# INTEGRATION STANDARDS & MATURITY MODEL FOR UGANDAN HEALTH SUPPLY CHAIN SYSTEMS

*Version 2.0 - Post-Validation Revision*

## INTRODUCTION

This document provides a realistic framework for data exchange across Uganda's health supply chain systems. It is grounded in the empirical findings of the 2025 Baseline Assessment, which revealed that 89% of facilities face unreliable internet, and that system fragmentation and parallel paper-based workflows are the norm, not the exception.

The objective is not to mandate an unattainable real-time integration, but to define a pragmatic maturity model that guides facilities from their current state of digital disconnection toward incremental levels of interoperability. This approach reduces duplicate data entry, enhances supply visibility, and supports decision-making within the constraints of existing infrastructure.

## FOUNDATIONAL PRINCIPLES & MATURITY MODEL

### Grounding in Baseline Reality

The baseline assessment found:

- System Fragmentation: Facilities operate multiple disconnected digital systems (DHIS2, eAFYA, CSSP, eLMIS) alongside paper records.
- Infrastructure Gaps: Unreliable power and internet prevent the consistent use of API-dependent systems.

Therefore, current integration efforts must prioritize practical, incremental data exchange over complex, real-time API orchestration.

### Integration Maturity Model

This model defines a graduated pathway, with the current project focus squarely on achieving Level 2 (Opportunistic Sync) as the primary target.

| Maturity Level | Description | Data Exchange Method | Target Facilities & Focus |
|---|---|---|---|
| Level 0: Paper-Centric | All records maintained on paper registers. No digital entry. | Physical transport of paper reports to district for manual data entry. | ~40% of lower-tier facilities (HCIIs). Focus: Digitization at source. |
| Level 1: Single-System Digital Entry | One digital system is used (e.g DHIS2 mobile), reducing duplicate entry but operating in isolation. | Weekly export of CSV/Excel files from the digital system, emailed or physically transported to district. | ~35% of facilities. Focus: Standardizing on the offline-first application. |
| Level 2: Opportunistic Sync | PRIMARY TARGET. The proposed offline-first app | The app syncs structured data packets (JSON) to a central server when | 80% of facilities by project end. This is the core deployment model. |

| Maturity Level | Description | Data Exchange Method | Target Facilities & Focus |
|---|---|---|---|
| | is used. Data is synced to a central server when connectivity allows. | online. It pulls down consolidated reports and forecasts. | |
| Level 3: Real-Time Interoperability | Full API-based, real-time data exchange between national systems (e-LMIS, eAFYA, DHIS2). | RESTful APIs, FHIR resources. Assumes stable connectivity and high technical capacity. | Regional Referral Hospitals & District HQs only. Future state, not initial assumption. |

## SYSTEM-SPECIFIC INTEGRATION STANDARDS BY MATURITY LEVEL

### DHIS2 Integration

- Level 2 (Opportunistic Sync): The central server will periodically pull aggregated consumption and stock data from DHIS2's API when available. It will push back forecast recommendations from the tiered forecasting system (Tier 2 hierarchical statistical forecasts and Tier 3 ML predictions), stockout alerts, and override logs as analytics outputs for district and national dashboards.
- Level 3 (Real-Time): RESTful API and FHIR standards for bidirectional data exchange with sub-minute latency.

### e-LMIS Integration

- Level 2 (Opportunistic Sync): Facility-level orders (generated using Tier 1 rule-based forecasts with optional human overrides) and stock counts are collected via the offline-first app. During sync, this data is pushed to a central queue. This queue is processed in batch jobs (running every 4-6 hours) to update the e-LMIS, eliminating the need for facility staff to use multiple systems. Delivery information from e-LMIS is pulled and pushed back to facilities during their next sync.
- Level 3 (Real-Time): Direct RESTful API integration between the central system and e-LMIS for real-time stock visibility and automated order submission.

### eAFYA Integration

- Level 2 (Opportunistic Sync): Patient attendance and service utilization data from eAFYA is used at the district level as a feature in the Tier 3 forecasting model. District IT officers export CSV files from eAFYA weekly using the built-in export functionality. These CSV files are uploaded to the district server via secure file transfer (SFTP or web interface). The data informs district-level allocation but does not trigger real-time deductions at the facility level, respecting the current fragmentation.
- Level 3 (Real-Time): Direct integration for automatic deduction of dispensed commodities from facility inventory in e-LMIS, using FHIR resources like MedicationRequest.

### WFP LESS (Logistics Execution Support System) Integration

- Level 2 (Opportunistic Sync): Delivery status updates and tracking from WFP LESS are pulled by the central server via API calls (every 6-12 hours) and pushed to relevant facilities during their next sync, providing near-real-time visibility into last-mile logistics. This supports proactive redistribution planning when delivery delays are detected.

- Level 3 (Real-Time): API endpoints for live shipment tracking and automated receipt confirmations.

**Nutrition Appointment Platform (WHO/WFP/UNICEF/UNHCR) Integration**
This platform supports nutrition service delivery for vulnerable populations including refugees and climate-affected communities. Integration priorities were identified in stakeholder feedback from WFP.

- Level 2 (Opportunistic Sync): The central server pulls nutrition program enrollment data and appointment schedules via scheduled API calls (weekly). This data feeds into Tier 3 district-level forecasting models as demand signals for nutrition-specific commodities (Ready-to-Use Therapeutic Food, micronutrient supplements, etc.). Supply adequacy indicators (current stock vs projected need) are pushed back to the Nutrition Appointment Platform to inform program planning.
- Level 3 (Real-Time): Real-time bidirectional integration where nutrition appointment confirmations automatically trigger commodity allocation adjustments and stock deductions.

## DATA GOVERNANCE, SECURITY, AND COMPLIANCE

All data exchange, regardless of maturity level, must adhere to Uganda's Data Protection and Privacy Act (2019).

**Security Standards**

- Encryption: All transmitted data must use TLS 1.3 encryption. Local data stored on mobile devices uses AES-256 encryption with keys managed via Android Keystore System.
- Authentication: User authentication must be role-based (Principle of Least Privilege). Roles include: Facility Staff, Store Manager, District Supply Officer, National Administrator.

**Conflict Resolution Protocol**

**CRITICAL DESIGN PRINCIPLE:** In case of conflicting data edits from multiple sources, the system applies a 'local user edits always win' policy. This respects the offline-first architecture and the human-in-the-loop philosophy validated by technical review.

Rationale: The health worker physically present at the facility has ground truth. If a facility worker manually adjusts an order quantity after counting physical stock, and a district officer or automated system also modified it, the facility worker's version is preserved.

- Implementation: All conflicts are logged to the override audit trail for review by district officers. The district officer can then contact the facility to understand the reasoning, but cannot retroactively override without facility consent.
- Exception: During declared emergencies (disease outbreak, humanitarian crisis), district officers can flag orders for mandatory review, but the facility's data remains the system of record until the facility explicitly approves changes.

**Data Validation Rules**

The system enforces these plausibility checks at data entry (mobile app) and upon central receipt:

- Order quantities must be positive integers
- Orders cannot exceed 200% of the facility's 6-month historical maximum without override justification. This validation applies regardless of which tier generated the forecast (Tier 1 rule-based, Tier 2 hierarchical statistical, or Tier 3 ML model).
- Facility-level orders must align with facility type capacity (e.g HCII cannot order surgical equipment)
- Stock levels cannot be negative
- Duplicate detection: Check for identical facility ID, commodity code, and timestamp within 24-hour window

**Audit Trails**
All transactions must be logged with:

- User ID and role
- Timestamp (UTC)
- Action type (data entry, sync, override, forecast generation)
- If applicable: forecast tier that generated the recommendation (Tier 1, Tier 2, or Tier 3)
- Manual override justification (free text)

**Tier 2 Forecast Data Management**
**Important architectural note:** Tier 2 hierarchical statistical forecasts (generated by district servers using HES) are pushed to facilities as informational guidance only. They are stored separately from the operational SQLite database to prevent concurrent write conflicts during background sync operations.

Facility staff can view Tier 2 forecasts in a read-only dashboard section of the mobile app, but the primary Tier 1 rule-based forecast remains the default for order generation. This design respects the technical validation finding that concurrent read/write operations on SQLite require careful transaction management.

## REALISTIC INTEGRATION SCENARIOS & USE CASES

Based on baseline findings and stakeholder feedback, the following scenarios are critical. The system must support them primarily at Level 2:

**Disease Outbreaks**
Facility uses offline app to mark Outbreak Mode, justifying a large manual order override (e.g 300% increase in antimalarials). This override is synced to the district, alerting them to a potential redistribution need. The override audit log captures the facility worker's justification and the system flags it for district review without blocking the order.

**Delivery Delays**
A district officer, seeing a LESS update about a road washout delaying shipments to facilities in Karamoja, uses the central dashboard to manually reassign shipments from an affected facility to an accessible one. This reassignment is pushed to facilities during their next sync. The affected facility receives a notification explaining the delay and alternative pickup arrangements.

**Budget Adjustments**
A mid-year budget change at the district level is entered into the central system. The new budget ceilings are pushed to facilities during their next sync. Facilities then see updated, budget-aware forecast recommendations from Tier 2 and Tier 3 models upon sync. The Tier 1 rule-based forecast continues to generate orders within the new budget constraints automatically.

**Power/Network Downtime**
The core workflow continues uninterrupted on the offline app. All data is stored locally in the encrypted SQLite database configured with WAL mode. When connectivity is restored (automatically detected or manually triggered), data is synchronized with automatic conflict resolution favoring the facility's local edits. No operational delay occurs even after weeks of offline operation.

**Nutrition Program Expansion**
WFP scales up a nutrition program in refugee settlements, adding 500 beneficiaries. The Nutrition Appointment Platform updates enrollment data, which is pulled by the central server during the weekly scheduled sync. Tier 3 district forecasting models automatically adjust predicted demand for RUTF and micronutrients for affected facilities. District officers

receive alerts about the increased demand and can proactively reallocate stock before shortages occur.

## MONITORING, EVALUATION, AND COMPLIANCE

Success must be measured against the maturity model and the system's ability to reduce frontline worker burden while improving supply chain visibility.

### Key Performance Indicators

- Integration maturity: Percentage of facilities operating at Level 2 or higher (target: 80% by project end)
- Technical reliability: Sync success rate (target: >95%), data packet completeness, average time since last successful sync
- Forecast accuracy: Mean Absolute Percentage Error (MAPE) by tier (Tier 1 target: <30%, Tier 2 target: <25%, Tier 3 target: <20%)
- User engagement: Daily active users, override frequency (target: <15% of orders), paper form generation frequency as proxy for digital trust
- Operational impact: Stockout frequency and duration, time spent on supply chain tasks (baseline: 'almost spend a week' per stakeholder quote, target: 50% reduction)

### Compliance Audits

Semi-annual audits should assess:

- Technical integration: Verify data flows between systems, check API endpoint functionality, review error logs
- Data quality: Assess completeness, accuracy, and timeliness of synced data, validate conflict resolution logs
- Usability at facility level: Interview frontline workers to confirm the system reduces rather than increases workload burden
- Privacy compliance: Review audit trails, verify encryption implementation, confirm role-based access controls are functioning

## POST-GRANT IMPLEMENTATION ROADMAP& GOVERNANCE

### Phased Integration Deployment

- Phase 1 (Months 1-3): Deploy offline-first mobile app with Tier 1 forecasting. No external system integration yet. Focus on digitizing facility-level data entry and building user trust.
- Phase 2 (Months 4-6): Activate Level 2 integration with e-LMIS and DHIS2. Deploy district servers with Tier 2/3 forecasting. Begin opportunistic sync.
- Phase 3 (Months 7-9): Add eAFYA, WFP LESS, and Nutrition Appointment Platform integration at Level 2. Establish weekly data flows.
- Phase 4 (Months 10-12): Pilot Level 3 real-time integration at 2-3 regional referral hospitals. Evaluate performance before broader rollout.

### Governance Structure

Based on stakeholder feedback from the November 2025 validation event:

- District-level ownership: District Health Officers designated as primary system owners, involved as core partners throughout implementation.
- Ministry of Health oversight: Framework to be presented to MoH thematic working groups for policy-level review and alignment with national digital health strategy.
- Quarterly review committee: Cross-stakeholder committee (MoH, district officers, facility representatives, implementing partners) to review integration performance, override patterns, and recommend refinements.

## CONCLUSION

This integration framework is designed to meet Uganda's health supply chain where it currently operates, not where we wish it to be. By prioritizing Level 2 (Opportunistic Sync) integration, we provide a pragmatic path that respects infrastructure constraints while delivering tangible benefits: reduced duplicate data entry, enhanced supply visibility, and better-informed decision-making.

The framework explicitly rejects integration approaches that would increase frontline worker burden or require always-online connectivity. Instead, it builds incrementally from the offline-first foundation, adding integration touchpoints only where they provide clear value without introducing new points of failure.

*This is integration designed for resilience, not fragility.*

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## DOCUMENT REVISION HISTORY

| Version | Date | Changes |
|---|---|---|
| 1.0 | Oct 2025 | Initial integration standards based on baseline assessment |
| 2.0 | Nov 2025 | Post-validation revision incorporating:<br>- Changed conflict resolution from authority hierarchy to 'local user edits always win' policy<br>- Added Nutrition Appointment Platform integration (WHO/WFP/UNICEF/UNHCR)<br>- Clarified Tier 2 forecast data is informational only, stored separately<br>- Aligned data validation rules with tiered forecasting system<br>- Specified eAFYA CSV workflow (district IT officer weekly export)<br>- Added nutrition program expansion use case<br>- Expanded KPIs to include forecast accuracy by tier and workload reduction targets |