

User Feedback and System Performance of Laboratory Information Management Systems (LIMS) in Uganda: Findings from a National Survey

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ABSTRACT

Background: Laboratory Information Management System (LIMS) is essential for improving data accuracy, workflow efficiency, and clinical decision-making. Uganda drafted a modular national LIMS strategy in 2017 to strengthen laboratory services; however, evidence on progress of system performance and user experience remains limited. This study evaluates LIMS performance, user satisfaction, organizational impact, and compliance with data protection regulations.

Methods: A cross-sectional study was conducted between August and September 2024 across 42 health facilities in Uganda, purposively selected by region, level of care, and LIMS implementation status. A semi-structured digital questionnaire, informed by the DeLone and McLean Information Systems Success Model, was administered via Kobo collect. The instrument assessed system and information quality, user satisfaction, organizational impact, and compliance with the Uganda Data Protection and Privacy Act 2019. Data were analyzed using STATA 12.0 and Microsoft Excel, with descriptive statistics summarized across all variables.

Results: A total of 114 respondents participated, predominantly laboratory personnel, across National Referral Hospitals (n=6), Regional Referral Hospitals (n=16), General Hospitals (n=11), and Health Centre IVs (n=9). Awareness of LIMS was high (>80%), with near-universal access to core modules; however, access to specialized systems remained limited, including Lab Results SMS (38%) and HIV Drug Resistance Dashboard (45%). System reliability was high ($\geq 80\%$) for most modules, but infrastructure challenges particularly power outages (32%) and network failures (29%) significantly affected system availability. Integration was limited, with only 34% of laboratory analyzers interfaced and EMR(Electronic Medical Records) LIMS integration reported in 19% of facilities. LIMS use was associated with improved data utilization (85%) and enhanced communication and collaboration (97.6%). However, gaps in data governance were

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observed, including absence of Information and Communication Technology (ICT) data safety Standard Operating Procedures (SOPs) in 35% of facilities, credential sharing (33%), and use of personal email for transmission (35.7%)

Conclusion: LIMS implementation in Uganda has achieved substantial progress, particularly in the widespread adoption of core systems, high levels of system reliability, and notable improvements in data use and communication across facilities. However, important gaps remain, including infrastructure-related disruptions, limited interoperability with analyzers and EMRs, uneven access across facility levels, and inconsistencies in data governance practices. Addressing these areas presents a clear opportunity to enhance system performance.

Keywords: Laboratory Information Management System; LIMS; Health Informatics; User Experience; Data Protection; Uganda; Digital Health.

Introduction

Background

Laboratory Information Management Systems (LIMS) have become foundational components of modern health systems, enabling the efficient management of laboratory data, improving workflow processes, and supporting clinical decision-making. Laboratory results contribute substantially to patient diagnosis and treatment, and the reliability, timeliness, and accessibility of these data are directly linked to healthcare quality outcomes. In this context, LIMS play a critical role in strengthening laboratory performance and improving patient care by reducing errors, enhancing turnaround times, and facilitating data-driven decision-making.

Over the past two decades, LIMS have evolved from basic data entry platforms into complex, integrated systems that support automation, interoperability, and real-time information exchange. These systems reduce reliance on manual processes, thereby minimizing transcription errors and improving data integrity. In high-resource settings, integration of LIMS with EMRs and clinical decision support systems has been associated with improved coordination of care, reduced duplication of diagnostic testing, and enhanced patient safety.

In sub-Saharan Africa, the adoption of digital health technologies, including LIMS, has accelerated in response to increasing demand for efficient health information systems. However, implementation in low-resource settings remains constrained by infrastructural limitations, including unreliable electricity, limited internet connectivity, and shortages

of trained personnel. These constraints often affect system performance, sustainability, and user adoption, limiting the potential benefits of digital health investments.

The Ugandan Context

Uganda's health system comprises approximately 7,000 health facilities organized across six levels of care, from Health Centre IIs to National Referral Hospitals (Third National Development Plan III, 2020-21-2024-25, n.d.). The laboratory network includes over 1,500 facilities performing diagnostic testing, with significant variation in capacity, staffing, and infrastructure. Prior to LIMS implementation, laboratory data management in Uganda was predominantly paper-based, characterized by fragmented recording, delayed reporting, limited data utilization, and challenges in tracking specimens and results across the referral network (Baseke et al., 2022)

Recognizing these challenges, the National Health Laboratory and Diagnostic Services (NHLDS) developed a comprehensive LIMS Master Plan in 2014, with implementation beginning in 2016 through substantial support from the United States Centers for Disease Control and Prevention (CDC) and the African Society for Laboratory Medicine (ASLM) (*UGANDA NATIONAL HEALTH LABORATORY SERVICES POLICY_0*, n.d.). The system was designed using a modular approach targeting six priority business areas: Routine and reference testing (RRT), Quality Assurance (QA), Logistics (LOG), Blood Bank (BB), Disease Surveillance and Response (DSR), and Laboratory Management (MGT).

The implementation roadmap from 2016 to 2024

envisioned progressive deployment across the laboratory network, beginning with initial site assessments and pilot implementations. The TEN (10) implemented systems include: Viral Load (VL) Dashboard for supporting HIV patient monitoring, Early Infant Diagnosis (EID) Dashboard for enabling early identification of HIV in infants, Quality Assurance (QA) Dashboard for monitoring laboratory quality metrics, Sample Tracking Application enabling specimen tracking across the referral network, Africa Laboratory Information System (ALIS) for comprehensive laboratory management, Results Dispatch System (RDS) facilitating result delivery to clinics, Facility Inventory Management System (FIMS) managing laboratory supplies, Lab Results SMS mobile-based result delivery, HIV Drug Resistance (HIV DR) Dashboard for monitoring antiretroviral resistance, and Lab Xpert for supporting GeneXpert testing workflows

Problem Statement

Despite significant investment in LIMS deployment, limited systematic evidence exists regarding user experiences, system performance, and impact on laboratory operations in developing countries (Bagherian & Sattari, 2022). Understanding user perspectives is critical for several reasons. First, user adoption is a key determinant of information system success, with poorly designed or implemented systems facing resistance and underutilization (Bagherian & Sattari, 2022). Second, user feedback provides valuable insights into system strengths, weaknesses, and areas requiring improvement (Desmal et al., 2023). Third, assessing compliance with data protection regulations has become increasingly important in the context of growing concerns about health data privacy and security (Kwon & Johnson, 2013).

The Uganda Data Protection and Privacy Act 2019 establishes comprehensive requirements for the collection, processing, storage, and use of personal data, including health information (Data-Protection-and-Privacy-Act-2019, n.d.). Compliance with this legislation is not only a legal obligation but also essential for maintaining patient trust and ensuring ethical data management practices. However, the extent to which LIMS implementations align with these requirements has not been systematically evaluated.

Study Objectives

This study aimed to conduct a comprehensive user-centered evaluation of LIMS implementation across Ugandan health facilities. The specific objectives were:

1. To assess system and information quality of implemented LIMS modules, including awareness, access, reliability, functionality, and integration with other health information systems
2. To evaluate user satisfaction with implemented systems, including perceived efficiency, likelihood of recommendation, and technical support responsiveness
3. To examine individual and organizational impacts of LIMS implementation, including effects on data use, job satisfaction, and interdisciplinary collaboration
4. To assess compliance with the Uganda Data Protection and Privacy Act 2019 across key principles including accountability, security safeguards, data minimization, retention limitation, and information quality

The findings are intended to inform strategic improvements in LIMS design, implementation, and support; guide resource allocation for system enhancements and infrastructure investments; strengthen data protection and security practices across the laboratory network; provide evidence for policy development and digital health strategy refinement; and contribute to the broader evidence base on health information system implementation in low-resource settings.

Conceptual Framework

This study was guided by the DeLone and McLean Information Systems Success Model, a widely used framework for evaluating the effectiveness of information systems. The model conceptualizes system success as a function of interrelated components, including system quality, information quality, service quality, system use, user satisfaction, and net benefits (DeLone & McLean, 2003, 2016).

In the context of LIMS, system quality refers to the technical performance of the system, including reliability, usability, and functionality, while information quality reflects the accuracy, completeness, and relevance of the data produced. User satisfaction captures the perceptions and experiences of system users, and net benefits represent the broader impact of the system on individuals and organizations.

This framework was extended in the present study to incorporate data protection and governance considerations, reflecting the increasing importance of privacy, security, and regulatory compliance in

digital health systems. By integrating these additional dimensions, the framework provides a comprehensive

basis for evaluating both technical and organizational aspects of LIMS performance.

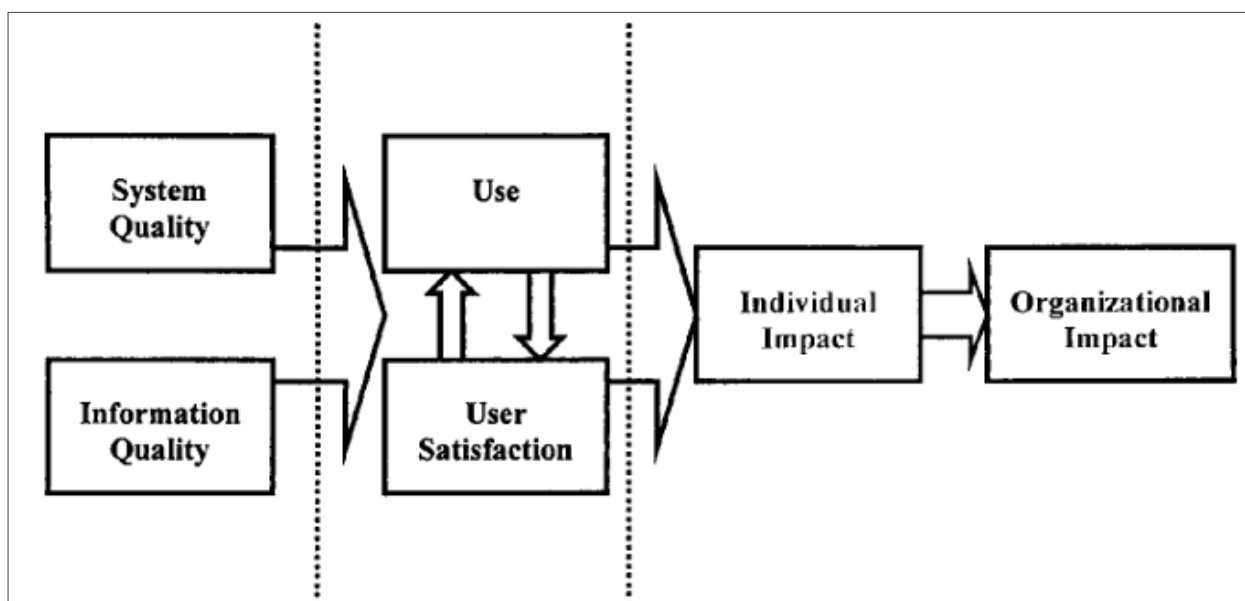


Figure 1. The DeLone and McLean Information Systems Success Model

Methods

Study Design and Setting

A cross-sectional descriptive study design was employed to assess user experiences with LIMS implementation across selected health facilities in Uganda. This design enabled the collection of data at a single point in time, providing a comprehensive snapshot of system performance, user perceptions, and operational challenges across multiple levels of the health system. The study was conducted between August and September 2024 across 42 health facilities in Uganda.

Facilities were purposively selected to ensure representation across different levels of care, including national referral hospitals, regional referral hospitals, general hospitals, and Health Centre IV facilities. This approach allowed for the examination of variations in system access, utilization, and performance across the hierarchical structure of the health system.

Participant Selection and Recruitment

The study targeted three categories of health facility staff with direct experience using LIMS modules: Laboratory personnel—including laboratory technicians, technologists, and laboratory managers responsible for conducting tests, entering results, and managing laboratory workflows; Clinicians—including medical officers, clinical officers, and nurses who make requests and access laboratory results for patient management decisions; Information Technology assistants—staff responsible for system maintenance, user support,

and troubleshooting. Facility in-charges assisted in identifying eligible participants based on their roles and responsibilities. All participants consented after receiving detailed information about study purposes, procedures, and confidentiality protection.

Study Population and Sampling

The study population comprised health facility staff with direct experience using LIMS, including laboratory personnel, clinicians, and information technology staff. Including multiple categories of users allowed for a comprehensive assessment of system performance from the perspectives of both data producers and data consumers, as well as those responsible for system maintenance. Participants were selected using purposive sampling, with facility leadership assisting in identifying individuals with regular exposure to LIMS. This ensured that responses were informed by practical experience with system use rather than theoretical knowledge (Rai & Thapa, 2015).

Data Collection

Data were collected using a pretested, structured questionnaire developed based on established information systems evaluation frameworks. The instrument was designed to capture multiple dimensions of system performance, including system quality, access, reliability, user satisfaction, organizational impact, and data governance practices. The questionnaire was administered digitally using mobile data collection tools, enabling real-time data entry and validation.

Data Analysis

Data was exported from KoboCollect to Microsoft Excel for initial cleaning and organization. Cleaned data were imported into STATA 12.0 (StataCorp, College Station, TX, USA) for statistical analysis. Data were analyzed using descriptive statistical methods. Frequencies and percentages were calculated for categorical variables, and key indicators were examined across different facility levels to identify patterns and disparities. Open-ended responses were analyzed using thematic analysis (Braun & Clarke, 2006; Vayro et al., 2023). Disaggregation of results by facility level provided insight into structural inequities in system access and performance across the health system.

Ethical Considerations

An introductory letter from the office of the Director General of Health Services introducing the purpose of the programmatic assessment to the respective assessed health facilities, and all participants provided informed consent prior to participation. Measures were implemented to ensure confidentiality and secure handling of data, including the use of unique identifiers and storage of data on password-protected systems.

Results

Facility and Participant Characteristics

A total of 42 health facilities were included in the study, comprising National Referral Hospitals (14.3%, $n = 6$), Regional Referral Hospitals (38.1%, $n = 16$),

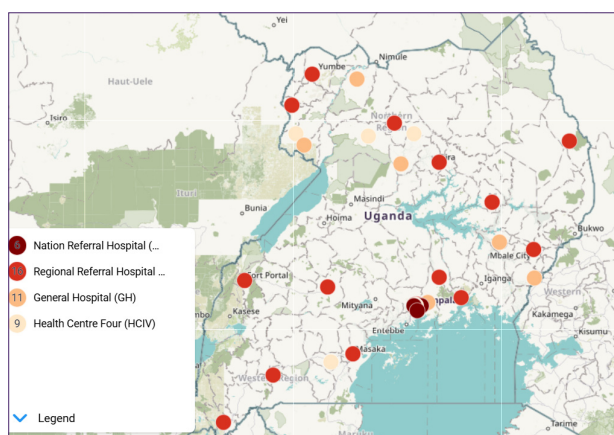


Figure 2. Map of Uganda showing the facilities assessed

General Hospitals (26.2%, $n = 11$), and Health Centre IV facilities (21.4%, $n = 9$). This distribution ensured representation across all levels of care, with higher-level facilities accounting for over half of the sample (52.4%).

Across these facilities, 114 participants were surveyed. Laboratory personnel constituted the majority (75%,

$n = 85$), followed by administrative and support staff (11%, $n = 13$), IT personnel (6%, $n = 7$), and quality assurance staff (7%, $n = 8$), while clinicians represented only 1% ($n = 1$). The heavy representation of laboratory personnel indicates that findings primarily reflect operational system use, while clinical perspectives are comparatively limited.

Table 1. Presents the detailed distribution of participants by cadre.

Cadre	No. interviewed	%
Clinicians	1	1%
Lab Personnel	85	75%
IT Officers	7	6%
QA	8	7%
Others (Admin, Logistics, Data etc.)	13	11%
Total	114	100%

System and Information Quality

Awareness of LIMS Modules

Awareness of LIMS modules was uniformly high across respondents, with most systems recognized by over 80% of participants. Core systems such as the VL Dashboard and EID Dashboard achieved universal

awareness (100%), while other systems—including ALIS, Sample Tracking, RDS, and FIMS—were recognized by approximately 95% of respondents. The QA Dashboard and Lab Xpert also demonstrated high awareness levels (93%). However, awareness declined for more specialized systems, including the HIV Drug Resistance Dashboard (79%) and Lab Results SMS

(71%). This represents a gap of 21–29 percentage points compared to core systems, indicating that awareness is strongly associated with system centrality to routine workflows.

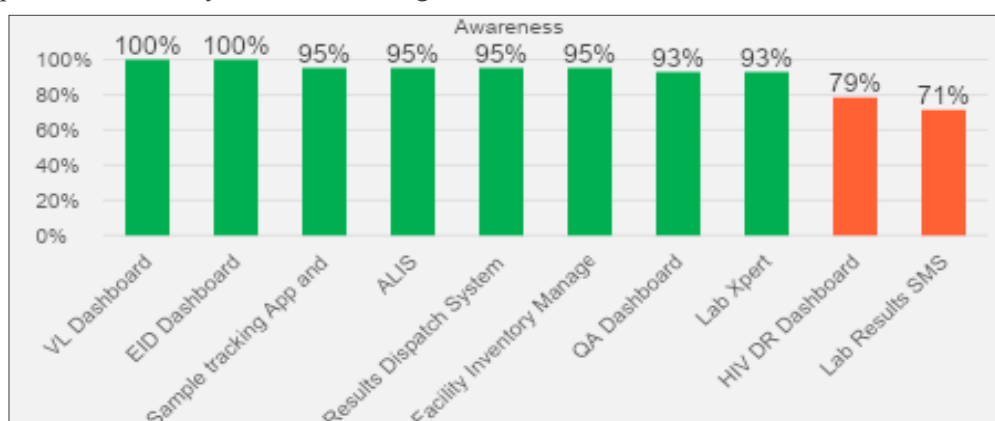


Figure 3. System Awareness

Access to LIMS Modules

Access to LIMS modules closely followed awareness patterns but revealed important disparities. Core systems such as the VL Dashboard and EID Dashboard were accessible to approximately 98% of respondents, while Lab Xpert (91.0%) and RDS (89.2%) also demonstrated high access levels. In contrast, access to specialized systems was more limited. Lab Results

SMS was accessible to only 62% of respondents, representing a 36 percentage point gap compared to VL Dashboard access. Similarly, the QA Dashboard (64%) and HIV DR Dashboard (76%) showed moderate access levels. These differences highlight a clear gradient between widely deployed core systems and more restricted specialized modules.

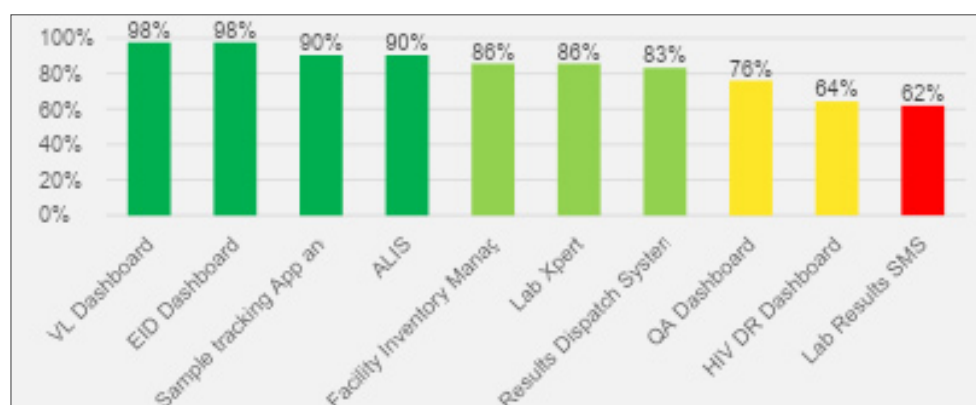


Figure 4. Percentage of Facilities with Access to these Systems

Disaggregation by facility level revealed further disparities. higher-level facilities reported near universal access (approaching 100%) for most systems, while lower-level facilities reported access levels

as low as 81.5–88.9% for key systems such as Lab Xpert and EID Dashboard. This represents a relative access gap of approximately 10–15 percentage points between facility levels.

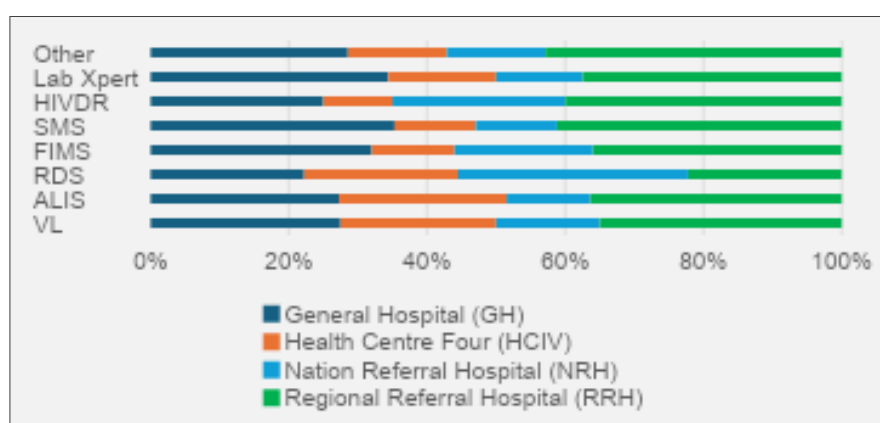


Figure 5. Level of care and System Access

System Utilization by Facility Level

System utilization patterns reflected disparities observed in access. Overall, the VL Dashboard was the most consistently utilized system, with 95.2% (40/42) of respondents reporting “always” use. ALIS (78.6%) and Lab Xpert (76.2%) also demonstrated relatively high utilization, while FIMS showed moderate use (59.5%). In contrast, specialized systems demonstrated substantially lower utilization, including the HIV DR Dashboard (47.6%), Lab Results SMS (40.5%), and

RDS (21.4%). This represents a utilization gap of over 70 percentage points between the most and least used systems. Utilization varied significantly by facility level. For example, VL Dashboard utilization ranged from 85.7% at NRHs to 100% at GHs and HC IVs, while RDS utilization remained low across all levels (13.3%–22.2%). These findings indicate that even when systems are available, they are not uniformly integrated into routine workflows.

Table 2. Distribution of Respondents Reporting “Always” Use of LIMS Modules by Facility Level

Facility Level	N	VL	ALIS	RDS	FIMS	Lab SMS	HIV DR	Lab Xpert
NRH	7	6 (85.7%)	4 (57.1%)	3 (42.9%)	5 (71.4%)	2 (28.6%)	5 (71.4%)	4 (57.1%)
RRH	15	14 (93.3%)	12 (80.0%)	2 (13.3%)	9 (60.0%)	7 (46.7%)	8 (53.3%)	12 (80.0%)
GH	11	11 (100.0%)	9 (81.8%)	2 (18.2%)	8 (72.7%)	6 (54.5%)	5 (45.5%)	11 (100.0%)
HC IV	9	9 (100.0%)	8 (88.9%)	2 (22.2%)	3 (33.3%)	2 (22.2%)	2 (22.2%)	5 (55.6%)
Total	42	40 (95.2%)	33 (78.6%)	9 (21.4%)	25 (59.5%)	17 (40.5%)	20 (47.6%)	32 (76.2%)

Source: LIMS User Feedback Survey, NHLDS Uganda, August-September 2024.

System Reliability

System reliability was generally high, with most core systems achieving agreement levels above 80%. The VL Dashboard and EID Dashboard demonstrated the highest reliability (98%), followed by Lab Xpert, RDS, and the Sample Tracking Application (each approximately 90%).

However, variability was observed in other systems. ALIS achieved 85% agreement but with 10% neutral responses, while Lab Results SMS had the lowest reliability at 64%, including 28% neutral responses and small proportions of dissatisfaction. This indicates that while systems are broadly functional, user experiences vary significantly across modules.

Table 3. User-Reported Reliability of LIMS Systems

System	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total Agreement (TotAgree)
VL Dashboard	74%	24%	2%	0%	0%	0%	98%
EID Dashboard	78%	20%	0%	0%	2%	0%	98%
Lab Xpert	78%	12%	2%	2%	0%	5%	90%
Results Dispatch System (RDS)	63%	27%	5%	2%	0%	2%	90%
Sample Tracking App	64%	26%	5%	0%	3%	3%	90%
Facility Inventory Management	61%	24%	10%	2%	0%	2%	85%
ALIS	44%	41%	10%	2%	0%	2%	85%
QA Dashboard	56%	23%	8%	3%	3%	8%	80%
HIV DR Dashboard	56%	22%	12%	0%	0%	10%	78%
Lab Results SMS	46%	18%	28%	3%	0%	5%	64%

Source: LIMS User Feedback Survey, NHLDS Uganda, August-September 2024.

Functionality Alignment with User Needs

Overall, 52.3% of respondents reported that systems fully met their functional needs, while 31.2% were neutral and 16.5% expressed dissatisfaction. The VL Dashboard demonstrated the highest functionality alignment (95% positive agreement), followed by the EID Dashboard (91%). In contrast, systems such as ALIS (79%), QA Dashboard (72%), and Lab

Results SMS (67%) showed lower alignment, with disagreement rates reaching up to 11% for ALIS and 10% for QA Dashboard. This indicates a gap of over 25 percentage points between the highest and lowest performing systems in terms of functionality.

The findings highlight that while system reliability is strong for most modules, functionality gaps remain significant. The VL and EID Dashboards demonstrate

that systems designed with clear use cases and sustained investment can achieve exceptional functionality alignment exceeding 90%. Conversely, systems with diffuse user populations, less mature implementation, or restricted access show substantially lower alignment. The substantial “Agree” (rather than “Strongly Agree”) responses across many systems indicate that while functionality is acceptable, it has not yet achieved the level of workflow transformation that users desire.

Notable N/A rates for HIV DR Dashboard (15%), QA Dashboard (10%), and Lab Results SMS (9%) reinforce access disparities documented elsewhere. Prioritizing functionality enhancements for systems with the highest disagreement rates (ALIS, Sample Tracking Application, QA Dashboard) while maintaining strong performance of VL and EID Dashboards should guide future LIMS development.

Table 4. *Functionality Alignment with User Needs by System*

System	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A
VL Dashboard	73.2%	22.0%	2.4%	0.0%	2.4%	0.0%
EID Dashboard	70.7%	19.5%	4.9%	0.0%	4.9%	0.0%
Results Dispatch System (RDS)	62.5%	25.0%	2.5%	0.0%	7.5%	2.5%
Lab Xpert	58.5%	22.0%	9.8%	0.0%	4.9%	4.9%
Sample tracking App and Dashboard	56.1%	24.4%	7.3%	4.9%	7.3%	0.0%
HIV DR Dashboard	51.2%	19.5%	12.2%	0.0%	2.4%	14.7%
QA Dashboard	48.7%	23.1%	7.7%	5.1%	5.1%	10.3%
Facility Inventory Management System	46.0%	40.5%	5.4%	0.0%	8.1%	0.0%
ALIS	41.0%	38.5%	7.7%	7.7%	2.6%	2.6%
Lab Results SMS	38.2%	29.4%	14.7%	5.9%	2.9%	8.8%

Source: LIMS User Feedback Survey, NHLDS Uganda, August-September 2024.

System Effectiveness for HMIS Reporting

Perceived effectiveness for HMIS reporting varied across systems. ALIS was rated effective by 76% of users, though 17% reported it as ineffective. Lab Xpert demonstrated stronger performance, with 71% effectiveness and only 7% reporting inefficiency.

The VL Dashboard (68% effective) and EID Dashboard (66% effective) showed moderate effectiveness, while remaining systems demonstrated mixed performance. These findings suggest that while most systems support reporting, effectiveness remains below optimal levels across modules.

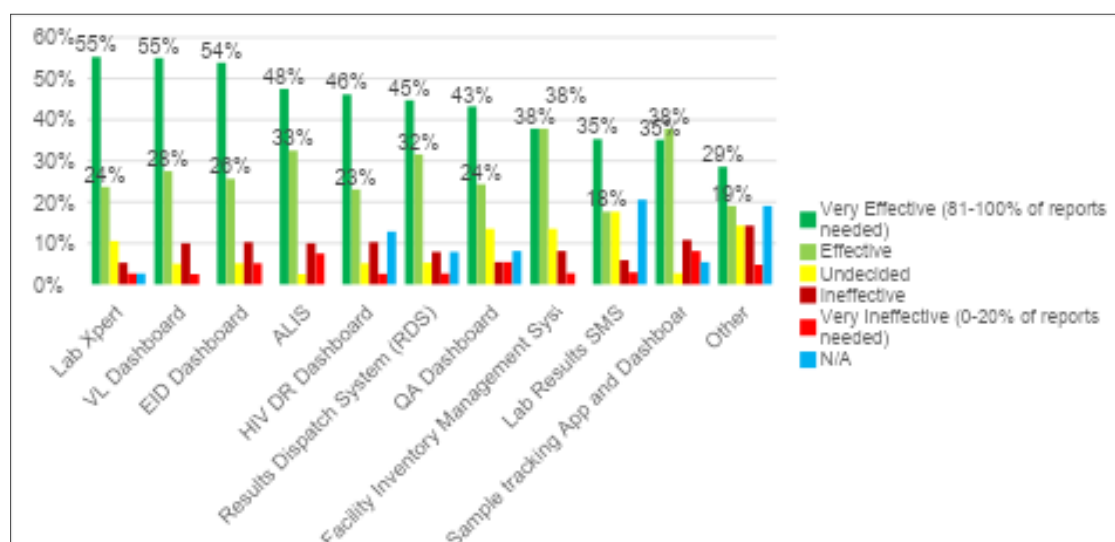


Figure 6. *Systems Effectiveness in Providing HMIS Reports*

Factors Affecting System Availability

System availability was mostly affected by power outages (32.4%) and network failures (29.1%), together affecting over 60% of respondents. Hardware failures, though less frequently reported, resulted in the longest downtime, averaging 228 hours, compared

to 34.6 hours for power outages and 16.5 hours for network failures. Software issues affected 18.2% of users, with an average downtime of 107.4 hours. These findings indicate that while infrastructure issues are more frequent, hardware failures have the greatest operational impact.

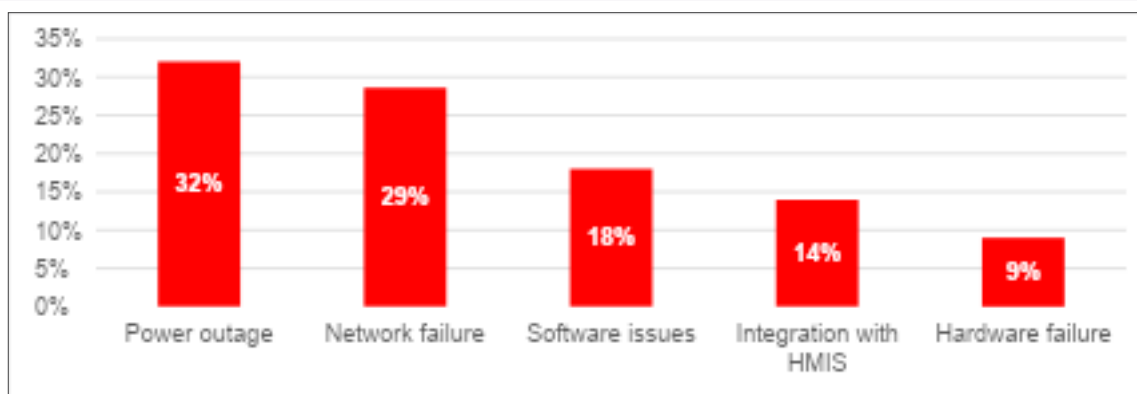


Figure 7. Frequency of Hindrances to System Availability

Downtime Impact

Hardware failures caused the longest interruptions, with mean downtime of 228 hours (approximately 9.5 days). These extended outages typically required external technical support, parts replacement, or equipment repair. Software challenges greatly affected

18% of users though resulted in downtime (mean 107.4 hours). HMIS integration issues had the most limited impact (14% of users) and shortest downtime (mean 10.8 hours), though qualitative feedback indicated these problems could be frustrating when they occurred.

Table 5. Factors affecting system downtime

System	Very much: The issues greatly affect the availability of the system(s), resulting in extensive and frequent downtime	Significantly: The issues significantly impact the availability of the system(s), leading to frequent downtime	Moderately: The issues moderately affect the availability of the system(s), causing occasional disruptions	Slightly: The issues have a minor impact on the availability of the system(s), but it's manageable	Not at all: The issues have no impact on the availability of the system(s)	Average Downtime Duration in hrs
Power outage	32%	7%	10%	22%	29%	34.6
Hardware failure	9%	15%	20%	15%	41%	228
Network failure	29%	26%	17%	17%	12%	16.5
Software issues	18%	12%	22%	24%	24%	107.4
Integration with HMIS	14%	8%	6%	16%	56%	10.8

These findings carry a clear strategic implication: while system effectiveness is moderate to strong, prolonged system downtime particularly power, hardware, and network connectivity remains the biggest threat to sustained system performance. Investments in system functionality must be matched by investments in the foundational infrastructure that enables increased system availability or minimal system downtime.

System Integration

System integration is the process of bringing together different system components, subsystems, hardware, software, people, and processes so that they function as a coordinated and effective whole throughout the system lifecycle (Sage & Lynch, 1998). A key aspect of system integration is system interfacing, which

involves the specification, design, and management of the points of interaction and communication between systems, subsystems, components, or users to facilitate the exchange of information and services (Sage & Lynch, 1998). In laboratory settings, effective interfacing between the Laboratory Information Management System (LIMS), analyzers, and Electronic Medical Records (EMRs) is essential for automating data exchange, reducing manual data entry, and improving workflow efficiency.

Analyzer Interfacing

Integration between LIMS and other systems remained limited. Only 31.0% of chemistry analyzers, 36.1% of hematology analyzers, and 34.5% of microbiology analyzers were interfaced with LIMS. Similarly,

only 19% of facilities reported EMR integration. This indicates that over 60% of laboratory processes still rely on manual data entry, significantly limiting

efficiency gains that could be gain by implementing an electronic LIMS.

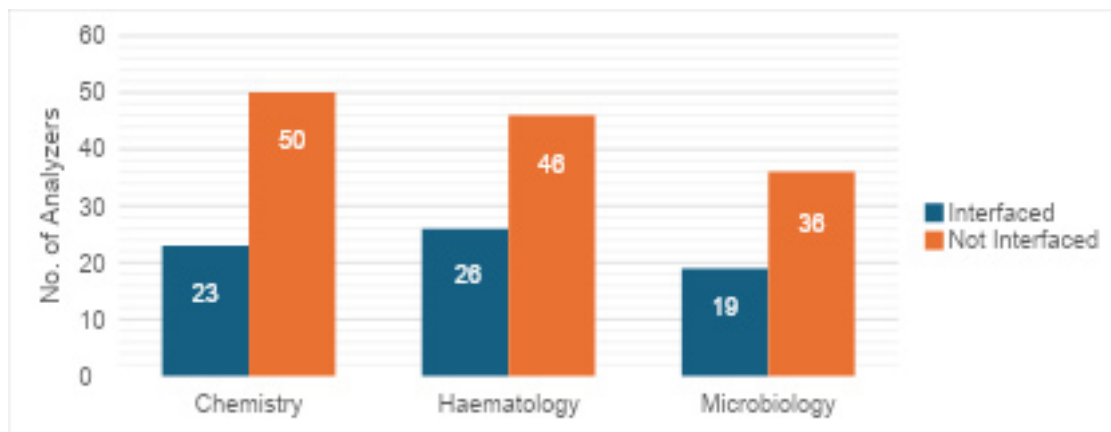


Figure 7. Analyzer Interface Status

EMR Integration

Only 8 facilities (19.0%) reported any form of EMR-LIMS integration. In most settings, laboratory results must be manually transferred from LIMS to EMR

systems or accessed separately by clinicians. This fragmentation impedes comprehensive patient record access, complicates clinical decision-making, and reduces the value of both systems.

Table 6. EMR integration status

Integrated EMRs	No. of facilities	Integrated LIMS
Clinic Master	5	ALIS
E-Afya	1	Lab Xpert
ICEA	1	ALIS & VL
Uganda EMR	1	ALIS & VL
Total	8	

User Satisfaction

This section explores key dimensions of user experience, including perceived system efficiency, overall satisfaction, likelihood of recommending the systems, availability of IT personnel and responsiveness of technical support. Together, these indicators provide a comprehensive understanding of how end users perceive the performance, usability, and support structures of the various systems, while also

highlighting gaps and disparities that may influence adoption, effectiveness, and sustained use.

Perceived System Efficiency

By adding the percentage scores of respondents who “Strongly Agree” and those who “Agree”, the perceived efficiency was highest for the EID Dashboard (69+29 = 98%), followed by RDS and VL Dashboard (each approximately 88%). ALIS, Sample tracking

Table 7. Perceived System Efficiency by System

System	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A
EID Dashboard	69%	29%	0%	0%	0%	2%
Results Dispatch System (RDS)	57%	31%	10%	0%	0%	2%
VL Dashboard	67%	21%	0%	2%	7%	2%
ALIS	50%	35%	7%	3%	3%	2%
Sample tracking App and Dashboard	55%	29%	8%	3%	5%	0%
Facility Inventory Management System	50%	33%	8%	2%	7%	0%
Lab Xpert	61%	22%	7%	2%	5%	2%
QA Dashboard	40%	35%	10%	5%	5%	5%
HIV DR Dashboard	48%	25%	17%	0%	5%	5%
Lab Results SMS	37%	22%	27%	2%	7%	5%

Source: LIMS User Feedback Survey, NHLDS Uganda, August-September 2024.

App and Dashboard, Facility Inventory Management System (FIMS) and Lab Xpert demonstrated moderate efficiency (83–85%), while Lab Results SMS showed the lowest efficiency (59%), with a high neutral response rate (27%). This represents a nearly 40 percentage point gap between the most and least efficient systems.

Satisfaction with Implemented Systems

User satisfaction was highest for the EID Dashboard (71+29=100%), followed by VL Dashboard (67+26 = 93%) and Lab Xpert (68+22= 90%). Moderate satisfaction levels were observed for ALIS (44+44 = 88%) and Sample Tracking (52+31=83%), while lower

Table 8. *Satisfaction with Implemented Systems by System, Uganda 2024 (n=42)*

System	Very Satisfied	Satisfied	Neither	Dissatisfied	Very Dissatisfied	N/A
VL Dashboard	67%	26%	2%	5%	0%	0%
EID Dashboard	71%	29%	0%	0%	0%	0%
QA Dashboard	31%	31%	14%	7%	0%	10%
Sample tracking App	52%	31%	12%	0%	0%	2%
ALIS	44%	44%	2%	7%	0%	2%
RDS	57%	24%	5%	2%	0%	5%
FIMS	38%	36%	14%	2%	2%	0%
Lab Results SMS	43%	17%	21%	7%	0%	7%
HIV DR Dashboard	45%	25%	13%	3%	0%	15%
Lab Xpert	68%	22%	5%	2%	0%	2%

satisfaction was reported for QA Dashboard (31+31= 62%) and Lab Results SMS (43+17= 60%). These findings indicate a satisfaction gap of approximately

40 percentage points across the highest scored and lowest scored systems.

Table 9. *Likelihood of Recommending Systems by System, Uganda 2024 (n=42)*

System	Very Likely	Likely	Neutral	Unlikely	Very Unlikely	N/A
VL Dashboard	76%	19%	0%	0%	2%	2%
EID Dashboard	76%	21%	2%	0%	0%	0%
QA Dashboard	51%	30%	14%	5%	0%	0%
Sample tracking App	72%	21%	5%	0%	3%	0%
ALIS	79%	13%	8%	0%	0%	0%
RDS	65%	30%	5%	0%	0%	0%
FIMS	59%	34%	5%	2%	0%	0%
Lab Results SMS	54%	10%	28%	3%	0%	5%
HIV DR Dashboard	57%	21%	12%	0%	0%	10%
Lab Xpert	78%	10%	10%	0%	0%	2%

Source: LIMS User Feedback Survey, NHLDS Uganda, August-September 2024.

Likelihood of Recommending Systems

Overall, 80.1% of respondents reported that they would recommend LIMS systems. Recommendation rates were highest for VL and EID Dashboards (95%), while Lab Results SMS showed the lowest recommendation rate (64%), with 28% neutral responses. This suggests that endorsement is strongly influenced by both usability and accessibility.

Technical Support Responsiveness

Technical support responsiveness varied significantly. Lab Xpert demonstrated the highest responsiveness, with 58% of issues resolved within six hours and cumulatively 82% (58+ 24) within 24 hours. In contrast, ALIS had only 29% of issues resolved within six hours, with 63% (29+ 34) resolved within 24 hours. This indicates a responsiveness gap of 19 percentage points between systems.

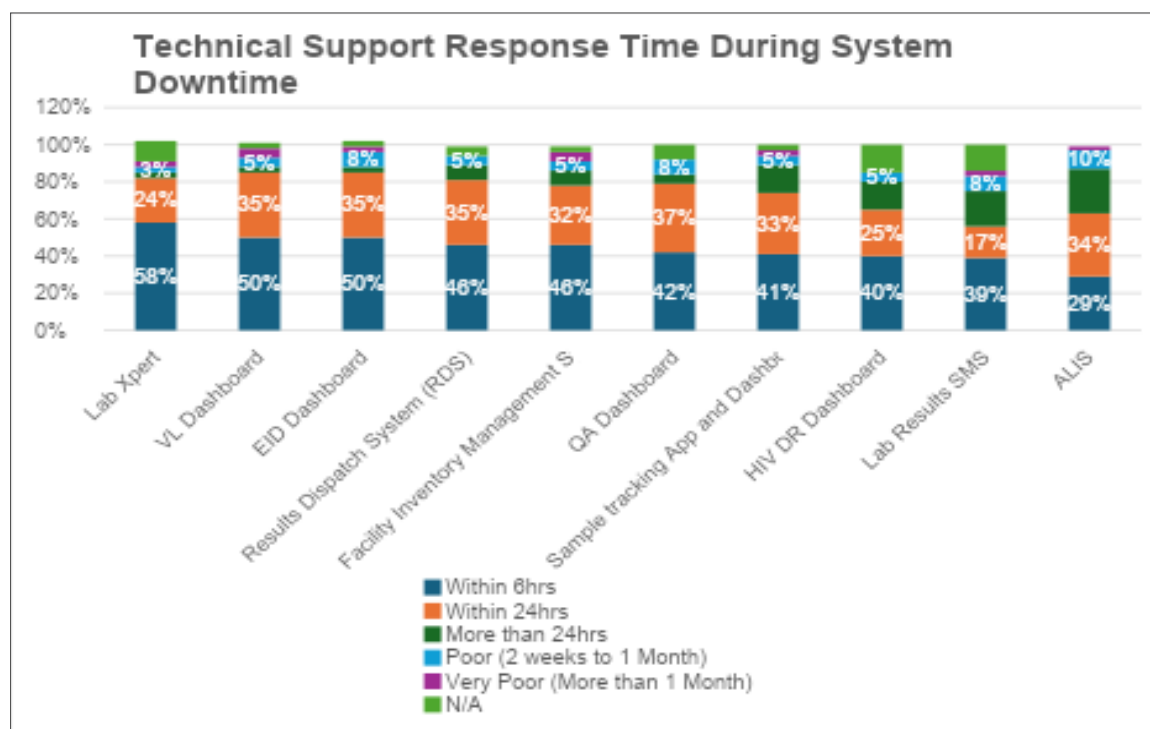


Figure 8. IT Officer Coverage by Facility Level, Uganda 2024

Figure 8: Technical Support Response Time During System Downtime by System (n=42 facilities)

Information Technology (IT) Officer Coverage

Across the 42 health facilities assessed, a total of 28 IT officers were attached across all sites, yielding an overall average of 0.7 IT officers per facility. IT support coverage varied by facility level, with 100% of NRHs having dedicated IT staff compared to only 33% of HC IVs. Overall, the average IT staffing level was 0.7 staff per facility. This disparity likely contributes directly to differences in system performance and downtime across facility levels.

Organizational Impact

Impact on Patient Care

Most users reported that LIMS improved patient care, particularly through reduced turnaround times and improved data accessibility. The VL and EID Dashboards demonstrated the highest perceived impact, with over 95% of users (VL: 90+7=97%) and (EID: 88+10= 98%) reporting improvement. The impact was less pronounced for systems with limited access or indirect clinical functions such as Facility Inventory Management System (FIMS), QA Dashboard and Lab Results SMS. Detailed findings are presented in Table 12.

Table 12. Perceived Impact of LIMS on Patient Care by System, Uganda 2024 (n=42)

System	Much better (5)	Somewhat better (4)	Stayed the same (3)	Somewhat worse (2)	Much worse (1)	N/A
VL Dashboard	90%	7%	2%	0%	0%	0%
EID Dashboard	88%	10%	2%	0%	0%	0%
Lab Xpert	80%	7%	2%	2%	0%	7%
Results Dispatch System (RDS)	69%	21%	5%	0%	0%	5%
HIV DR Dashboard	60%	15%	3%	3%	0%	20%
ALIS	59%	34%	2%	2%	0%	2%
Sample tracking App and Dashboard	55%	25%	8%	3%	0%	10%
Facility Inventory Management System	45%	33%	8%	3%	0%	13%
QA Dashboard	41%	32%	7%	2%	0%	17%
Lab Results SMS	38%	21%	8%	3%	0%	31%

Source: LIMS User Feedback Survey, NHLDS Uganda, August-September 2024.

Impact on Data Use

LIMS implementation was associated with substantial improvements in data use for clinical care and program reporting. Core systems enabled users to generate reports, analyze trends, and support decision-

making more effectively. The strongest impact was observed in systems that facilitate data extraction and visualization, reinforcing the importance of usability in driving data use.

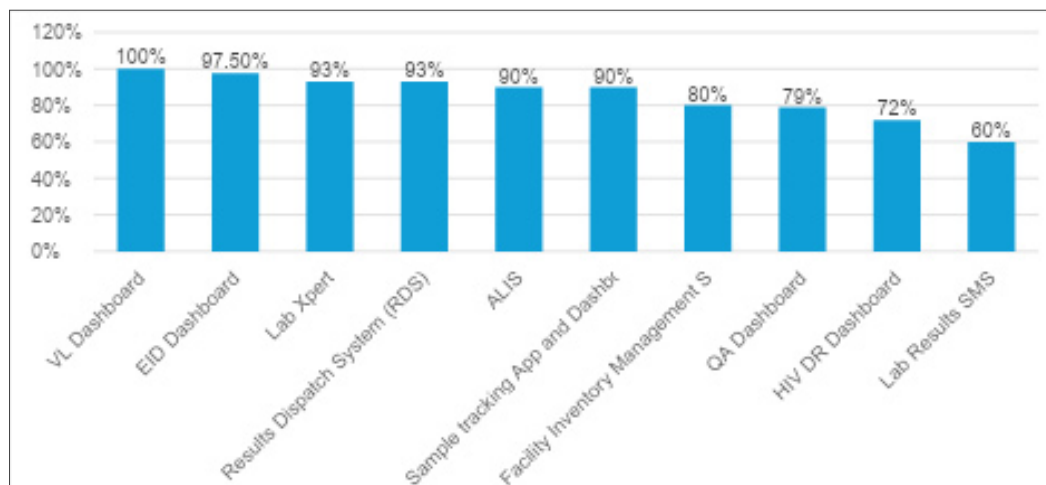


Figure 10. Total Positive Impact

Impact on Communication and Collaboration

Nearly all respondents (40 of 41 respondents = 97.6%) reported improved overall communication following LIMS implementation. This represents one of the most

significant benefits of the system, highlighting its role in improving coordination across departments and facilities.

Table 13. Systems impact on communication and collaboration within the organization

Status	Freq.	Percent	Cum.
Stayed the same	1	2.44	2.44
Somewhat better	11	26.83	29.27
Much better	29	70.73	100
Total	41	100	

Source: LIMS User Feedback Survey, NHLDS Uganda, August-September 2024.

Impact on Cost Reduction

Perceptions of cost reduction were mixed, with 58.3% reporting cost savings, while others reported increased

operational costs associated with system maintenance and infrastructure.

Table 14. System Impact on Cost reduction

System	Printing cost	Air time	Patient waiting time	Patients visits	Specimen custody	Average
VL Dashboard	2	3	4	3	3	3
EID Dashboard	2	3	4	3	3	3
Results Dispatch System (RDS)	3	4	4	3	3	3
ALIS	3	3	4	3	3	3
Lab Xpert	3	3	3	3	3	3
HIV DR Dashboard	2	2	3	2	2	2
Lab Results SMS	3	2	3	3	2	3
Sample tracking App and Dashboard	3	3	3	3	4	3
Facility Inventory Management System	4	3	2	2	2	2
QA Dashboard	2	3	2	2	2	2
Average	3	3	3	3	3	3
Not all=1, Slightly=2, Moderately=3, Very much =4, Extremely=5						

Data Backup Practices

Data backup practices varied, with 73% of facilities reporting adequate backup systems, while 27%

reported no backup at all or practice unsafe backup mechanisms. This represents a significant risk to data security and continuity.

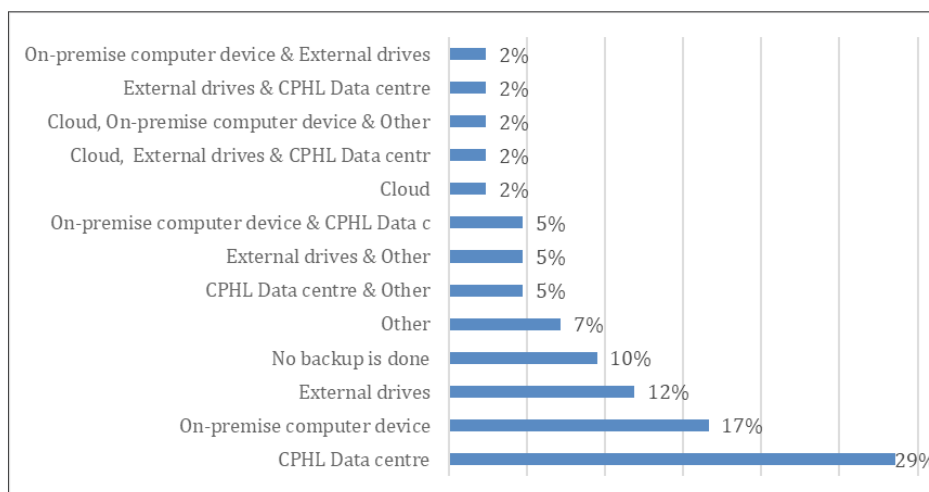


Figure 11. Backup Locations

Internet Connectivity

Internet connectivity was inconsistent, with only 31% of facilities reporting stable connections. Connectivity

challenges contribute directly to system downtime and reduced usability.

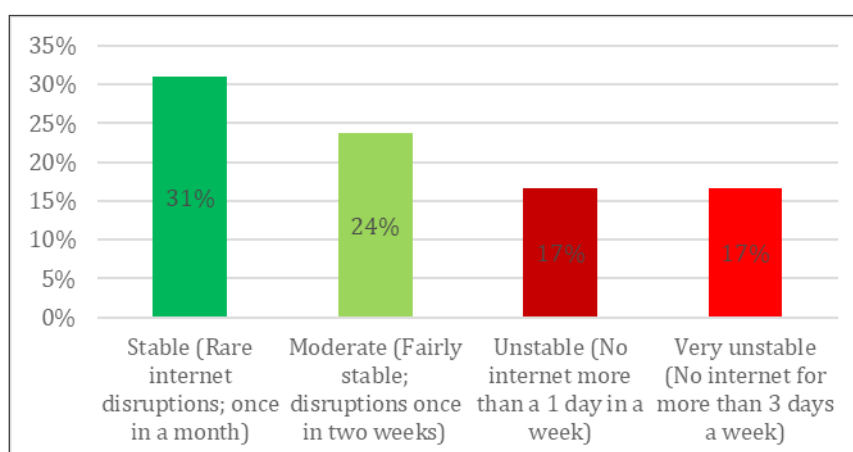


Figure 12. Internet Stability

Data Protection Compliance

Assessment of compliance with the Uganda Data Protection and Privacy Act 2019 revealed significant gaps. Approximately 40% of facilities lacked formal data protection SOPs, and insecure practices such

as credential sharing and use of personal email were common. While role-based access control was widely implemented, additional safeguards such as audits and training were limited, indicating incomplete implementation of data governance frameworks.

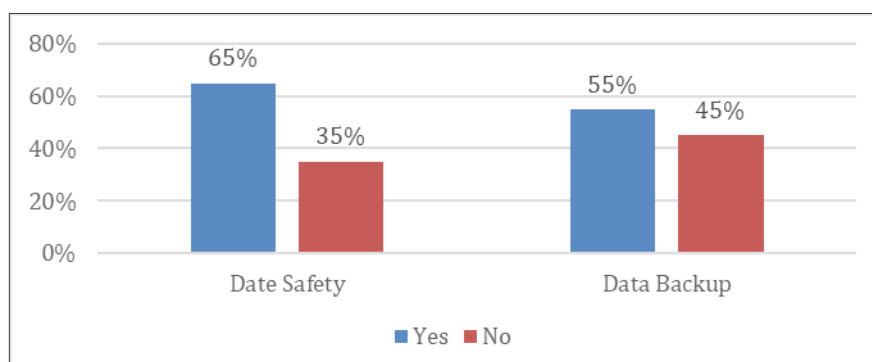


Figure 13. Availability of SOPs

Discussion

This study aimed to evaluate the implementation status of Laboratory Information Management Systems (LIMS). These findings suggest that LIMS implementation has progressed beyond initial deployment but remains in a partial optimization phase, where core functionalities perform well while broader system integration and equitable access remain limited (Harrison & McDowell, 2008; Nakakawa et al., 2024).

LIMS and Healthcare Quality Improvement

The improvements observed in data use (85%) and communication (97.6%) highlight the role of LIMS as a driver of healthcare quality improvement. This aligns with evidence that laboratory information systems enhance healthcare quality by improving turnaround times, reducing errors, and enabling more efficient clinical workflows (Harrison & McDowell, 2008; Tchatchueng-Mbougua et al., n.d.; Tikoo, 2014). However, system benefits were concentrated in modules that are tightly integrated into routine clinical workflows, LabXpert, EID & VL dashboards, more than for those with lab-centric workflows (RDS, QA dashboard). Systems with limited access or functionality demonstrated weaker performance, suggesting that system effectiveness is highly dependent on user interaction and workflow alignment. This is consistent with technology adoption models, which emphasize perceived usefulness and system accessibility as key determinants of successful adoption (Riana et al., 2021).

Infrastructure Constraints

Infrastructure challenges, including power outages (32.4%) and network failures (29.1%)—were the most frequently reported barriers to system availability. Hardware failures, while less frequent, resulted in significantly longer downtime (about 228 hours). These findings reinforce the importance of technological infrastructure as a key determinant of information system performance, particularly in public health settings (Hemed & Issa, 2021; Oakley et al., 2025). Without reliable infrastructure, the potential benefits of LIMS cannot be fully realized.

Integration and Interoperability

The low level of system integration represents a major limitation. Manual data entry remains predominant in over 60% of cases due to limited analyzer interfacing and minimal EMR integration. This finding aligns with Shah et al. (2016), who documented that interoperability remains elusive for many public health agencies, with 30% of local health departments

reporting no interoperable systems whatsoever. The barriers they identified—including systems developed by different organizations using incompatible codes and standards, lack of IT staff, and resource-intensive integration efforts—mirror the challenges observed in Ugandan facilities. This lack of integration reduces efficiency and increases the risk of error, limiting the overall impact of LIMS on healthcare delivery (Harrison & McDowell, 2008; Shah et al., 2016). It also reflects broader adoption challenges where system compatibility and technological readiness influence effective system use (Nakakawa et al., 2024; Riana et al., 2021).

Inequities in Access and Utilization

Clear disparities were observed across facility levels, with higher-level facilities demonstrating greater access and utilization compared to lower-level facilities. This pattern reflects structural inequalities in technological infrastructure and organizational capacity, which are known determinants of information system adoption (Hemed & Issa, 2021). If not addressed, these disparities risk creating unequal benefits from digital health investments.

Data Governance Challenges

Significant gaps in data governance were identified, including credential sharing (33%), use of personal email (35.7%), and lack of SOPs in 35% of facilities. These findings indicate that technological implementation has outpaced governance frameworks, a common challenge in digital health adoption (Riana et al., 2021). Without strong governance mechanisms, system risks may increase despite improvements in efficiency.

Organizational and Human Factors

Variability in IT support across facility levels contributed to differences in system performance. Facilities with dedicated IT staff demonstrated better system reliability and faster issue resolution. Shah et al. (2016) similarly found that lack of IT staff availability was a major barrier to interoperability, with qualitative interview data revealing that many health departments ‘do not have an IT staff that can prepare software to connect’ disparate systems. Leadership support emerged as the strongest predictor of interoperability in their study (AOR=3.54), reinforcing the importance of organizational commitment to information system success. This finding aligns with evidence that organizational support and technical capacity are critical for successful information system adoption (Hemed & Issa, 2021).

Conclusion

This study provides a comprehensive, evidence-based assessment of LIMS implementation across Uganda's health system, demonstrating that significant progress has been made since the national rollout began in 2017. High levels of system awareness reaching near-universal recognition for core modules such as the VL and EID Dashboards alongside strong reliability scores ($\geq 90\%$) and widespread improvements in data use (85%) and communication (97.6%) confirm that LIMS has become a foundational pillar of laboratory service delivery in Uganda. User satisfaction was notably high for core systems, with the EID Dashboard achieving 100% satisfaction and the VL Dashboard reaching 93%, and over 80% of respondents reported they would recommend LIMS systems to peers. Effective diagnostic capacity is crucial for clinical decision-making, with up to 70% of decisions in high-resource settings based on laboratory test results, yet in low- and middle-income countries, access to diagnostic services is often limited due to the absence of functional LIMS (Oakley et al., 2025). Uganda's achievement of near-universal core system adoption therefore represents a meaningful gain for laboratory-driven clinical care,

Nevertheless, the study reveals a system at a critical inflection point. While core modules perform strongly, the broader LIMS ecosystem remains unevenly developed. Specialized systems such as Lab Results SMS (38% access), the HIV Drug Resistance Dashboard (45% access), and the QA Dashboard (64% access) lag considerably behind, with utilization rates for some modules particularly RDS at 21.4% indicating that availability alone does not guarantee meaningful use. This performance gradient between core and specialized systems is consistent with broader evidence from sub-Saharan Africa, where early stages of digital health adoption in the region focused on foundational aspects such as digitization of records and reduction of manual errors, while later phases document the integration of more advanced functionalities including interoperability, analytics capabilities, and mobile health solutions though significant barriers to widespread adoption persist (Mugauri et al., 2025).

Infrastructure constraints remain the most immediate operational threat. Power outages (32.4%) and network failures (29.1%) together disrupted system availability for the majority of facilities, while hardware failures, though less frequent, produced the most severe downtime, averaging 228 hours per incident. These findings are consistent with wider regional evidence.

Limited infrastructure, including unreliable electricity and insufficient internet connectivity, remains a significant barrier in many settings, and the experiences in Ethiopia and Kenya underscore the importance of investing in reliable power backup systems and improving internet infrastructure to support continuous digital health system operations (Mugauri et al., 2025). With only 30.95% of facilities reporting stable internet connectivity and 26.2% lacking adequate data backup systems, Uganda's LIMS infrastructure profile mirrors these documented regional challenges. Responsible health digitalization in LMICs requires prioritizing the three key enablers of governance, infrastructure, and security, as without these foundational elements digital health investments cannot achieve their intended impact (Monlezun et al., 2025).

Integration and interoperability represent another critical area requiring urgent attention. With only 31–36% of laboratory analyzers interfaced with LIMS and EMR-LIMS integration reported in just 19% of facilities, manual data entry continues to dominate laboratory workflows in the majority of settings. Fragmentation of digital health technologies remains a significant unresolved challenge in developing countries, with little consideration given to linking different systems, thereby limiting their value for comprehensive patient data management (Ndlovu et al., 2021). This lack of integration not only negates efficiency gains but also undermines clinical decision-making. Strong health information systems are critical in the integration process, and gaps in interoperability combined with limited digital literacy among healthcare workers hinder the full potential of health information systems, even where individual components are well-performing (Dzinamarira et al., 2025). Interoperability in healthcare information systems is critical for improving service quality and effectiveness, yet achieving it remains complex due to the fragmented and often difficult-to-navigate landscape of e-health standards, particularly within the African context (Adebisin et al., 2013). Advancing system connectivity such as expanding analyzer interfacing and prioritizing integration with electronic medical records should be considered a strategic priority in the next phase of implementation.

Inequities in access across facility levels further compound these challenges. The finding that only 33% of Health Centre IVs had dedicated IT support compared to 100% of National Referral Hospitals reflects a structural gradient that directly shapes system performance. Disparities in internet connectivity, mobile

phone access, and digital literacy disproportionately affect rural and low-income populations, limiting the benefits of digital health interventions for those most in need (Awosiku et al., 2025). If left unaddressed, such disparities risk entrenching unequal benefits from digital health investments across Uganda's facility network, undermining the broader goals of universal health coverage.

Data governance gaps present an equally serious concern. The identification of credential sharing in 33% of facilities, use of personal email for data transmission in 35.7%, and the absence of ICT data safety SOPs in 35% of facilities indicates that the pace of technological deployment has outstripped the development of governance frameworks needed to protect it. In low-income contexts, the adoption of data protection regulations for digital health platforms is slow, and as a result of poor data governance frameworks and limited enforcement, many health information systems fail to satisfy privacy, safety, and ethical standards, exposing confidential data to potential breaches (Femi-Lawal & Aderemi, 2025). Furthermore, digital health integration challenges in comparable settings reflect a governance execution gap rather than an absence of strategies or technologies, with persistent gaps associated with fragmented mandates, weak enforcement mechanisms, and constrained subnational capacity highlighting the need to shift from strategy-led coordination toward enforceable, rule-based governance (Nyarko et al., 2026). In the context of the Uganda Data Protection and Privacy Act 2019, strengthening data governance is not a peripheral concern but a core component of responsible system stewardship.

Taken together, these findings point to a clear and actionable agenda for the next phase of LIMS development in Uganda. Infrastructure investments including solar backup power, offline-capable system functionalities, and hardware maintenance programs must be scaled to ensure baseline system availability across all facility levels. A national interoperability strategy should accelerate analyzer interfacing and EMR-LIMS integration, reducing dependence on manual processes and enabling more complete patient data flows. Equity in access must be explicitly addressed through targeted support for lower-level facilities, including expanded IT staffing, enhanced technical support responsiveness, and differentiated training programs. Data governance frameworks must be formalized and enforced system-wide, ensuring that LIMS operates within a culture of accountability, security, and regulatory compliance. Finally,

underperforming modules — particularly Lab Results SMS, the QA Dashboard, and ALIS require focused functionality reviews and user-centered redesign to close the gap with higher-performing systems.

Uganda's LIMS journey demonstrates that political commitment, sustained investment, and a modular implementation approach can achieve meaningful health system impact even in a resource-constrained environment. In low-resource settings, laboratory errors are further exacerbated by poor infrastructure and shortages in a trained workforce, and informatics interventions such as LIMS can be used to address some of the most critical sources of these errors (Mtonga et al., 2019). The foundation is strong. With targeted, systems-level action to address infrastructure, integration, equity, and governance gaps, LIMS has the potential to transition from a partially optimized platform into a fully integrated, high-performing health information ecosystem, one capable of supporting Uganda's ambitions for data-driven, high-quality laboratory and diagnostic services across all levels of care (Harrison & McDowell, 2008; Hemed & Issa, 2021)

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