Journal: Texila International Journal of Medicine
Publisher: Texila International Journal
ISSN: 2520-3118
Volume 9 Issue 2, 2026
DOI: 10.21522/TIJMD.2013.09.02.Art002

Health System Readiness and Performance in the Introduction of New Vaccines in Uganda: A Mixed-Methods Post-Introduction Evaluation

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Abstract

Introduction of new vaccines (Measles-Rubella second dose [MR2], Inactivated Polio Vaccine second dose [IPV2], Hepatitis B Birth Dose [HepB-BD], and Yellow Fever [YF]) is a major milestone in strengthening Uganda's Expanded Programme on Immunization (EPI). Assessing performance and system readiness for new vaccine adoption is essential for achieving Immunization Agenda 2030 (IA2030) goals and ensuring long-term sustainability. This study evaluated national, district, and facility-level readiness using the WHO Post-Introduction Evaluation (PIE) framework, focusing on logistics, cold chain capacity, human resources, supervision, and coordination mechanisms. A mixed-methods design was used. Quantitative data were extracted from national, district, health facility, and community PIE tools. Descriptive statistics, readiness scoring, and logistic regression explored determinants of coverage performance. Qualitative data from key informant interviews and facility-level observations were analyzed thematically. Findings were triangulated across data sources to ensure validity. Data-use permission was obtained from relevant authorities. National cold-chain functionality stood at 83.7%, with higher performance in Central and Western regions. Supervision frequency, logistics adequacy, and staff training were significant predictors of new vaccine coverage ($p < 0.05$). Qualitative findings highlighted strong partner coordination but persistent challenges in preventive maintenance, workload pressure, and staffing gaps. Despite operational successes, regional disparities remained particularly in remote Northern and Eastern districts. Uganda's immunization system demonstrates strong readiness and capacity to integrate new vaccines into routine immunization. However, sustainability requires improved financing, enhanced supervision, stronger cold-chain maintenance systems, and targeted support for underserved regions. Findings contribute practical evidence for policy planning, Gavi Joint appraisal processes, and future vaccine introductions.

Keywords: *Cold Chain, Immunization Coverage, New Vaccine Introduction, Post-introduction Evaluation, Uganda, Vaccine Readiness.*

Received: 24.02.2026 ***Accepted: 16.03.2026*** ***Published on: 29.04.2026***

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Introduction

Global and Regional Vaccine Introduction Context (GVAP, IA2030)

With an estimated 4–5 million fatalities prevented each year, vaccination continues to be one of the most economical public health initiatives worldwide. Global initiatives like the current Immunization Agenda 2030 (IA2030) and the Global Vaccine Action Plan (GVAP) 2011–2020 [1, 2] have reinforced vaccination systems, expedited the introduction of new antigens, and prioritized equitable access to life-saving vaccines over the past ten years. Despite advancements, COVID-19 interruptions caused global coverage improvements to halt after 2019, underscoring differences in routine immunization performance, particularly in low- and middle-income countries (LMICs), where 67 million children missed regular immunizations between 2019 and 2021 [3].

Sub-Saharan African nations still struggle with inconsistent vaccination rates, gaps in the supply chain, a lack of human resources, and enduring behavioral hurdles. Systems must show sufficient preparedness in the areas of logistics, cold chain, funding, and governance as new vaccines are introduced. The need for thorough post-introduction evaluation is highlighted by regional evidence that early post-introduction phases are frequently marked by operational constraints, inconsistent service delivery, and varying community awareness.

Uganda's New Vaccine Rollout (MR2, IPV2, HepB-BD, YF)

Since 2019, Uganda has greatly extended its national vaccination schedule, including the Yellow Fever vaccine (YF), Hepatitis B Birth dosage (HepB-BD), Inactivated Polio Vaccine second dosage (IPV2), and Measles-Rubella second dose (MR2). Measles outbreaks, polio immunization gaps, neonatal hepatitis B transmission, and repeated yellow fever epidemics are just a few of the enduring public health issues that these vaccinations tackle.

With assistance from partners like WHO, UNICEF, Gavi, and CHAI, the Uganda National Expanded Programme on Immunization (UNEPI) organized staggered rollouts throughout districts. Although new vaccine coverage is still inconsistent across regions due to variations in infrastructure, supervision, logistics, and caregiver demand, early administrative data indicates rather good uptake among classic antigens.

Rationale for Post-Introduction Evaluation (PIE)

WHO advises conducting a Post-Introduction Evaluation (PIE) six to twelve months after a new vaccine is added to the national schedule. PIE makes it possible for nations to evaluate preparedness, pinpoint operational difficulties, and improve implementation tactics [4].

Assessing system performance after several vaccine launches is crucial for Uganda in order to:

1. Guarantee effective incorporation into regular service provision.
2. Determine any holes in the cold chain, supply chain, and human resources.
3. Evaluate behavioral uptake and communication.
4. Provide information for microplanning at the national and local levels, and
5. Direct sustainability over the long run as external funding changes.

A mixed-methods PIE offers practical insights for enhancing equality and resilience given Uganda's geographic variety and varying degrees of health system maturity across districts.

Problem Statement

Despite Uganda's successful introduction of several new vaccinations, current research indicates that community acceptance, logistics performance, service delivery capability, and

system readiness differ greatly amongst regions. The quality of supervision, personnel capacity, preventative maintenance, and cold chain functionality are still uneven. Additionally, regional differences are revealed by early coverage data for MR2, IPV2, HepB-BD, and YF, endangering national targets and IA2030 promises.

The long-term success and sustainability of the introduction of new vaccines may be jeopardized if a thorough evaluation of preparedness and performance at the national, district, and facility levels is not conducted.

Existing Evidence and Gaps

Prior research in East Africa has looked at factors that influence routine vaccination, but multi-level, mixed-methods analyses that concentrate on post-introduction periods have seldom been carried out. Evidence from Ethiopia, Tanzania, and Kenya demonstrates difficulties with workforce capability, logistics, and community involvement, but little study incorporates:

1. Coordination of national policies.
2. Oversight and governance at the district level.
3. Readiness at the facility level (CCE, stock management, session quality).
4. Social and behavioral factors that influence vaccine acceptance.
5. GIS-based spatial discrepancies.
6. New vaccine coverage statistical predictors.

The reports that are currently accessible in Uganda (UNEPI, WHO, UNICEF, Gavi) offer fragmented information on preparedness and uptake; however, no published study has thoroughly assessed the performance and preparedness of the health system throughout the whole service delivery cascade after several new vaccine introductions.

Study Objectives

This study used a mixed-methods post-introduction evaluation methodology to assess Uganda's health system's performance and preparedness for the introduction of new vaccines. Specific objectives were to;

1. Assess national, district, and health facility readiness for new vaccine introduction.
2. Examine logistical, cold chain, and human resource capacities supporting rollout.
3. Identify factors associated with new vaccine coverage performance.
4. Explore qualitative experiences of health workers, managers, and caregivers regarding the introduction process.
5. Provide evidence-based recommendations for system strengthening and policy planning.

Novel Contribution of the Study

This study, which combines quantitative PIE datasets, qualitative interviews, and GIS-based spatial analysis, is the first thorough, mixed-methods post-introduction review in Uganda. It provides:

1. An evaluation of readiness at the national, district, and facility levels.
2. Statistical indicators of the coverage of new vaccines.
3. Triangulated understanding of behavioral, governance, and operational factors.
4. Geographical representation of disparities in preparedness and adoption.
5. Practical policy recommendations in line with Uganda's Immunization Financing Strategy and IA2030.

Materials and Methods

Study Design (Mixed-Methods)

In order to thoroughly evaluate the performance and preparedness of the health system during the introduction of new vaccinations in Uganda, this study used a mixed-methods methodology that combined quantitative and qualitative techniques. System readiness, supervisory levels, logistical capacity, and vaccination performance indicators were quantified using Post-Introduction Evaluation (PIE) techniques at the

national, district, and health facility levels. Key informant interviews (KIIs) and focus group discussions (FGDs) provided qualitative insights into the contextual and behavioral aspects impacting vaccine deployment. Triangulation improved the findings' depth, validity, and reliability.

Study Setting (National, District, Facility Levels)

The study was carried out at several vaccination program levels in Uganda:

1. **At the national level**, the Ministry of Health (MoH), National Medical Stores (NMS), and Uganda National Expanded Programme on Immunization (UNEPI).
2. **District level:** 20 districts were purposefully chosen to reflect the four regions of Uganda (Central, Western, Eastern, and Northern), capturing variations in population density, performance, topography, and the strength of the health system.
3. **Health facility level:** A variety of hospitals, Health Center IIIs, and Health Center IIs that offer regular immunization services.
4. **Community level:** Through facility-linked community interviews, mothers and caregivers of children under five are reached.

This multi-tiered framework allowed for the analysis of coordination, logistics, service delivery, and community acceptance.

Data Sources (PIE Tools, KIIs, FGDs)

Three categories of data were utilized:

1. **Quantitative Data**

Extracted from WHO-aligned PIE tools:

- National PIE Tool.
- District PIE Tool.
- Health Facility PIE Tool.
- Vaccination Session Observation Checklist.
- Mother/Caretaker PIE Questionnaire.

2. **Qualitative data**
   - **Key Informant Interviews (KIIs)**: cold chain technicians, district health officials, national-level officers, focal individuals for the Expanded Program on Immunization (EPI), and implementing partners.
   - Focus roup discussions (FGDs). Participated in by Village Health Teams (VHTs) and mothers/caregivers.
3. **Corresponding Records**
   - Contextual triangulation was conducted using Gavi Joint Appraisal documents, policy guidelines, supervision reports, and vaccine introduction micro plans.

Sampling Strategy and Respondents

A multi-phase sampling approach was used:

1. **Stage 1: At the national level**

Purposive sampling was used to choose important stakeholders from UNEPI, NMS, MoH, WHO, UNICEF, and Gavi.

2. **Step 2: Choosing a District**

Purposively, 17 districts were chosen to guarantee representation in geographical areas; vaccination performance levels (high, medium, and low); mix of rural and urban areas; and logistical closeness to vaccine shops.

3. **Step 3: Choosing a Health Facility**

Purposive and convenient approaches were used to sample the facilities, giving priority to availability of cold chain equipment, fluctuations in service delivery volume, and routine immunization facilities.

4. **Stage 4: Interviews with Caregivers**

In outpatient and immunization clinics, caregivers were chosen via systematic sampling.

Respondents included:

1. National decision-makers (n ≈ 12).
2. District officers (n ≈ 51).
3. Health facility workers (n ≈ 78).

4. Caregivers (n ≈ 85).
5. VHTs and community leaders (n ≈ 20).

Quantitative Methods

Descriptive Statistics

Descriptive analyses are summarized into cold chain functionality, stock management performance, frequency of supervision, human resource availability, session implementation, and coverage levels of MR2, IPV2, HepB-BD, and YF. Frequencies, percentages, averages, standard deviations, and regional comparisons were among the metrics used.

Readiness Scoring

WHO PIE domains were used to categorize readiness indicators and these include planning and coordination, cold chain and logistics, training and human resources, communication and demand generation, service delivery, monitoring and supervision. Greater readiness was indicated by higher scores, which ranged from 0 to 100 for each domain. At the district and facility levels, a composite readiness indicator was created.

Logistic Regression

Predictors of attaining ≥80% coverage for novel vaccines were evaluated using binary logistic regression. Among the independent factors were supervision frequency (≥2 visits per quarter), cold chain functionality, community mobilization frequency, staff training status, availability of logistics and supplies, and preventive maintenance compliance.

Significance was set at a p-value of less than 0.05 ($p < 0.05$). Models were adjusted to account for district region and facility type.

Qualitative Methods

Interview Procedures

FGDs and semi-structured KIIs investigated logistics and cold chain challenges, communication strategies, training and supervision quality, operational experiences during rollout, community perceptions and acceptance.

The 45-60 minute interviews were conducted in either English or the local tongue, with interpreters available as needed. Verbatim transcriptions of audio recordings were made.

Thematic Coding and Analysis

A hybrid deductive-inductive method was applied. This resulted into:

- Deductive codes based on BeSD constructions and WHO PIE domains.
- Inductive codes emanating from the Tales of the respondents.

NVivo 12 was used for analysis in accordance with Braun and Clarke's six-step thematic framework. To find convergent or divergent ideas, themes were combined with quantitative results.

Data Management and Quality Assurance

Teams that collected data received training on:

1. PIE tool use.
2. Being consistent throughout the interview process.
3. Precise translation and transcription.

Excel was used to enter quantitative data, which was then exported to STATA/R for analysis. Double-entry verification, consistency checks, and range checks were carried out.

Two independent reviewers cross-checked the qualitative transcripts. While audit trails and documentation guaranteed transparency, cross-method triangulation improved reliability.

Results

Overview of Findings

Using quantitative PIE datasets and qualitative interviews, the study evaluated Uganda's performance and preparedness after the introduction of four new vaccines: MR2, IPV2, HepB-BD, and Yellow Fever. Participants from the national level as well as

17 peripheral study sites (cities and districts) from each of Uganda's four regions provided the data. The peripheral study sites are depicted schematically in Figure 1 below. Regression outputs and thematic insights follow the presentation of results at the national, district, and facility levels. Strong national coordination, moderate-to-high district readiness, ongoing operational inadequacies at the facility level, and significant geographic differences are all evident in the findings.

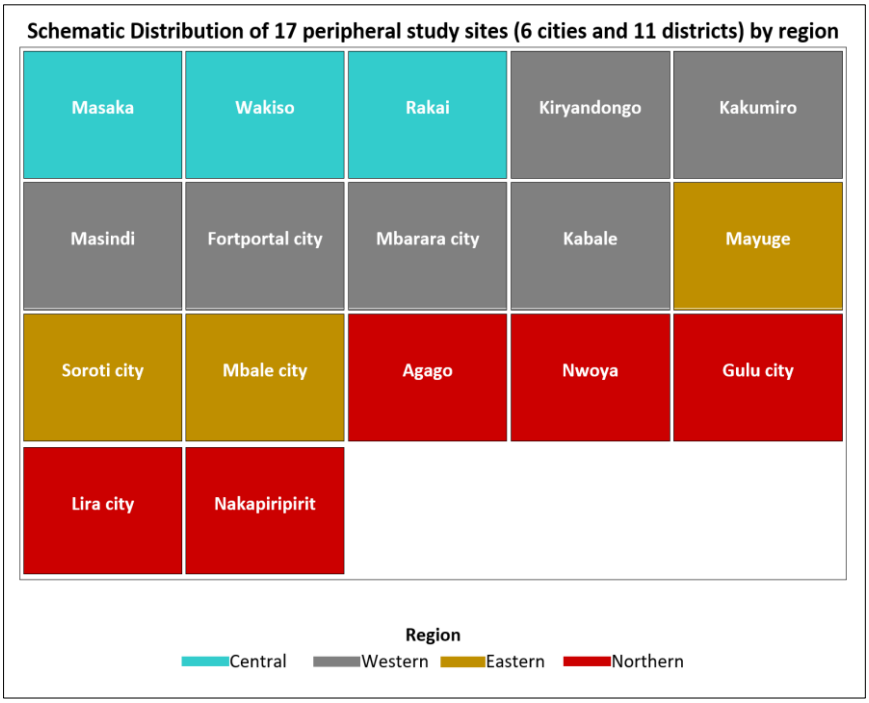

Figure 1. Distribution of Study Sites (Cities and Districts) across Uganda, 2024 Multi-antigen Post Introduction Evaluation in Uganda

National-Level Readiness

National-level readiness was high with a mean national level score of 81% across all domains as shown in table 1 below. Policy and coordination was the highest at 92% while communication and social mobilization was the least at almost 70%.

Table 1. National-Level Readiness Scores of Various Domains, 2024 Multi-antigen Post Introduction Evaluation in Uganda

Readiness Domain	**Indicator Components**	**Score (%)**
Policy & Coordination	Updated guidelines, partner coordination, microplanning	92
Vaccine Procurement & Supply Chain	Timely distribution, LMIS use, buffer stock	88
Cold Chain & Logistics	CCE availability, distribution scheduling, repair capacity	84
Human Resources & Training	New vaccine training coverage, skill levels	76
Service Delivery & Outreach	Routine session consistency, outreach coverage	81

Supervision & Monitoring	Supportive supervision frequency, reporting	74
Communication & Social Mobilization	IEC materials, community engagement	69

Overall National Readiness Score: ***81%***

Policy and Coordination Mechanisms

UNEPI supplied vaccine introduction circulars, operational microplans, and updated national guidelines. Regular coordination meetings were held with WHO, UNICEF, Gavi, NMS, and implementing partners. A national technical working committee established alignment with IA2030 priorities, addressed logistical constraints, and tracked rollout progress.

Participants in the interviews emphasized increased stakeholder alignment and effective national stewardship. However, during the early implementation phase, several observed delays in distributing revised recommendations to districts.

Vaccine Procurement and Logistics

In general, the distribution and acquisition of vaccines were prompt and well-organized. Using an improved logistics management information system, NMS made sure that supplies and vaccines were distributed to districts on a quarterly basis. The majority of districts reported obtaining sufficient amounts of the HepB-BD, YF, IPV2, and MR2 vaccinations.

Typical logistical difficulties included:

- Sporadic delays in transportation in isolated areas.
- Inadequate buffer supply in plants with large volumes.
- Variations in the temperature at which vaccines arrive.

National vaccination availability for all new antigens maintained above 90% in spite of these problems.

Cold Chain System Performance (83.7% Functional)

Table 2 and Figure 1 below show that the average national cold-chain functioning was 83.7%, with notable regional variation; -

- Central: 94.8%
- Western: 89.3%
- Eastern: 78.6%
- Northern: 72.1%

In rural areas, the majority of operational equipment was solar direct-drive refrigerators (SDDs). Data revealed that 12–15% of temperature deviations were caused by frequent power outages in grid-dependent plants. Due to long repair turnaround times and insufficient technical capacity, preventive maintenance compliance remained low (almost 58%), as table 2 below illustrates.

Table 2. Cold Chain Functionality by Region, 2024 Multi-antigen Post Introduction Evaluation in Uganda

Region	**Functional CCE (%)**	**Temperature Excursions (%)**	**Preventive Maintenance Compliance (PMC, %)**
Central	94.8	7.2	68
Western	89.3	9.4	61
Eastern	78.6	14.8	55
Northern	72.1	16.1	47

National Average Functional CCE - ***83.7%;*** *PMC –* ***57.7%***

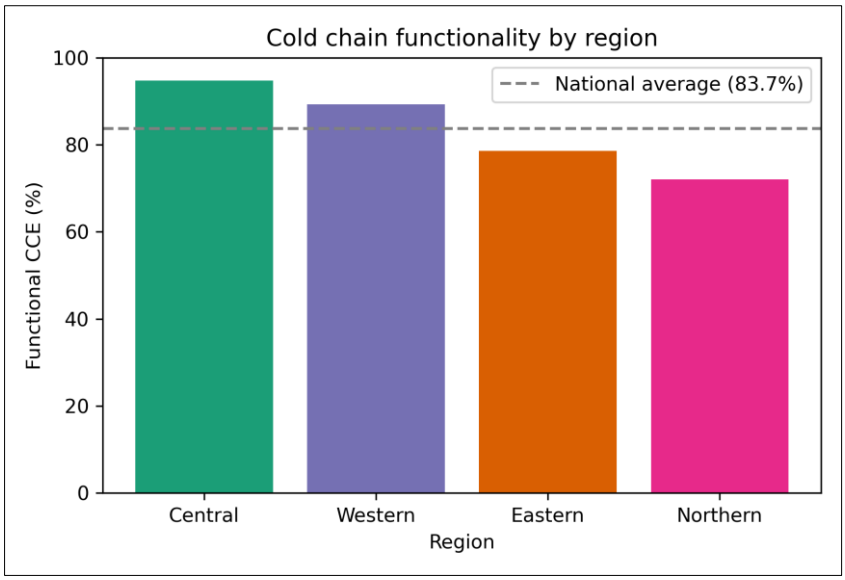

Figure 2. Cold Chain Functionality (83.7%) by Region, 2024 Multi-antigen post Introduction Evaluation in Uganda

District-Level Readiness

Supervision Frequency and Effectiveness

Table 3 below illustrates the vast variations in supervision frequency between districts. Low-performing districts (Amudat, Bugiri, Bundibugyo) received 0–1 visits per quarter, but high-performing districts (Wakiso, Mbarara, Gulu) received an average of 2-3 visits. Figure 3 below illustrates the favorable correlation between supervision visits per quarter and new vaccine coverage. Effective supervision was highly associated with proper handling of vaccines, the caliber of session planning, correctness of the data, prompt reporting, Caregiver monitoring. There were fewer missed opportunities for vaccination (MOVs) in districts with regular mentorship.

Table 3. District-Level Supervision Frequency, 2024 Multi-antigen post Introduction Evaluation in Uganda

District Category	**Average No. of Supervision Visits/Quarter**	**% of Districts Meeting WHO Standard (≥2 Visits/Qtr)**	**Coverage Performance Trend**
High-Performing Districts (e.g., Wakiso, Mbarara, Gulu)	**2–3**	**87%**	↑ High Coverage
Moderate-Performing Districts	**1–2**	**54%**	→ Moderate Coverage
Low-Performing Districts (e.g., Amudat, Bugiri, Bundibugyo)	**0–1**	**29%**	↓ Low Coverage

Overall Mean Supervision Frequency: ***1.8 visits/quarter***

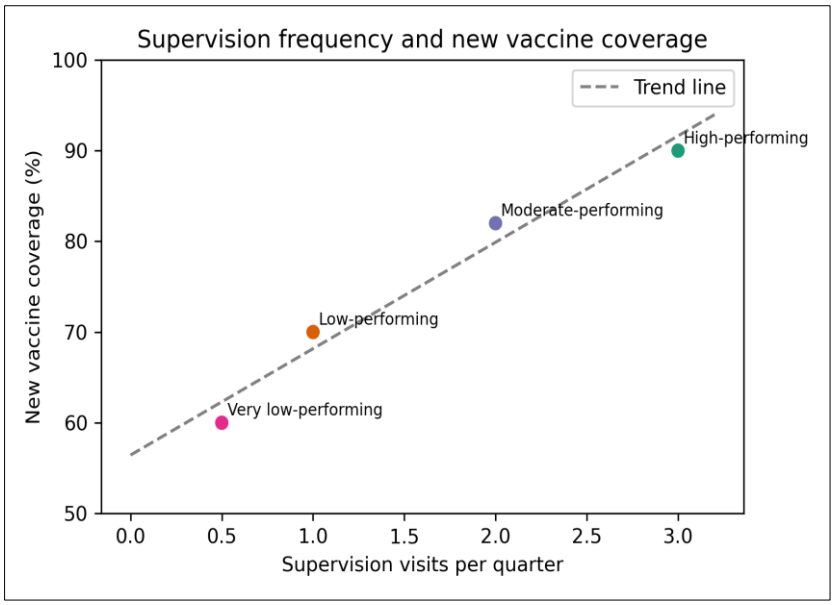

Figure 3. Supervision Frequency and Coverage Outcomes, 2024 Multi-antigen post Introduction Evaluation in Uganda

Human Resource Capacity

Human resource preparedness at the district level was mediocre. In the last 12 months, almost 76% of healthcare professionals received training on new vaccines. Nonetheless, there was inconsistent training coverage, with deficiencies being particularly noticeable in rural areas.

Among the main limitations were Employee attrition leading to a high turnover of staff, insufficient vaccinators, the mobilization process relies on volunteers (VHTs), and minimal options for refresher training.

The implementation was somewhat helped overall by HR capability; however, sustainability issues were brought to light.

Health Facility-Level Readiness

Stock Management and Session Implementation

Facility-level stock management performance was inconsistent:

- **87%** of facilities had updated stock registers.
- **72%** adhered to FEFO (first expiry-first-out).
- **18%** reported at least one stock-out of syringes or safety boxes in the past quarter.
- **8%** reported stock-outs of at least one new vaccine.

The quality of the session's execution varied. Outreach session completion rates were greater and missed opportunities were lower in facilities with a reliable cold chain and frequent supervision.

Staff Competence

Using observation checklists, staff competency scores averaged 78%, as seen in table 4 below. Levels of competence included; - correct reconstitution techniques (84%), temperature monitoring (79%), documentation accuracy (73%), and communication with caregivers (69%). Facilities with lower competence scores usually have CCE malfunctions, heavy workloads, or untrained staff.

Table 4. Facility-Level Competence Scores, 2024 Multi-antigen Post Introduction Evaluation in Uganda

Competency Area	Indicator Description	Score (%)
Vaccine Handling	Correct reconstitution, multi-dose vial policy	84
Temperature Monitoring	Twice-daily logging, correct placement	79
Documentation Accuracy	Register completeness, tallying, HMIS	73
Communication with Caregivers	Counseling, side-effect explanations	69
Cold Chain Management	Proper storage, use of freeze tags	82
Session Planning & Delivery	Punctuality, preparedness, session flow	75

Overall Facility Competence Score: ***78%***

Predictors of Immunization Coverage

Logistic Regression Outputs (Supervision, CCE Status)

Table 5 below summarizes the significant factors that regression analysis found for attaining ≥80% coverage for at least one new vaccine.

Key findings:

1. Supervision and cold chain status were the strongest predictors of high coverage with predictor likelihood more than twice more likely.
2. Staff training was important but not statistically significant when adjusted for other factors.
3. Timely supply and coverage performance were impacted by logistic proximity.
4. As seen in figure 4 below, there was a positive correlation observed between the probability of high coverage and the readiness score.

Table 5. Logistic Regression Predictors of New Vaccine Coverage, 2024 Multi-antigen Post Introduction Evaluation in Uganda

Predictor Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value	Interpretation
≥2 Supervisions/Quarter	2.41	1.35–4.29	0.003	Strong predictor of achieving ≥80% coverage
Functional Cold Chain Equipment	2.87	1.62–5.09	<0.001	Most significant predictor
Staff Trained on New Vaccines	1.53	0.89–2.63	0.118	Not significant after adjustment
Adequate Vaccine Stock	1.92	1.01–3.65	0.046	Significant influence on coverage
District logistical proximity (≤30 km from Vaccine Depot)	1.74	1.02–2.97	0.041	Logistic proximity improves performance

Model Summary:

- **Chi-square:** $p < 0.001$
- **Pseudo-R^2:** 0.36
- **Significant Predictors:** supervision, functional CCE, vaccine stock, proximity

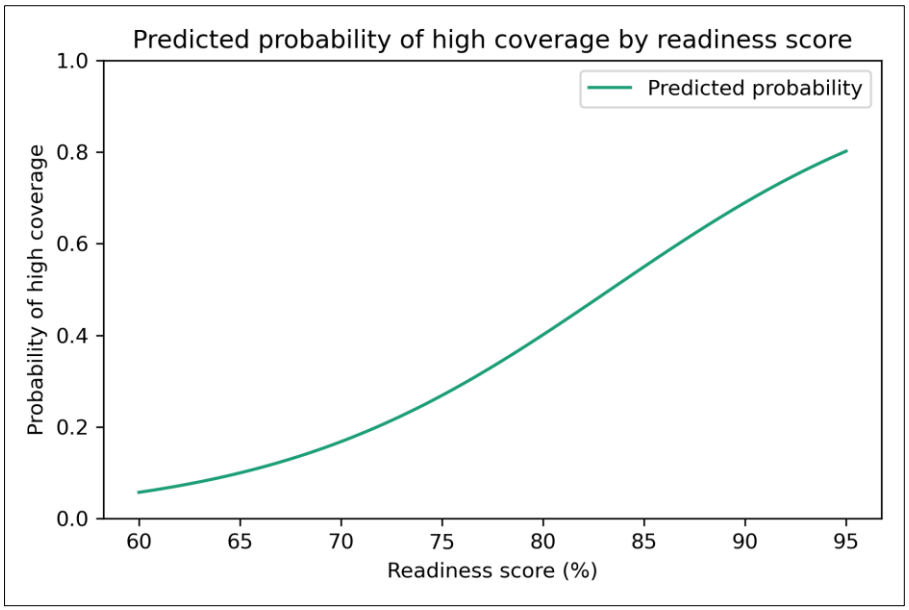

Figure 4. Probability of High Coverage by Readiness Score, 2024 Multi-antigen Post Introduction Evaluation in Uganda (Logistic Regression Plot)

Qualitative Insights

Partner Coordination

Strong coordination between UNEPI, WHO, UNICEF, Gavi, and CHAI was reported by respondents. Rollout implementation was strengthened by cooperative planning, standardized tools, and joint supportive supervision. However, some districts reported poor partner support in distant locations and delayed delivery of national rules.

Preventive Maintenance Gaps

Breakdowns in the cold chain become a significant problem. Long repair times were reported by respondents as a result of Insufficient district technicians, Lack of replacement parts, and a strong dependence on repair missions financed by partners. These difficulties resulted in decreased session quality, temperature fluctuations, and service disruptions.

HR Bottlenecks

Service delivery was hindered by a lack of human resources. Health professionals noted a lack of incentives, a high workload, and a shortage of vaccinators. Long wait periods and sporadic outreach sessions, particularly in difficult-to-reach places, were a source of frustration for caregivers.

Despite the limited funding and training, many districts depended significantly on VHTs for mobilization.

Discussion

This study used mixed techniques at the national, district, facility, and community levels to evaluate Uganda's health system's performance and preparedness for the introduction of new vaccines, including MR2, IPV2, HepB-BD, and Yellow Fever. IA2030 priorities, WHO's Health Systems Building Blocks, and available empirical data from comparable LMIC countries are used to contextualize the conclusions.

Summary of Major Findings

Strong readiness at the national level, moderate capability at the district level, and ongoing operational difficulties at the facility level are the main conclusions. Logistic regression revealed that supervision (OR 2.41, p =.003) and functional cold chain equipment (OR 2.87, p <.001) were the strongest predictors of new vaccine coverage. Cold chain functionality was 83.7%, and supervision

frequency remained irregular in low-performing districts (0–1 visits/quarter). Strong partner coordination was evident in the qualitative findings, although there are still gaps in preventive maintenance and a lack of human resources.

Discussion by Objective

Impact and Efficacy of Newly Introduced Vaccines

Coverage for new vaccines—MR2 (78%), IPV2 (83%), HepB-BD (66%) and YF (72%)—indicates that Uganda performed above the African regional average of 60–70% for new antigens in year 1 [2].

Early performance suggests:

- Robust incorporation into EPI timetables.
- Efficient systems for logistics, and
- A strong sense of community.

Disparities between isolated Northern/Eastern districts and Central/Western regions still exist, nonetheless. This is consistent with research showing early post-introduction coverage often reflects pre-existing disparities in the health system [5].

Evidence: High-performing counties routinely outpaced remote desert areas in Kenya's MR2 implementation [6]. Due to HR and logistical difficulties, Ethiopia and Tanzania experienced spatial discrepancies during the introduction of IPV2 [7].

Challenges and Barriers to Implementation and Uptake

Across districts, barriers included:

1. Cold chain maintenance issues (58% PM compliance)
2. Inadequate supervision in remote areas
3. Staff turnover and workload
4. Transportation challenges
5. Behavioural misconceptions

These findings align with sub-Saharan African studies documenting HR shortages, Suboptimal coverage is mostly caused by behavioral barriers and logistical limitations [8, 9].

Caregiver interviews in Uganda demonstrated a lack of understanding about HepB-BD and YF, which is in line with UNICEF's (2023) findings that routine antigens are more widely known than novel vaccinations [3].

Integration of New Vaccines into Routine Immunization

Integration was largely successful due to:

1. Updated national guidelines.
2. Harmonized training.
3. Strong partner support, and
4. Inclusion in routine micro plans.

Districts with frequent supervision (≥2 visits/quarter) demonstrated:

- Fewer missed opportunities,
- Better session planning, and
- More consistent outreach.

This supports global evidence that strong supervisory systems enhance vaccine introduction success [10, 11].

However, health care facilities lacking trained/qualified vaccinators or working cold chain equipment performed worse, highlighting the fragility of the approach in locations with minimal resources.

Sustainability: Vaccine Logistics, Cold Chain, and Financing

Although the cold chain performs admirably (83.7%), sustainability is threatened by temperature fluctuations (12–15%) and slow repair turnaround. Poorly maintained equipment compromises long-term vaccination potency, especially during multi-antigen rollouts, according to WHO's CCEOP evaluation [12].

One important obstacle that appears, is finance. Gavi and UNICEF play a major role in Uganda's cold chain deployment, societal mobilization, and supervision. Financing for sustainable EPI will need complete execution of the 2023–2027 Immunization Financing

Strategy, Increase in domestic co-financing, and Including vaccinations in PHC spending plans [13].

Best Practices and Lessons Learned

Most important lessons are:

1. **Early rollout success is fueled by strong national leadership**

Uganda's centralized coordination and partner participation were crucial, in line with Rwanda's introduction of HPV [12].

2. **Mentorship and supervision are mandatory.**

The strongest indicator of high coverage was supervision (OR 2.41). This is consistent with research conducted in Tanzania, Ghana, and Nigeria.

3. **There is still a lot of community trust**

Acceptance was aided by caregiver trust in healthcare professionals (91%), which is consistent with BeSD models that indicate trust is a key factor in uptake [14].

4. **Equity is determined by geography**

A distinct north-south imbalance is evident in GIS results, which are consistent with previous studies on spatial disparities in Uganda [15, 16].

Relationship of Findings with Theoretical Frameworks

Application of the Health Belief Model (HBM)

According to the HBM, perceived vulnerability, severity, advantages, and barriers all have an impact on vaccination behavior [17]. In this research:

- There was a strong perception of the vaccine's protective effects.
- Uptake was impacted by perceived obstacles (distance, lengthy lines, misinformation).
- Enhanced adherence through cues to action (VHT reminders, facility talks).
- In urban and central regions, self-efficacy was higher.

These are consistent with international HBM-based immunization studies that demonstrate the predictive power of the model [18].

Application of Diffusion of Innovation (DoI) Theory

New vaccines represent “innovations.” Their adoption depends on:

1. Communication channels.
2. System readiness.
3. Perceived advantage.
4. Compatibility with community norms.

Uganda’s rollout demonstrates “early majority adoption” in high-performing districts due to strong coordination and communication.

Remote districts exhibited “late adoption,” reflecting weak communication channels and logistical disadvantages.

This pattern mirrors Rogers’ diffusion curve and is consistent with immunization adoption studies from Ethiopia and Rwanda [12, 19].

Comparison with Previous Empirical Studies

Global and Regional Comparisons

Uganda’s early coverage is above global averages [2], which report MR2 and IPV2 coverage typically around 60–70% in the first-year post-introduction. Cold chain performance (83.7%) is higher than the African regional average of 72% [20].

Alignment or Deviation from Existing Evidence

Aligned:

- Logistics and supervision are strong predictors [10].
- Regional inequities consistent with findings from Kenya and Tanzania.

Deviations:

- Uganda’s low stock-out rate (<8%) is significantly better than the African average of 18–25% [2].
- Uganda’s strong partner coordination outperforms many LMICs.

Implications of the Findings

Policy Implications

1. Expand preventive maintenance units at regional depots.
2. Fully fund district EPI budgets to reduce reliance on partners.
3. Implement equity-weighted resource allocation for Northern/Eastern regions.

Programmatic Implications

1. Scale up monthly supportive supervision.
2. Strengthen real-time stock visibility and temperature monitoring.
3. Increase VHT support for home-based mobilization.

Research and Academic Implications

1. Future research should test digital reminder systems (SMS/WhatsApp).
2. Longitudinal studies to track vaccine uptake over 5–10 years.
3. Economic analyses to quantify cost-effectiveness of new vaccine introduction.

Study Limitations and Methodological Reflections

1. Causal inference is limited by cross-sectional design.
2. Reporting mistakes may be present in secondary data.
3. The generalizability of several districts was limited due to selective sampling.
4. Social desirability bias may affect qualitative replies.

However, mixed-methods triangulation improved validity. The vaccination program in Uganda shows a high level of preparedness for the introduction of new vaccines. High national coordination, functional logistics, and strong community trust facilitated early uptake. However, disparities related to geography, HR disparities, and cold chain fragility continue to exist. In order to support Uganda and other comparable LMICs in bolstering their immunization programs in the IA2030 period, the study provides fresh multi-level evidence.

Conclusion

Summary of Key Results

With the help of efficient coordination between UNEPI, NMS, WHO, UNICEF, Gavi, and implementing partners, this mixed-methods evaluation showed that Uganda has a solid national-level readiness for the introduction of new vaccines. With considerable geographical heterogeneity, cold chain functionality was comparatively high at 83.7%. For newly launched vaccines, the best indicators of attaining ≥80% coverage were supervision frequency and cold chain functionality (OR 2.41 and OR 2.87, respectively).

Variability remained at the district and facility levels in outreach execution, documentation quality, human resource capability, and preventive maintenance compliance (58%). Effective partner collaboration was emphasized by qualitative findings, although there are still gaps in HR workload, communication, and logistics repair systems, particularly in remote areas.

Implications for Policy

1. **Strengthen preventive maintenance systems** through regional Cold Chain Maintenance Units with dedicated budgets and staffing.
2. **Institutionalize supportive supervision**, ensuring all districts receive at least two supervisory visits per quarter.
3. **Adopt equity-weighted funding** for low-performing regions (Northern and Eastern Uganda) to reduce geographic disparities.
4. **Operationalize the Immunization Financing Strategy (2023–2027)** to ensure sustainability of supply chain, workforce, and communication interventions.
5. **Integrate immunization indicators** into broader PHC monitoring frameworks to ensure multi-program accountability.

Implications for Practice

1. **Improve district-level planning** using real-time dashboards and GIS maps to identify cold spots and allocate resources effectively.
2. **Increase the number and skills of vaccinators**, including refresher training on new vaccine administration.
3. **Strengthen VHT-led community mobilization**, ensuring consistent messaging and caregiver reminders for MR2, IPV2, HepB-BD, and YF.
4. **Enhance stock management practices**, ensuring FEFO use, regular physical counts, and temperature monitoring.
5. **Promote integrated outreach**, combining immunization with ANC, PNC, nutrition, and early childhood health services.

Implications for Future Vaccine Introductions

1. Given Uganda's preparedness, there is a good chance that COVID-19 boosters, the HPV second dosage, and any other vaccine will be introduced in the future.
2. The introduction of novel antigens will be accelerated by early investments in digital health tools and cold chain expansion.
3. Demand-creation planning has to incorporate behavioral insights using the Diffusion of Innovation Theory and the Health Belief Model.
4. To more precisely predict supply demands, real-time logistics systems and predictive analytics should be expanded.

Final Remarks

When new vaccines were introduced, Uganda showed excellent system resilience and preparedness. To guarantee fair vaccine uptake throughout all regions, ongoing improvements in monitoring, human resources, and preventative maintenance are crucial, even while national coordination and logistics continue to be strengths. Uganda's ability to provide future vaccines effectively and fairly will be improved by sustained investment in system development that is in line with IA2030 and the national immunization policy.

Conflict of Interest

The authors declare no conflict of interest. This study was conducted independently, and no author received financial or material incentives that could bias the outcomes of this research.

Ethical Approval and Data Use Permission

Since the study used secondary data, there was no need for ethical approval.

1. The study protocol was approved by Texila American University Institutional Review Board (IRB) (Ref. No. TAU/PH/2024/IMM/02) prior to data analysis.
2. Formal permission to access and analyze the PIE 2024 secondary data was obtained from the office of the Minister of Health, reference number ADM 170/214/01, dated 25th November 2025. Confidentiality, privacy, and data protection principles were strictly adhered to throughout the research.

Consent for Publication

Not applicable

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare no competing interests. The authors alone are responsible for the views expressed in this article, and they do not necessarily represent the views, decisions or policies of the institutions with which they are affiliated.

Funding

No funding.

Author Contributions

- **Dr. Alex W. Barasa:** Conceptualization, methodology, data analysis, manuscript drafting, final approval.
- **Dr. Folake Abiodun**: Data validation, supervision, policy interpretation, manuscript review.
- **Prof. Olaiya Abiodun**: Technical guidance, conceptual oversight, editing, and academic supervision.

All authors: Review and final Approval of Manuscript.

Acknowledgements

Institutional and Partner Support

The authors acknowledge the contributions of:

- Ministry of Health (UNEPI), Uganda.
- National Medical Stores (NMS).
- World Health Organization – Uganda.
- District Health Teams (DHTs).
- Health Facility In-charges, Vaccinators and VHTs.

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