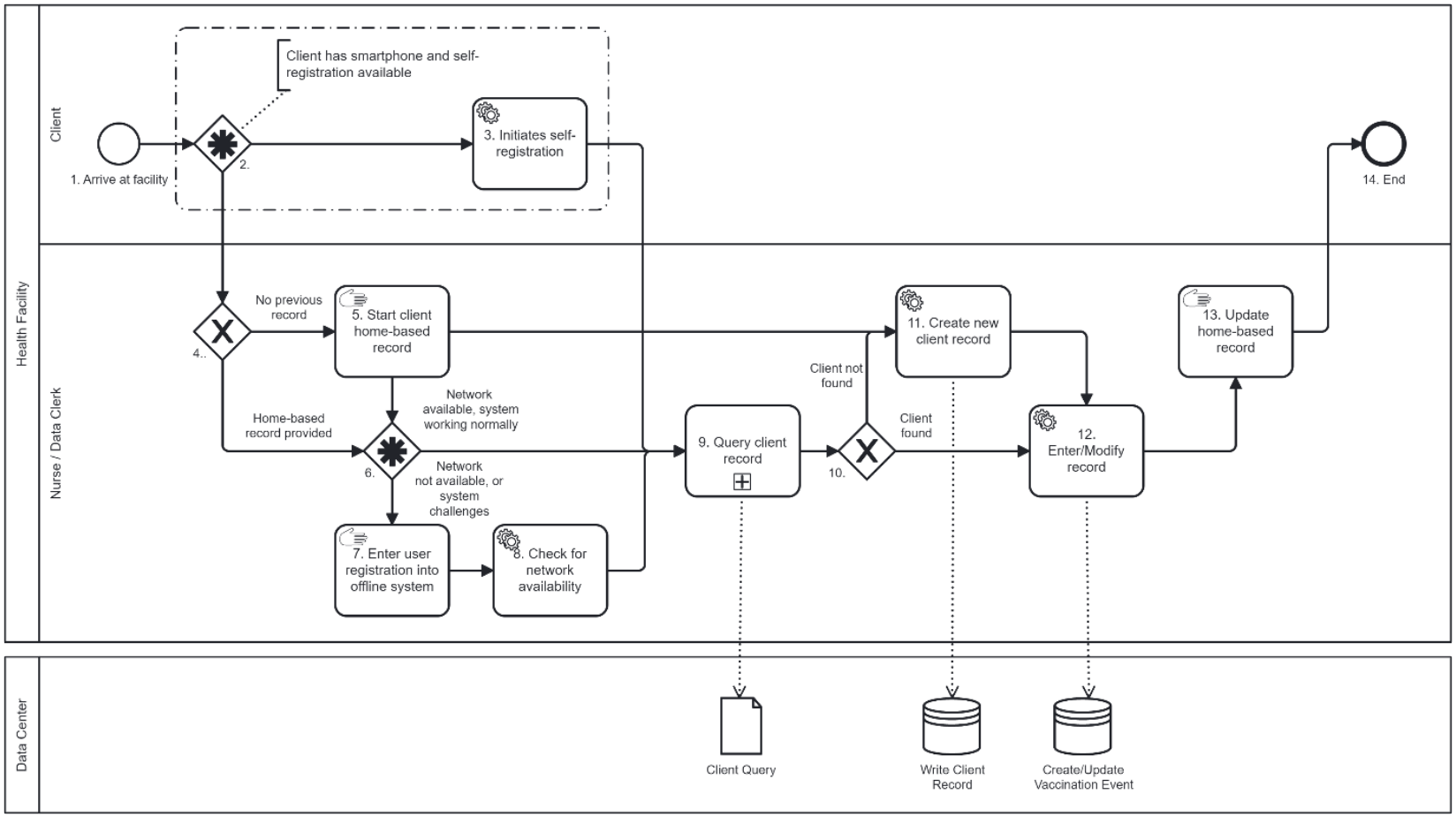
6. Many factors are at play regarding the ability to use the DHIS2 Tracker, including network access, a system that is working normally, and resources that are available for real-time data entry.

9. The nurse or data clerk will enter the client identifier—ideally a unique national number but possibly an identifier such as last name, date of birth, and/or phone number—to search for client record.

10. If the client record has not been found, a new record may be created. However, this triggers another process to resolve duplicates.

[6] See BPMN Specification - Business Process Model and Notation.
[7] BPMN versions of the business processes described are available upon request.

Figure 7. Register client



Administer Vaccine

Following client registration, the nurse will verify which vaccines a client needs, administer those, and record the relevant necessary data, both in the system and on the appropriate paper records. Figure 8 and Figure 9 provide flowcharts for facility and outreach/off-line administration, respectively. The annotations below provide additional information for various steps in each of the flowcharts.

Facility vaccine administration business process notes and annotations:

3. This reflects a similar complex decision regarding real-time data entry, including network and hardware access, system availability, and available time for the nurse to enter data. If the system is not available, the nurse will look to provide the vaccine still using the home-based record.

5. The nurse will check the age of the individual vs. the vaccine, eligibility for the dose, etc., before administering the vaccine.

8. A paper version of the electronic vaccine record providing additional documentation to the user is also updated during this step.

13. If an adverse event following immunization occurs, this sub-process also involves recording information in an adverse event following immunization system.

In situations where the facility does not have the resources to perform the data entry for vaccine administration at the time of administration (often during campaigns or outreach), an alternative flow may be used. The example provided in Figure 9 mimics a model where paper forms are pooled and entered by data entry clerks at another location.

Outreach/off-line vaccine administration business process notes and annotations:

3. Similar to clinical decision support that may be used with an online system, the nurse will check the age of the individual vs. the vaccine, eligibility for the dose, and other contraindications before administering the vaccine.

5. When the system is not available, the nurse resorts to manual data entry. In many situations, there are not common data forms for the nurse to use. In other instances, there is no ability at the time to query the system and see if an existing record exists. Ideally, the home-based record will be available to copy the unique client identifier used for the initial vaccination. If not, this may lead to duplicate records that need to be merged at a later date.

Figure 8. Administer vaccine (facility)

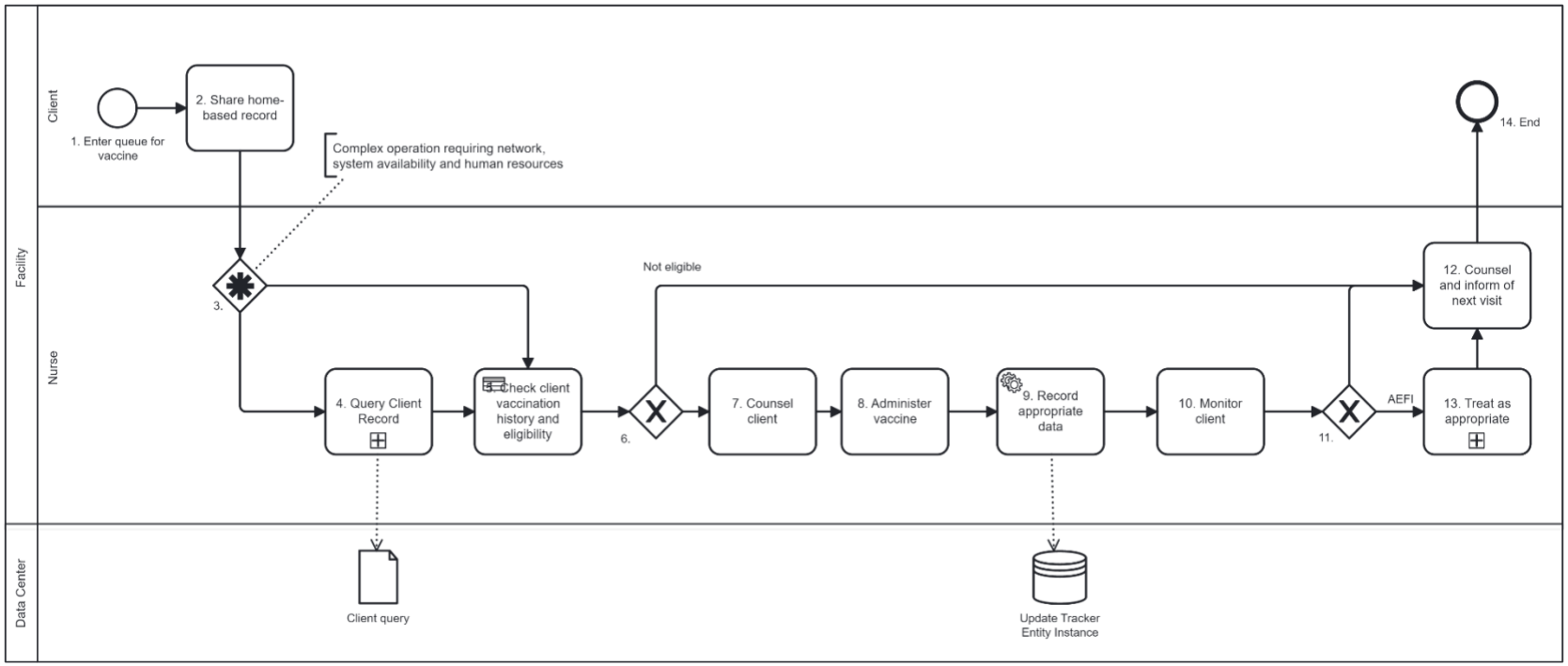
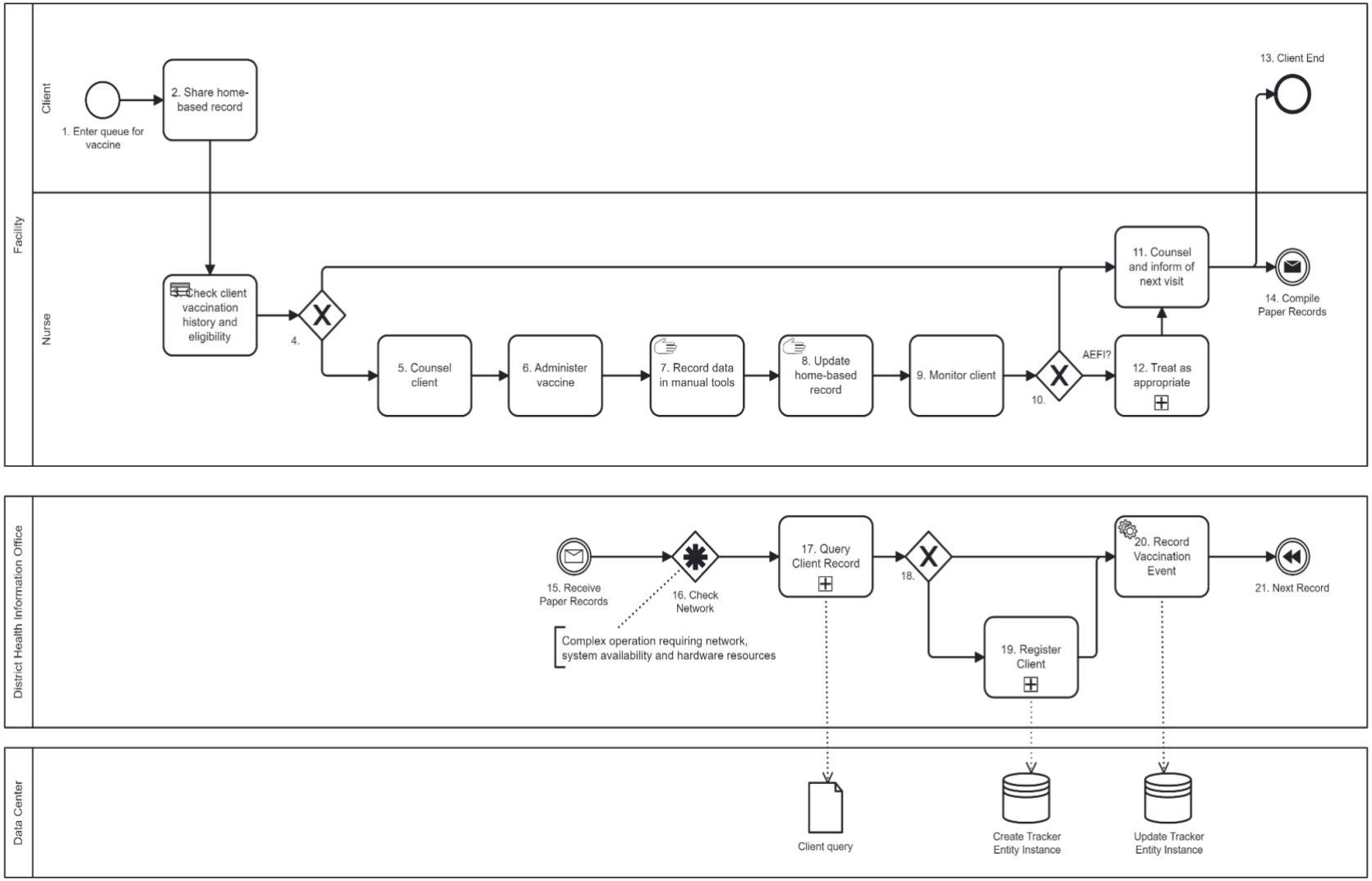


Figure 9. Administer vaccine (outreach/off-line)

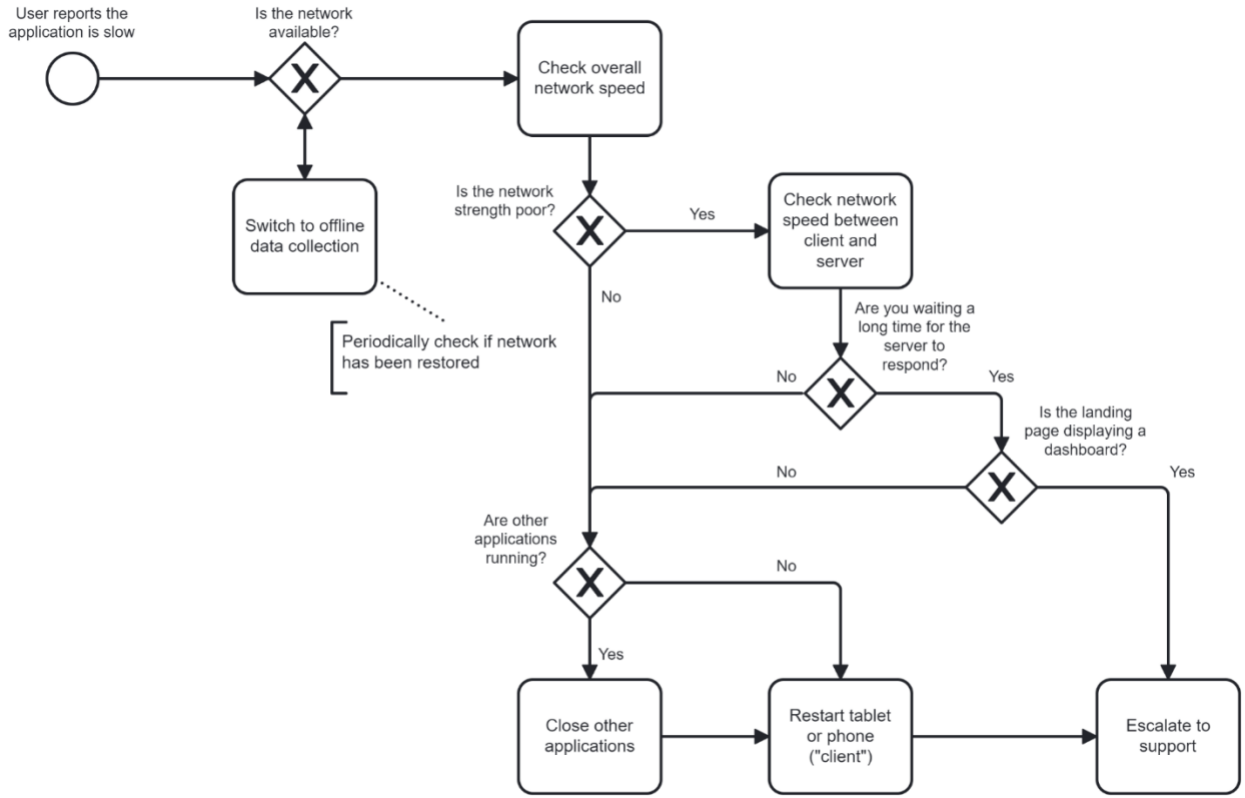


Tool 3: Facility troubleshooting flowchart

Facility flowchart preconditions are as follows: To support troubleshooting on issues reported by facilities, it is necessary to validate that the DHIS2 Tracker hosting environment is configured for performance at scale, as well as see that server monitoring software is running to further investigate issues corresponding with the same date and time. Ideally, the individuals on-site at the facility have the hosting support team's contact phone number to explore server-side conditions when they need to "escalate to support."

Figure 10 provides a flowchart/decision tree of steps a user can use to identify local application and network challenges.

Figure 10. Troubleshooting flowchart for facilities



Tool 4: Tracker performance at scale checklists

The following checklists and flowchart have been adapted from DHIS2 documentation and from interviews with system administrators creating high-availability environments.[8]

The checklist is intended for use by system administrators supporting MOHs with their national plans for COVID-19 vaccine delivery, and the flowchart, by subnational Information and Communication Technology and Health Information Officers supporting issues reported by facilities.

Figure 11 through Figure 13 provide guidance associated with server technical specifications, supported software application versions, and recommended configuration of the DHIS2 Tracker application.

Key:	
	Within recommended system specifications
	Software version may not yet be fully supported or is below speed recommendations for peak performance
	Below system recommendations

Figure 11. Server sizing (for Global VAX, at least the following)

CPU cores	☐ Less than 32	☐ 32 or greater	
Memory/RAM	☐ Less than 32 GB	☐ 32 GB or greater	
SSD/fast disk read speed	☐ Less than 150 MB/s	☐ Between 200 to 300 MB/s	☐ Greater than 350 MB/s
Fast/stable Internet and connectivity Latency/Round trip time (RTT)	☐ RTT greater than 200ms	☐ RTT between 20 and 200ms	☐ RTT less than 20ms
Packet loss	☐ Greater than 5% packet loss	☐ Between 1% and 5% packet loss	☐ 0% packet loss
Jitter	☐ Request Timed Out, Transmit Failed, or Destination Host Unreachable	☐ No network errors received	
Is the server in a shared environment?	☐ Yes	☐ No	
If in shared environment, verify does the server have the specified resources needed?	☐ No	☐ Yes	
Dedicated server for database/PostgreSQL?	☐ No	☐ Yes	

Abbreviations: Global VAX, Global COVID-19 Vaccine Access; CPU, central processing unit.

[8] Annex A ("Interview guides") provides a larger list of questions used for the initial diagnosis and root cause analysis.

Key:	
	Within recommended system specifications
	Software version may not yet be fully supported or is below speed recommendations for peak performance
	Below system recommendations

Figure 12. Software (appropriate software versions are used)

Java Development Kit	☐ 10 or lower	☐ 11*	☐ 12 or higher
PostgreSQL	☐ 11 or lower	☐ 12 or 13*	☐ 14 or higher
DHIS2 version	☐ 2.34 or lower	☐ 2.35 or later*	
Latest patch installed†	☐ No	☐ Yes	
Server monitoring is set up	☐ No	☐ Yes	
Sever monitoring software	☐ No	Yes: ☐ Glowroot ☐ Munin ☐ Other (enter name):	

* Denotes recommended versions as of April 7, 2023. Several performance improvements were made in the DHIS2 2.35 release.
† See DHIS2 Downloads page for latest patch.
Abbreviation: DHIS2, District Health Information System 2.

Figure 13. Configuration

Program indicators appearing on dashboards?	☐ No	☐ Yes*
Dashboards used as “landing page”?	☐ No	☐ Yes†
Access to dashboards used for program indicators limited?	☐ No	☐ Yes‡
Analytics cache enabled?	☐ No	☐ Yes
Continuous analytics used?	☐ No	☐ Yes
“Display front page list” check in the program details disabled?	☐ No	☐ Yes
Database indexes for frequently searched TEI attributes applied?	☐ No	☐ Yes
System-generated attributes use random pattern?	☐ No	☐ Yes

* As an alternative, establish serving tracker analytics through the aggregate data model. See strategies described in Tracker performance at scale on DHIS2 Documentation website.
† As an alternative, set up a text-only / information-landing dashboard that excludes tracker analytics.
‡ Limited dashboards based on program indicators only for those users or user groups who need them for analytical purposes (e.g., not for general data entry users).
Abbreviation: TEI, tracker entity instance.

Note: Checklists adapted from: DHIS2 Documentation website. Tracker performance at scale page. Accessed January 19, 2023.

Tool 5: Sample issue ticket

Requester Details		
Name	**Phone**	
Email	**WhatsApp**	
Facility Name		
Request Information		
Date/Time	**Priority**	☐ Critical (Work stoppage) ☐ High (Resorting to manual processes) ☐ Medium (Work slowdown) ☐ Low (Feature request)
Issue Headline		
Issue Details (*provide as much information as you can to recreate or troubleshoot the issue*)		
Issue Resolution (*provide the steps completed to resolve the issue*)		

General recommendations

Bob Jolliffe from the DHIS2 Integration team has stated that “the most important requirement is human.” With the DHIS2 Tracker implementations at the scale necessary for full-population vaccination, a country needs a large cadre of users performing the data entry, a team of individuals providing and maintaining the mobile devices and data plans, a strong relationship with the ministry overseeing the programmatic use to identify the data bottlenecks, and skilled hosting providers ensuring a high-availability environment.

The pandemic brought volumes of data much higher than previously experienced which led to constrained systems and data backlogs as a result. This guide and the tools included are designed to provide system administrators processes and advice to address these challenges and prepare against future burdens. Four key recommendations to address and avoid performance issues with DHIS2 tracker are below:

1. **Consult with DHIS2 teams and HISP network on sizing hosting environment.**
   Begin by consulting with the DHIS2 teams and HISP network and size the infrastructure according to current best practices for the population and vaccination events expected. However, countries should be prepared to monitor the server environment and adjust accordingly.

2. **Consider procuring dedicated hosting resources vs. a shared environment.**
   For high-performance applications, purchasing dedicated resources vs. shared ones may be better. If working with a local data center, validate the service-level agreements and provide evidence to the provider regarding resource allocation. Over-provisioning and throttling are common. If you do not have good monitoring in place, you will not be able to make the argument that changes are needed.

3. **Document support processes with contact information and plan for hardware and network outages**
   Mapping the process flows and associated roles is key to troubleshooting when the system is down or underperforming, as well as knowing whom to call to repair/fix the problem.

4. **Provision facilities with data entry resources (human, hardware, and network) to prevent data backlog.**
   The burden of data entry may be overwhelming when the number of cases reaches a certain threshold at a facility. The tendency to capture data on paper and then later transfer them to Tracker creates a time-consuming and burdensome process as well as reducing data quality and accuracy because of an inability to verify. The best case on how to handle a surge of data entry is to provision the server and the facilities with the resources needed to prevent a data backlog in the first place.

There are significantly fewer routine immunization sites with adequate equipment and connectivity—and if the information reported by users is any lesson, the burden of data entry is significant, and these same facilities often do not have the luxury of a data entry clerk.

As the world begins to look beyond the COVID-19 pandemic and determine how the lessons can be applied for other vaccinations and challenges, ministries will need to continue to take into account the needs of the users, data size, and data use demands. While this toolkit was designed in response to COVID-19 emergency response needs, the framework and tools can be applied to routine immunization as well as preparation against the next medical emergency.

Annexes

Annex A. Interview guides

Interview guide to diagnose server hosting/storage and specifications

1. Where are servers hosted (location)?
2. What is the size of the inbound data pipeline connectivity to the application environment?
3. At peak traffic, what is the percentage of utilization?
4. What is the purpose of each server in the environment?
5. Provide details of the application hosting environment:
   a. Which type of hosting is used (on-premises/mixed/cloud-based)?
   b. Which type of server (physical/virtual)?
   c. How many servers / virtual machines are available?
   d. What is the allocated processing capacity (CPUs/vCPUs)?
   e. What is the memory (RAM) per server / virtual machine?
   f. What is the operating system and version of server / virtual machine?
   g. What additional services are enabled on the server (SMTP, FTP, etc.)?
   h. What is the available and allocated storage capacity?
   i. Is load balancing configured to manage application traffic?
   j. Is the application hosted behind a proxy server?
   k. Is the application hosted behind a web-application firewall?
   l. Is there dedicated bandwidth (Quality of Service) for the front-end server or servers)?
   m. Is the server regularly maintained, including security and recommended patches, updates, or upgrades?
6. Is the environment a single-node setup?
7. Which version of DHIS2 is installed?
8. What relational database management system is installed, and which version?

9. Are there MySQL/MariaDB/PostgreSQL read replicas configured? If yes:
    a. How many?
    b. Where (same or different server)?
10. Are there separate web servers? If yes, how many?
11. Are there additional applications hosted on the same server (besides DHIS2)? If yes:
    a. Which ones (and are they critical)?
    b. What is their resource configuration on the server?
    c. Can the server capacity accommodate these configurations?
12. Is there any application-specific log available (DHIS2, web server, relational database management system)? And if so, are there any critical or warning events?
13. Are there any operating system logs available (network, CPU, memory, applications used, services running)? And if so, are there any critical or warning events?
14. Is the DHIS2 application or web server given priority or increased CPU affinity?
15. How many users are configured on the DHIS2 server?
16. What is the purpose of resource-intensive application programming interfaces like the event one?
17. How many queries can be processed before DHIS2 becomes too busy to handle additional requests?
18. What is the schedule for incremental and full analytic runs?
19. Describe the procedure for installation of the DHIS2 Metadata package.

Facility diagnostics interview guide

Preconditions

Prior to visiting a facility, ideally the following has been established:

- The DHIS2 Tracker hosting environment has server monitoring software installed and running.
- The individuals on-site at the facility have the hosting support team's contact phone number to explore server-side conditions while on-site at the facility.
- The facility has reported issues with application performance.

- The time of day when issues are most likely to occur has been established.

User information

Name		**Telephone**	
Email		**WhatsApp**	
Facility Name		**District**	
Latitude		**Region/Province**	
Longitude		**Country**	

Hardware, communications, and software

On what devices are the clients/mobiles running (make/model)? _____

How much memory does the device have? _____

How much memory is available for the application? _____

How much storage does the device have? _____

How much storage space is free? _____

Which mobile network operator is being used? _____

What is the Internet connection speed on the end-user devices (2G/3G/4G/5G)? _____

What other mobile networks are available? _____

What is the version of the end-user application? _____

Interview

How often is the network not available during work hours? _____

When the network is not available, is there an off-line mode? _____

When are data typically entered into the system? _____

When are the peak data entry times? _____

Observations

Is the device fully charged regularly? _____

Is the device in good physical condition (no breaks or signs of physical damage)? _____

Does the device appear to have unneeded/unwanted applications (bloatware)? _____

What other applications are currently running (see running apps or battery usage)? _____

How long does it take for the first screen to appear? _____

Are dashboards with program indicators appearing as the first screen ("landing page")? _____

How long does it take to register a new client? _____

How long does it take to enter a vaccination event? _____

Additional tools

Table 4 summarizes additional tools that can be used to diagnose the network when on-site at the facility.

Table 4. On-site network diagnostic tools

Type	Purpose	Tools/apps
Ping and IP	Assess latency, packet loss	Watcher, LAN, Ping, GeoPing, Traceroute, iPerf, Speedtest, port scanner, UPnP Scanner, Wi-Fi Scanner, Subnet Scanner, Whois, DNS Lookup, Wake-on-LAN, IP Calculator, WiFi Analyzer
Network speed	Assess speed	Speedtest
Network coverage	Assess 3G/4G/5G coverage	OpenSignal

Annex B. Methods and approach

The methods used to create this troubleshooting guide balanced rigor with efficiency to provide actionable data for decision-making. By including the user personas in and workflows, we have come to realize that context matters, and delving deeper into an issue is required rather than simply identifying it. Furthermore, collaboration and multiple stakeholder views are needed to produce interventions that are quickly actionable and have the most impact.

We documented the journey of the vaccination data record from multiple points of entry through to data visualization and use on a national scale (see the Business process maps). We used a human-centered design approach to document the various roles that interact with the data, along with the challenges in resolving the data backlog and opportunities to do so. Additionally, we focused on data-process mapping to generate solutions to alleviate and avoid backlogs.

The process entailed probing questions to understand the who, what, where, when, and how to help in assessing challenges related to the vaccination process, including data capture, data entry, and reporting of COVID-19 vaccinations. These questions include the following:

- How do patients/clients flow through the vaccination site from arrival to departure?
- Who is responsible for administering the vaccinations, and who is responsible for entering data?
- How is the data entered, and when is the data synced? How often is data syncing taking place? What happens to the data after entry?
- Where did the data entry or technical challenge occur in the business process or data flow?
- How widespread is the challenge or problem?

The approach included mixed methods of observations of vaccine data recording, interviews with key stakeholders, and data-flow mapping. The approach to diagnosing backlog issues comprised:

- Data spot checks and standard operating procedures. Digital Square staff reviewed the vaccination registers to understand what data are being gathered and document the data flow from vaccination registers to data entry, resulting in a standard operating procedure and/or guidance document to optimize future data-input processes.

- Mapping of the vaccination flow process. Digital Square mapped common data flows in Tanzania, Senegal, and Kenya from patient creation of an appointment to vaccine certificate generation—identifying how people move through the vaccination site from arrival to departure, who vaccinates, who does the data entry, when does data entry happen, how are the data entered, how and when are the data synced and how often does data syncing take place, and what happens to the data after entry. Where possible, we performed system reviews and demonstrations to document the client-side technology configuration and infrastructure available and make recommendations for upgrades to match the current recommendations for using DHIS2 Tracker at scale.

- Quantification of the backlog. Digital Square worked with ministries of health (MOHs) to review data sources (e.g., stock data, line lists, aggregate reporting) to help quantify how many doses have been used versus how many doses are reported in various systems, as well as to quantify the number of paper registers not yet input into various systems against facilities to identify which facilities have the largest burden of underreported or inconsistent data. Facilities with the highest burden were further investigated to identify possible as-yet-unknown bottlenecks and determine alleviation strategies.

A sampling matrix of facilities that received COVID-19 vaccine for distribution was created based on available data and discussion with each study country's MOH. Sampling in this study was not designed based on the individuals to be interviewed; instead, it was based on the health facilities the individuals

represented. Facility-sampling choices were made based on the need to maximize variations in the following characteristics:

- Urban-rural variations.
- Facility types.
- Facility ownership.
- Catchment population.
- Infrastructure (different levels of infrastructure with regard to electricity and Internet availability).
- Existence of vaccine data backlog (facilities with a variation of existing/growing backlogs or significantly lower backlogs in comparison to other facilities).

Within each facility, individuals to be interviewed were selected based on diversity in roles. Two main types of roles were administrative and service provision ones, such as health care workers and data entry clerks.

Annex C. Limitations

During the height of vaccination campaigns in Kenya, Senegal, and Tanzania in 2022, a deeper-level root cause analysis[9] was undertaken to explore the reasons for the growing data backlog. During interviews and surveys, users reported several issues with data entry into the system of record, as recorded in the next section. Both Senegal and Tanzania were using DHIS2 to record each vaccination event, and as a response, this guide was produced to help with both rightsizing the server configuration and troubleshooting client-side issues.

Several issues were reported, although most issues were not observed during the facility visits and interactions with the hosting personnel. The initial push on mass vaccination campaigns waned, and the associated simultaneous load on the servers diminished. However, this guide serves to compile the best practices from the DHIS2,[10] the HISP [Health Information Systems Program] network,[11] and other sources as countries continue to establish the infrastructure for transactional immunization data to keep their citizens healthy.

[9] USAID/PATH (2023). Multi-Country CN-18 COVID-19 Vaccination Data Backlog Root Cause Analysis - Kenya, Senegal, Tanzania.
[10] See https://docs.dhis2.org/en/home.html.
[11] See https://dhis2.org/hisp-network/.

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