

Digital Health Transformation in Liberia:

A Hybrid Incremental Digital Transition Framework (HIDTF) for Sustainable Electronic Health Record Implementation

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Abstract

Background: Despite two decades of global digital health investment, Liberia and comparable fragile, post-conflict health systems continue to operate predominantly on paper-based patient records. Electronic health record (EHR) initiatives introduced through successive donor programmes have consistently failed to achieve normalization or sustainable scale-up. This persistence is not an incidental outcome of technical shortcomings but reflects deep, mutually reinforcing structural dynamics rooted in governance fragmentation, donor dependency, infrastructural instability, workforce deficits, interoperability failure, and sociotechnical misalignment.

Objective: This conceptual implementation science paper provides a mechanism-based explanation of why digital health implementation repeatedly fails in Liberia and proposes the Hybrid Incremental Digital Transition Framework (HIDTF) — a novel phased framework for sustainable, resilience-oriented digital health transformation in fragile and low-resource health systems.

Methods: Conceptual synthesis and critical framework analysis integrating the Consolidated Framework for Implementation Research (CFIR), Normalization Process Theory (NPT), the Non-Adoption, Abandonment, Scale-up, Spread, and Sustainability (NASSS) framework, Sociotechnical Systems Theory, Resilience Theory, Diffusion of Innovations, Digital Equity Frameworks, and Implementation Complexity Theory. Peer-reviewed literature, WHO and Ministry of Health reports, grey literature, and Liberia-specific health system data were critically synthesized.

Findings: This paper makes three analytical contributions absent from existing reviews. First, it explains digital health implementation failure through the concept of recursive implementation failure: each unsuccessful attempt depletes institutional absorptive capacity and deepens organizational scepticism, progressively worsening conditions for subsequent attempts — a compounding ratchet effect that prior barrier catalogues document but do not explain. Second, it identifies reliability asymmetry as a distinct mechanism sustaining paper-system dominance: health worker reversion to paper under infrastructure failure is not resistance to technology but rational professional judgment, because paper genuinely outperforms digital systems under Liberian operating conditions. Framing this as comparative advantage rather than deficiency fundamentally reorients implementation strategy. Third, it provides a political economy explanation of why the failure pattern persists despite being well-documented: donor institutional incentive structures systematically reward activity over sustainability, making collapse structurally predictable regardless of technical quality. These three mechanisms interact recursively — each perpetuating the others — such that single-domain interventions consistently fail. Existing frameworks diagnose the components of this cycle comprehensively but provide no operational pathway for phased digital transition in fragile, post-conflict, donor-dependent health systems.

Framework Contribution: HIDTF explains why digital health implementation repeatedly fails and proposes a phased, readiness-based pathway for sustainable digital transformation. Its five phases — Paper System Optimization; Hybrid Paper-Digital Operations; Department-Level Digitization; Interoperable Electronic Health Records; and Advanced Analytics and Intelligent Health Systems — provide an operational transition roadmap that no existing framework

addresses, sequencing governance reform, infrastructure stabilization, and workforce development as preconditions for, rather than outcomes of, technology deployment.

Conclusion: Sustainable digital health transformation in Liberia requires abandonment of rapid deployment models in favour of systems-thinking approaches that prioritize governance coherence, legitimize hybrid paper-digital workflows, and integrate sustainability financing from the outset. HIDTF is theoretically grounded, policy-relevant, and transferable to analogous fragile health systems globally.

1. Introduction

The digitization of health information has emerged as a defining priority of twenty-first century global health governance. The World Health Organization's Global Strategy on Digital Health 2020–2025 positions electronic health records (EHRs) as foundational infrastructure for universal health coverage, patient safety, and health system resilience (WHO, 2019; WHO, 2021). Across high-income countries, EHR adoption has achieved near-universal penetration, enabling longitudinal patient care, clinical decision support, and cross-facility data integration (Sheikh et al., 2015). In low- and middle-income countries (LMICs), however, implementation trajectories diverge sharply from global narratives of digital progress — exposing a widening gap between technological possibility and institutional reality (Blaya et al., 2010; WHO, 2016).

In sub-Saharan Africa, the digital health landscape is characterized by fragmentation, pilot-project proliferation, and persistent non-normalization of electronic patient record systems (Braa et al., 2004; Sahay et al., 2013). EHR initiatives — frequently donor-funded and technically sophisticated — consistently fail to achieve sustainable institutional embedding. Liberia offers one of the most analytically instructive contexts for understanding these dynamics: a nation whose health system has been reshaped by civil conflict, the catastrophic 2014–2016 Ebola epidemic, and chronic donor dependency, yet which continues to grapple with the foundational challenge of transitioning from paper-based to electronic patient records (Ministry of Health, Republic of Liberia, 2021; Moon et al., 2015).

The scholarly discourse on digital health implementation has advanced considerably, drawing on implementation science (Damschroder et al., 2009), sociotechnical systems theory (Strong & Volkoff, 2010), normalization process theory (May et al., 2011), and diffusion theory (Rogers, 2003). Yet two decades of systematic reviews and country studies have converged on the same finding — electricity is unreliable, workforces are undertrained, governance is fragmented — without resolving a more fundamental question: why do these barriers persist despite being thoroughly documented, and why does addressing them individually produce no durable improvement (Heeks, 2006; Fraser et al., 2005; Fritz et al., 2015)? The literature describes what exists. It does not explain the mechanisms that sustain it, nor why the system is self-reinforcing.

This paper addresses that gap through three analytical moves that existing reviews have not made. The first is the concept of recursive implementation failure: each unsuccessful implementation attempt depletes absorptive capacity and deepens organizational scepticism, worsening the institutional conditions for the next attempt. Failure is not repeated randomly — it compounds. The second is the concept of reliability asymmetry: in contexts where power supply is unreliable, paper records genuinely outperform digital systems under actual operating conditions. Health worker reversion to paper is not irrational resistance; it is appropriate professional judgment. Implementation strategies that treat it as a barrier to overcome, rather than a rational adaptation to govern, are structurally misaligned with the operating environment. The third is a political economy explanation of why the failure cycle persists despite documentation: donor organizations are not uninformed about the pilot-to-collapse pattern. They perpetuate it because their institutional incentive structures — output-based accountability, three-to-five year budget cycles, competition for programme visibility — systematically reward the deployment logic that produces collapse. These three mechanisms interact and reinforce one another, forming a

self-sustaining failure system that no existing implementation framework has diagnosed or addressed as a whole.

On the basis of this analysis, the paper proposes the Hybrid Incremental Digital Transition Framework (HIDTF). HIDTF is built on three responses to the three mechanisms identified above. To recursive implementation failure, it responds with sequential conditionality: governance architecture, infrastructure reliability, and workforce competency must be established as preconditions for technology deployment, not developed in parallel with it. To reliability asymmetry, it responds with hybrid legitimacy: paper-digital workflows are not failure states but rational resilience strategies that should be designed, governed, and evaluated as such. To the political economy of donor dependency, it responds with enforcement architecture: a national governance body with statutory authority to mandate interoperability standards and restrict non-compliant deployments — making alignment with national standards institutionally obligatory rather than merely advisable. Together, these responses constitute a phased, readiness-based pathway for sustainable digital transformation that no existing framework provides.

1.1 Research Problem and Objectives

The central research problem is the persistent gap between digital health investment and implementation success in Liberia. Despite the Ministry of Health's National eHealth Strategy (2021–2025) and sustained donor investment, EHR adoption remains fragmented, clinically marginal, and structurally unsustainable. Three research questions guide this analysis: (1) What mechanisms sustain digital health implementation failure in Liberia? (2) How do governance, infrastructure, workforce, and donor dynamics interact to produce recursive implementation failure? (3) How can a phased hybrid framework address identified failure mechanisms in a manner appropriate to Liberian institutional conditions?

2. Background and Context

2.1 Liberia's Health System: Post-Conflict Reconstruction and Persistent Fragility

Liberia's contemporary health system cannot be understood without reference to the devastating legacy of two civil wars (1989–1997 and 1999–2003), which systematically dismantled health infrastructure, decimated the health workforce, and shattered the institutional governance architecture that had supported pre-war service delivery (Ministry of Health and Social Welfare, 2011; World Bank, 2022a). Post-conflict reconstruction, enabled substantially through international donor assistance, achieved significant physical rebuilding. However, reconstruction efforts largely replicated pre-existing governance fragmentation, prioritized disease-specific programme outputs over health system strengthening, and created parallel donor-managed delivery structures rather than building national institutional capacity (Pfeiffer & Chapman, 2010; Moon et al., 2015).

The 2014–2016 Ebola Virus Disease epidemic imposed a second catastrophic rupture, exposing with devastating clarity the life-threatening consequences of paper-based, fragmented health information management. The inability to track patient contacts, monitor disease spread in real time, or maintain continuity of care records across facilities directly contributed to epidemic

propagation and response failure (Moon et al., 2015). The epidemic simultaneously created impetus for digital health investment while demonstrating the depth of structural vulnerabilities that technology deployment alone cannot address (Ako-Egbe et al., 2023). Post-Ebola reconstruction introduced the District Health Information Software 2 (DHIS2) platform for aggregate data collection, but translation toward clinical EHR adoption remained limited, fragmented, and disconnected from broader governance architecture.

2.2 ICT Infrastructure: A Foundational Implementation Constraint

Liberia's information and communications technology infrastructure constitutes one of the most consequential structural constraints on digital health implementation. Electricity access remains deeply inequitable: health facilities in rural counties, serving the majority of Liberia's approximately five million population, frequently operate without grid electricity and rely on expensive, maintenance-intensive generator systems with episodic fuel supply chains (LISGIS, 2020; World Bank, 2022b). Fewer than 15% of rural households have electricity access — conditions most rural health facilities share. Internet connectivity remains concentrated in Monrovia and a small number of county capitals, with mobile data costs prohibitive relative to health worker salaries. These constraints directly undermine EHR implementations dependent on real-time synchronization or continuous internet availability (Fraser et al., 2005; Agarwal et al., 2015).

2.3 Health Workforce: Shortages, Attrition, and Digital Capacity

Liberia's physician density — approximately 0.04 physicians per 1,000 population — ranks among the lowest globally, a direct legacy of conflict-induced emigration, training system collapse, and chronic underinvestment in human resources for health (WHO, 2022). Health workers responsible for delivering patient care are simultaneously expected to manage data entry, system administration, and troubleshooting — functions requiring additional time, digital competency, and motivation that cannot be assumed against a baseline of chronic workforce stress. Digital literacy remains uneven across cohorts and geographies, and health workers trained in digital health competencies are subject to emigration and urban concentration, creating a persistent training-attrition cycle (McAuliffe et al., 2013; Dovlo, 2005).

2.4 Donor-Dependent Health System Development

Liberia's health system is structurally dependent on external development assistance, which finances an estimated 70–80% of total health expenditure and underpins the operational architecture of most service delivery programmes (World Bank, 2022a). The proliferation of vertical donor programmes — each with distinct data platforms, reporting requirements, and technical standards — has produced a digital health landscape characterized by institutional fragmentation and interoperability failure (Braa et al., 2004; Pfeiffer & Chapman, 2010). When donor funding cycles conclude — typically within three to five years — systems developed and maintained through donor-financed parallel structures frequently collapse, lacking the institutional embedding, domestic financing, and governance integration required for sustained operation (Heeks, 2006; Tilahun & Fritz, 2015).

2.5 Existing Digital Health Landscape in Liberia

The existing digital health infrastructure comprises DHIS2 deployment for aggregate health data reporting, selective EHR piloting through NGO and donor programmes at tertiary facilities, mHealth application deployment for specific disease programmes, and community health worker reporting platforms (Lee et al., 2016). These initiatives remain disconnected from one another and from national clinical information governance architecture. Interoperability between platforms is negligible; patient data does not follow patients across facility or programme boundaries; and national health information governance bodies lack the technical and financial capacity to harmonize an increasingly fragmented digital ecosystem (Ministry of Health, Republic of Liberia, 2021; Olufadewa et al., 2024).

3. Theoretical and Conceptual Foundations

Explaining digital health implementation failure in fragile health systems requires theoretical frameworks capable of engaging multi-level complexity, institutional dynamics, and the recursive interactions between technology, social systems, and governance architectures. Eight complementary frameworks are synthesized below, selected for their explanatory power and their ability to illuminate distinct dimensions of the recursive failure cycle. Table 1 summarizes their contributions, applications, and limitations in the Liberian context.

Table 1. Theoretical Frameworks Applied to Digital Health Implementation Failure in Liberia

Framework	Core Contribution	Application to Liberia	Limitation in Fragile-State Context
CFIR (Damschroder et al., 2009)	Multi-level implementation determinants: inner/outer setting, intervention, individuals, and implementation process	Exposes how post-conflict outer-setting pathologies interact with weak inner-setting capacity to systematically block EHR adoption	Primarily diagnostic; no operational pathway for phased transition under governance fragmentation and donor dependency
NASSS Framework (Greenhalgh et al., 2017)	Cumulative complexity across seven domains (condition, technology, value, adopters, organization, embedding, adaptation) predicts non-adoption	Explains how simultaneous complexity across all domains virtually guarantees abandonment in fragile systems	Developed for high-income contexts; no operational guidance for donor-mediated, infrastructure-constrained LMICs
Normalization Process Theory (May et al., 2011)	Four normalization mechanisms — coherence, cognitive participation, collective action, reflexive monitoring — explain embedding in practice	Each mechanism is structurally blocked in Liberia by governance fragmentation, workforce shortage, and institutional fragility	Underweights political economy of donor-funded implementation; assumes preconditions for normalization exist
Sociotechnical Systems Theory (Strong & Volkoff, 2010)	Technology and social systems must co-evolve; neither can be optimized in isolation	Reframes hybrid paper-digital workflows as rational sociotechnical adaptations, not implementation failure	Full analysis requires longitudinal ethnographic methods not yet available across Liberia at scale
Diffusion of Innovations (Rogers, 2003)	Adoption shaped by innovation attributes (relative advantage, compatibility, complexity) and adopter categories	Explains why EHRs fail to cross adoption thresholds under infrastructure failure and excessive complexity relative to training resources	Linear diffusion model underestimates recursive, structurally embedded failure; cannot explain why addressing individual

Framework	Core Contribution	Application to Liberia	Limitation in Fragile-State Context
			attributes fails to disrupt the cycle
Resilience Theory (Abimbola et al., 2019; Kruk et al., 2018)	Health systems maintain function under stress through absorptive, adaptive, and transformative capacities	Reframes hybrid workflows as legitimate resilience strategies; grounds HIDTF hybrid-legitimacy premise and transformative capacity orientation	Risk of normalizing chronic resource inadequacy if not paired with transformative governance reform
Implementation Complexity Theory	Multi-level interacting barriers produce non-linear, emergent failure disproportionate to individual barrier effects	Explains recursive failure: governance, donor, infrastructure, and workforce barriers interact to produce compounding institutional deterioration	Relatively new lens; limited empirical validation in sub-Saharan African health system contexts
Digital Equity Framework (Young, 2022; Ferryman & Pitcan, 2018)	Structural inequalities in digital access, capability, and governance reproduce health inequities through digital systems	Centers infrastructural inequity, connectivity disparities, digital literacy gaps, and donor politics as root causes requiring governance intervention	Risk of framing access gaps as sufficient explanatory variables without addressing governance reform requirements for redistribution

3.1 Consolidated Framework for Implementation Research (CFIR)

The CFIR provides a comprehensive taxonomy of implementation determinants organized across five domains: intervention characteristics, outer setting, inner setting, characteristics of individuals, and implementation process (Damschroder et al., 2009). Its primary utility for Liberia lies in the outer and inner setting constructs. The outer setting — encompassing sociopolitical conditions, donor-dominated financing, structural poverty, and post-conflict governance pathologies — systematically constrains digital health adoption in ways that CFIR's diagnostic framework effectively captures. Crucially, CFIR demonstrates that outer-setting pathologies in Liberia cannot be addressed through inner-setting interventions alone: governance reform is the prerequisite, not the product, of organizational-level capacity building.

3.2 NASSS Framework

Greenhalgh and colleagues' Non-Adoption, Abandonment, Scale-up, Spread, and Sustainability framework addresses why technology programmes fail to scale when complexity accumulates across multiple dimensions (Greenhalgh et al., 2017). The NASSS concept of cumulative complexity is particularly powerful for the Liberian context: EHR implementation simultaneously encounters complexity across every domain — technology, value proposition, adopters, organization, and embedding environment — such that cumulative complexity virtually guarantees non-adoption or abandonment under prevailing structural conditions.

3.3 Normalization Process Theory

Normalization Process Theory (NPT) examines the social processes through which complex health interventions become routinely embedded in practice, identifying four generative mechanisms: coherence, cognitive participation, collective action, and reflexive monitoring (May

et al., 2011; Murray et al., 2010). In Liberia's context, each NPT mechanism is structurally blocked: coherence is undermined when systems fail under infrastructure constraints; cognitive participation cannot be sustained when workforce shortages exhaust clinical bandwidth; collective action is fragmented by multi-donor governance architectures; and reflexive monitoring cannot function without institutional evaluation capacity that governance fragmentation prevents.

3.4 Sociotechnical Systems Theory

Sociotechnical Systems Theory (SST) insists that technology and social systems must co-evolve for successful implementation (Strong & Volkoff, 2010). In Liberia, EHR failures consistently reflect sociotechnical misalignment: systems designed for continuous electricity, consistent connectivity, and trained informaticists encounter a social subsystem — health workers' practices, clinical routines, and paper-based competencies — that has adapted rationally to resource-constrained conditions. SST reframes hybrid paper-digital workflows from implementation failure indicators to legitimate sociotechnical adaptations — a framing central to the HIDTF's hybrid legitimacy premise.

3.5 Diffusion of Innovations Theory

Rogers' (2003) Diffusion of Innovations Theory explains adoption patterns through innovation attributes. In Liberia, EHR systems consistently fail on multiple attributes: relative advantage is not experienced under unreliable infrastructure; compatibility failures are severe; complexity exceeds available training resources. Diffusion theory effectively diagnoses adoption failure but its linear model underestimates the recursive, structurally embedded nature of failure in fragile systems — motivating integration with Implementation Complexity Theory.

3.6 Implementation Complexity Theory

Implementation Complexity Theory characterizes failure in terms of emergent, non-linear interactions between multiple barriers producing outcomes disproportionate to any individual barrier's effect. It is arguably the most analytically powerful framework for Liberia because it explains why addressing any single barrier — improving electricity, training health workers, or updating software — consistently fails to resolve implementation failure when other barriers remain intact and mutually reinforcing. The recursive failure cycle is an emergent property of a complex adaptive system that cannot be disrupted by linear, single-domain interventions.

3.7 Digital Equity Framework

Digital equity frameworks situate digital health implementation within structural analyses of power, resource distribution, and differential access (Young, 2022; Ferryman & Pitcan, 2018). Applied to Liberia, this framework exposes how electricity disparities, urban-rural connectivity inequities, and differential digital literacy are not technical deficits awaiting technological solutions but political-economic conditions requiring governance intervention and resource redistribution.

3.8 Resilience Theory

Resilience Theory examines health systems' capacity to absorb shocks, maintain function under stress, and adapt to changing conditions (Abimbola et al., 2019; Kruk et al., 2018). Applied to digital health, resilience theory reframes hybrid paper-digital workflows as legitimate adaptive

strategies and provides the conceptual foundation for the HIDTF's resilience-orientation premise: sustainable digital health implementation in fragile systems requires designing for resilience from the outset, not treating disruption as an exceptional event.

3.9 Limitations of Existing Implementation Frameworks

While CFIR, NPT, and NASSS represent the most widely applied frameworks in digital health implementation research, each exhibits critical limitations in the context of fragile, post-conflict, donor-dependent health systems. CFIR comprehensively diagnoses structural conditions but provides no operational pathway for governing the transition from paper to digital systems — no guidance on sequencing governance reform against technology deployment, no logic for managing prolonged hybrid coexistence as a deliberate strategy, and no mechanism for enforcing interoperability standards against resistant donor actors.

NPT explains what normalization requires but provides no phased implementation pathway for contexts where the preconditions for normalization are structurally absent and must themselves be constructed. NASSS predicts non-adoption with precision and recommends simplifying technology and building organizational capacity, but the framework was developed for high-income contexts and provides no operational guidance for navigating donor dependency or infrastructure-contingent hybrid workflows in fragile states.

The critical shared limitation is the absence of an operational transition pathway specifying the sequence, conditions, and governance mechanisms for moving from chronic paper-based operation to sustainable digital health practice in fragile, post-conflict, donor-dependent health systems. This prescriptive gap — phased migration logic under governance fragmentation, prolonged hybrid operation as a governed strategy, and enforcement-backed interoperability sequencing — is precisely what HIDTF fills.

4. Why Digital Health Implementation Fails in Liberia: Mechanisms, Interactions, and Recursive Failure

This section provides a mechanism-based account of why digital health implementation fails in Liberia — not a catalogue of what barriers exist, but an explanation of how they function, how they interact, and why their combined effect is more resistant to intervention than any individual barrier. Three analytical claims organize the analysis. First, recursive implementation failure: barriers do not accumulate additively but interact recursively, and each failed attempt actively worsens the conditions for the next through a compounding ratchet effect. Second, reliability asymmetry: health worker reversion to paper under infrastructure failure is not resistance but rational professional judgment, because paper genuinely outperforms digital systems under actual Liberian operating conditions — a mechanism that implementation strategies consistently misdiagnose. Third, the political economy of persistence: donor institutional incentive structures systematically produce the pilot-to-collapse cycle regardless of technical quality, explaining why the failure pattern recurs despite documentation. These three mechanisms are not independent; they interact and reinforce one another, forming a self-sustaining failure system. Table 2 maps barrier domains, primary mechanisms, interactions, systemic effects, and corresponding HIDTF responses.

Table 2. Mechanism-Based Interaction Map of Digital Health Implementation Barriers in Liberia

Barrier Domain	Primary Mechanism	Interacting Domains	Systemic Effect	HIDTF Response
Governance Fragmentation	Uncoordinated policy architecture creates governance vacuums; no body holds authority to enforce digital health standards or coordinate donor platforms	Donor Dependency, Interoperability, Institutional Fragility	Perpetuates siloed systems; blocks standards enforcement; prevents coherent national EHR adoption	Phase 1: National Digital Health Governance Coordination Body with statutory enforcement authority; FHIR mandate
Donor Dependency Cycles	Externally funded pilots lack domestic institutionalization capacity; bounded three-to-five year cycles produce abrupt technical and human resource withdrawal	Governance, Sustainability Financing, Technical Capacity	Short-term gains collapse post-funding; progressive depletion of organizational trust and absorptive capacity	Phase 1 MoU framework; multi-cycle financing commitment; domestic capacity development embedded in all phases
Infrastructural Instability	Electricity unreliability and connectivity absence interrupt digital workflows at points of greatest clinical need, generating reliability asymmetry favouring paper	Workforce Engagement, Sociotechnical Alignment, Sustainability	Rational retreat to paper becomes permanent; digital unreliability erodes trust in EHR systems before normalization can occur	Phase 2: offline-capable EMR design; solar integration; local data storage and backup; mesh connectivity
Workforce Shortages and Digital Illiteracy	Absolute shortages exhaust cognitive bandwidth; digital literacy gaps generate entry errors; trained staff emigrate or transfer to NGO sector	Infrastructure, Governance, Sociotechnical Alignment	Critical mass for normalization not achieved; system abandonment triggered; resistance deepens in subsequent implementations	Phase 2 task-shifting champion model; progressive competency development within absorptive capacity limits
Interoperability Failure	Vertical donor programmes deploy incompatible systems without accountability to national standards; no enforcement mechanism exists	Governance Fragmentation, Donor Dependency, Clinical Utility	Data silos fragment longitudinal records; negates core EHR value proposition; imposes multiple documentation burdens	Phase 1 FHIR mandate; Phase 3 national HIE activation; legally enforceable restriction on non-compliant deployments
Sociotechnical Misalignment	System designs embed high-resource assumptions; participatory design absent; workflow disruption	Workforce, Infrastructure, Institutional Resistance	High abandonment rates; rational reversion to paper; deepened skepticism toward subsequent implementations	Phase 2 participatory design; hybrid workflow legitimization; co-evolution rather than forced displacement

Barrier Domain	Primary Mechanism	Interacting Domains	Systemic Effect	HIDTF Response
	disadvantages health workers			
Institutional Fragility	Post-conflict absorptive capacity deficits prevent governance coordination, workforce development, and domestic financing mobilization	All barrier domains	Prevents scale-up; sustains implementation discontinuity; generates ratchet effect of progressive institutional hardening	Sequential conditionality across all phases; resilience mechanisms at infrastructure, operational, and governance levels

4.1 Governance Fragmentation: The Architectural Foundation of Failure

Governance fragmentation is the architecturally foundational barrier to digital health implementation in Liberia — not because it is the most immediately visible obstacle, but because it is the structural condition that enables and sustains all other barriers. Liberia's health system operates through a complex, uncoordinated assemblage of actors: the Ministry of Health, county health teams, bilateral donor agencies, multilateral organizations, international NGOs, and faith-based health networks, each with distinct mandates, accountability structures, and institutional interests. This produces what Braa and colleagues (2004) term 'networks without action' — multiple actors in proximate governance spaces without the coordination architecture needed to generate convergent outcomes.

For digital health specifically, fragmented governance manifests in the absence of enforceable national interoperability standards, inconsistent implementation of the National eHealth Strategy, absence of a functioning national health information exchange, and proliferation of parallel digital systems deployed without integration with national infrastructure. No governance body holds sufficient authority to hold technology deployers accountable to national architecture requirements. The Ministry of Health's Health Information Division, while nominally responsible for national digital health governance, has historically lacked enforcement authority, technical staffing, and financial resources to regulate donor-funded technology deployments — a capacity gap that the HIDTF's National Digital Health Governance Coordination Body is specifically designed to address.

4.2 Financing Constraints: Donor Dependency and the Pilot-to-Collapse Cycle

Donor dependency operates through reinforcing mechanisms that collectively prevent sustainable institutionalization. Donor organizations design and deploy digital systems to meet their own programmatic accountability requirements — generating data on programme outputs — rather than to serve the national health information system's clinical and governance needs. This objective misalignment means that even technically successful EHR pilots are designed for donor accountability rather than national institutional embedding.

When funding concludes — typically within three to five years — the technical and human resources supporting digital systems withdraw simultaneously, leaving facilities without

operational capacity. This 'implementation discontinuity' (Heeks, 2006) collapses rather than consolidates systems. Health workers who invested time learning digital tools, only to watch them fail and be abandoned, develop generalized disengagement from implementation processes — substantially impeding subsequent attempts.

This persistence requires explanation beyond technical failure. The pilot-to-collapse cycle is well-documented in the literature; what the literature has not explained is why it continues to be reproduced by organizations that are not uninformed about it. The answer lies in the political economy of donor-funded implementation: donor institutional incentive structures systematically reward the deployment logic that produces collapse. Output-based accountability frameworks measure systems deployed and health workers trained — not outcomes observed three years after funding withdrawal. Budget cycles of three to five years make the eight-to-ten year institutional commitment that sustainable digital health transformation requires structurally impossible within any single funding envelope. Competition between donor organizations for programme visibility incentivizes proprietary platform deployment over national standards alignment. The result is that collapse is not an implementation failure in the conventional sense — a failure of planning, technical quality, or execution — but a structurally predictable outcome of incentive systems oriented toward activity rather than sustainability. This political economy analysis is analytically distinct from barrier cataloguing: it explains not merely that donor dependency is a problem, but the specific institutional mechanisms through which it reproduces failure independent of the goodwill or technical competence of individual organizations or projects.

4.3 Technology Constraints: Infrastructural Instability and Interoperability Failure

Infrastructural constraints have typically been framed in the digital health literature as barriers to overcome — problems of supply, logistics, and maintenance that better project management could resolve. This paper offers a different diagnosis. The operative mechanism is reliability asymmetry: under Liberian operating conditions, paper records genuinely outperform digital systems. Paper functions regardless of power availability; digital systems fail at precisely the moments of greatest clinical need. This is not a marginal disadvantage — it is a systematic performance reversal that rational health workers respond to by maintaining paper as their primary system. Their reversion to paper is not resistance to technology, not a training deficit, and not a change management failure. It is appropriate professional judgment under conditions where digital unreliability directly threatens patient care. Implementation strategies that diagnose this behaviour as a barrier to overcome — and respond with more training, more change management, or more technology — are structurally misaligned with the operating environment. The correct response, which HIDTF encodes, is to design hybrid systems that govern paper-digital coexistence as a legitimate steady state rather than treat it as a transitional deficiency.

Interoperability failure functions simultaneously as cause and consequence of governance fragmentation. As a cause, incompatible systems prevent the clinical data flows that would demonstrate EHR value to health workers, undermining adoption incentives. As a consequence, governance fragmentation permits donor organizations to deploy incompatible systems without accountability to national standards. The result is a fragmented technical landscape in which a patient attending an HIV clinic, a maternal health service, and general outpatient care at the same

facility may exist in three separate digital systems with no mechanism for clinical data integration — negating EHR utility while imposing multiple documentation burdens.

4.4 Workforce Constraints: Turnover, Digital Literacy, and Change Management Failures

The workforce dimension operates through three interlocking mechanisms. First, absolute workforce shortages create conditions in which health workers manage patient volumes that overwhelm clinical capacity, leaving no temporal margin for learning new digital systems. Second, digital literacy gaps — particularly among older and rurally stationed health workers — generate interaction competency deficits that translate directly into data quality problems and system abandonment. Third, EHR systems typically require workflow reorganization that increases encounter duration and redistributes documentation labour in ways that disadvantage senior clinical staff, generating resistance from precisely the personnel whose engagement NPT's cognitive participation mechanism requires.

Staff trained in digital health competencies are subject to emigration, NGO sector absorption, and urban concentration — creating a persistent training-attrition cycle. Change management failures compound the problem: donor-funded pilots that lack dedicated change management resources cannot generate the normalization mechanisms requiring sustained organizational investment in coherence-building and collective action coordination.

4.5 Organizational Constraints: Weak Ownership, Competing Priorities, and Implementation Fatigue

Weak institutional ownership of digital health systems reflects the structural consequences of donor-mediated implementation: when systems are designed, deployed, managed, and evaluated by external organizations, domestic institutional ownership does not develop. When donor programmes conclude, a political and institutional vacuum of accountability emerges. Competing priorities further constrain organizational engagement: in a health system managing high disease burdens with severely constrained resources, digital health implementation rationally yields to immediate clinical demands.

Implementation fatigue — the progressive organizational disengagement generated by repeated cycles of adoption and abandonment — is one of the most consequential and least quantified costs of the pilot-to-collapse cycle. Its effects are measurable in reduced adoption rates, lower training engagement, and increased health worker resistance in subsequent implementations. Each recursive failure cycle generates a ratchet effect: progressive institutional hardening against digital adoption that makes each subsequent attempt more difficult than the last, even when technical conditions improve.

4.6 Systems-Level Explanation: How Barriers Reinforce One Another

The five barrier domains constitute a mutually reinforcing system whose collective effect is more resistant to intervention than any individual barrier. Governance fragmentation enables donor proliferation by creating vacuums that international organizations fill with parallel structures. Donor proliferation generates interoperability failure by deploying incompatible systems without accountability to national standards. Interoperability failure undermines clinical utility by

preventing longitudinal patient records. Reduced clinical utility generates workforce disengagement as health workers accurately assess an unfavourable cost-benefit calculus. Workforce disengagement prevents normalization by blocking NPT's social mechanisms. Non-normalization sustains governance fragmentation by failing to demonstrate digital health's value to decision-makers, perpetuating the policy inconsistency that enables continued donor proliferation.

This recursive cycle cannot be disrupted by linear, single-domain interventions. The cycle also has a temporal dimension: each failed implementation depletes absorptive capacity, deepens implementation fatigue, and worsens institutional conditions for subsequent attempts — producing the compounding ratchet effect that Implementation Complexity Theory predicts and that distinguishes recursive failure from ordinary repeated failure. This mechanism-based account is the paper's central analytical contribution and the direct motivation for the HIDTF's systems-level, multi-domain, sequenced approach.

4.7 Cybersecurity, Data Governance, and Institutional Trust

An underexamined dimension of implementation failure is the intersection of cybersecurity vulnerability, data governance inadequacy, and institutional trust deficits. Liberia's capacity for health data governance — regulatory frameworks, enforcement mechanisms, technical security infrastructure — remains nascent and insufficient for national-scale EHR deployment. Patient trust in digital record systems is shaped by cultural perceptions of privacy and institutional accountability that implementers frequently underestimate, particularly in communities whose relationship with government has been shaped by conflict and institutional failure. Data governance is not a technical afterthought but a foundational component of the trust infrastructure that sustainable digital health adoption requires.

5. The Hybrid Incremental Digital Transition Framework (HIDTF)

HIDTF is a phased implementation framework that enables sustainable digital transformation through progressive migration from paper-based systems to interoperable digital health ecosystems, sequenced according to infrastructure readiness, workforce capacity, governance maturity, and organizational adaptability. The framework's design is grounded in three foundational premises derived from the foregoing analysis.

First, sequential conditionality: governance architecture, infrastructure reliability, workforce competency, and institutional trust must be established as preconditions for, rather than outcomes of, technology deployment. This premise directly addresses the architectural inversion identified as the root cause of recursive failure. Second, hybrid legitimacy: paper-digital hybrid workflows are not failure states or transitional deficits but legitimate adaptive strategies appropriate to infrastructure-constrained environments, which should be designed, governed, and evaluated as such. Third, resilience-orientation: implementation frameworks for fragile systems must incorporate redundancy, flexibility, and adaptive capacity enabling function under conditions of infrastructural and institutional stress.

5.1 Theoretical Novelty: What HIDTF Contributes Beyond Existing Frameworks

HIDTF is not a synthesis of CFIR, NPT, and NASSS prescriptions but a response to their collective prescriptive gap. Applied individually or in combination, these frameworks diagnose barriers comprehensively but converge on no operational pathway for phased digital transition in fragile, post-conflict, donor-dependent health systems. HIDTF's distinct contributions are:

- Phased transition logic with explicit readiness-based progression criteria absent from all existing frameworks
- Readiness-based implementation sequencing that conditions technology deployment on governance, infrastructure, and workforce preconditions rather than project timelines or donor funding cycles
- Governance sequencing that establishes enforcement authority before technology deployment, rather than assuming governance capacity exists
- Hybrid paper-digital management as a positively governed strategy rather than an implicit transitional deficit
- Sustainability-oriented implementation integrating domestic financing, curriculum integration, and governance institutionalization from Phase 1
- Explicit design for fragile-state applicability, including donor political economy analysis, absorptive capacity constraints, and post-conflict institutional dynamics

Compared to CFIR, HIDTF provides prescriptive sequencing rather than diagnostic taxonomy. Compared to NPT, HIDTF specifies how to build the preconditions for normalization that NPT assumes exist. Compared to NASSS, HIDTF provides an operational transition pathway for the fragile-state context that NASSS does not address. Compared to Diffusion of Innovations Theory, HIDTF addresses not only innovation attributes but the structural governance conditions determining whether adoption is institutionally achievable. Compared to Sociotechnical Systems Theory, HIDTF operationalizes the co-evolution principle through specific phase activities rather than leaving it as an analytical observation.

Figure 1 presents the HIDTF architecture, illustrating the five phases in progressive sequence and the cross-cutting enablers that govern implementation continuity throughout. Detailed phase specifications are provided in Table 4 (Section 5.3) and in the phase descriptions that follow.

Implementation Dimension	CFIR	NPT	NASSS	HIDTF
Barrier identification	Comprehensive multi-level taxonomy across five domains	Focuses on social processes blocking four normalization mechanisms	Cumulative complexity mapping across seven domains	Mechanism-based interaction map identifying recursive structural couplings between barrier domains
Adoption processes	Describes facilitators and barriers; limited sequencing guidance	Four normalization mechanisms; process-focused but no sequencing roadmap	Complexity management strategies; primarily diagnostic	Phased progression with explicit readiness-based criteria conditioning each phase transition
Governance sequencing	Identifies governance as outer-setting factor; no sequencing or reform guidance	Does not address governance architecture reform	Notes organizational embedding complexity; no governance roadmap	Governance architecture as Phase 1 prerequisite; enforcement-backed interoperability mandates before technology deployment
Hybrid paper-digital transition	Not addressed; implies adoption or non-adoption binary	Does not conceptualize prolonged hybrid operation	Not addressed	Explicitly legitimizes and governs hybrid workflows as a designed resilience strategy across Phases 1–3
Sustainability planning	Implementation process domain notes sustainability; limited specificity	Reflexive monitoring supports adaptation; no financing guidance	Sustainability domain; no fragile-state operationalization	Dedicated sustainability mechanisms; domestic financing from Phase 1; curriculum integration in Phase 5
Donor dependency	Outer setting identifies external policy context; does not analyze donor political economy	Not addressed	Not addressed	Explicit political economy analysis; donor MoU framework; FHIR enforcement restricting non-compliant deployments
Fragile-state applicability	Developed for high-income healthcare organizations; requires recontextualization	Developed primarily for NHS-type high-income contexts	Explicitly for high-income health and social care settings	Designed specifically for post-conflict, resource-constrained, donor-dependent health systems
Implementation roadmap	No phased operational pathway provided	No phased operational pathway provided	No phased operational pathway provided	Five-phase, 84-month sequenced roadmap with readiness indicators, governance milestones, and progression criteria

Implementation Dimension	CFIR	NPT	NASSS	HIDTF
Health outcomes linkage	Noted but not operationalized	Implicitly through normalization of care processes	Value proposition touches outcomes; not operationalized	Explicitly links phases to continuity of care, disease surveillance, AMR monitoring, MCH outcomes, and health equity

5.3 Phase Architecture

Table 4 provides a concise summary of HIDTF's five phases, including goals, key activities, readiness indicators, expected outcomes, and progression criteria. The phases overlap temporally in their transition windows to accommodate the iterative readiness validation that conditions phase advancement.

Table 4. HIDTF Phase Implementation Table: Goals, Activities, Readiness Indicators, Outcomes, and Progression Criteria

Phase	Goal	Key Activities	Readiness Indicators	Expected Outcomes	Progression Criteria
Phase 1 Paper System Optimization (Months 0–18)	Stabilize governance; legitimize hybrid workflows; map system-wide digital readiness	National infrastructure audit; establish governance body; revise National eHealth Strategy; workforce digital literacy assessment; donor coordination MoU; standardize paper records; mandate FHIR compliance	Governance body legally constituted; infrastructure audit complete; donor MoU signed; FHIR mandate enacted; hybrid workflow policy adopted	Stable governance architecture; coordinated donor engagement; mapped workforce capacity; standardized paper records; interoperability standards adopted	All readiness indicators achieved; eHealth Strategy revised; baseline data published; FHIR mandate operational
Phase 2 Hybrid Paper-Digital Operations (Months 12–36)	Deploy offline-capable EHR at pilot facilities in parallel with paper; build champion cadre; validate interoperability	Offline EMR at 10–15 referral hospitals; structured parallel paper-digital workflows; digital health champion training; FHIR architecture validation; solar integration pilots	Minimum infrastructure verified at pilots; champion cadre trained; offline EMR operational; parallel workflows documented	Functional hybrid systems at pilots; growing workforce confidence; interoperability architecture validated; empirical data generated for Phase 3 decisions	≥80% champions trained; FHIR architecture validated; paper-digital protocols operational; infrastructure readiness verified
Phase 3 Department-Level Digitization (Months 30–60)	Expand EHR to counties meeting readiness criteria; activate national HIE; enforce FHIR compliance	Criteria-based county expansion; national HIE activation; DHIS2-EMR integration; domestic server infrastructure; quality improvement	County infrastructure at readiness threshold; county digital coordinators deployed; DHIS2-EMR integration	County-level digital coverage in compliant facilities; interoperable data flows; nationally governed HIS; reduced structural	National HIE live; DHIS2-EMR integration operational; ≥70% county facilities at readiness threshold

Phase	Goal	Key Activities	Readiness Indicators	Expected Outcomes	Progression Criteria
	across all actors	cycles; enforce non-FHIR-compliant restriction	tested; restriction enforced	donor dependency	
Phase 4 Interoperable Electronic Health Records (Months 48–84)	Achieve national EHR coverage; embed sustainability financing; institute digital health regulatory framework; achieve regional integration	National EHR in ready facilities; domestic budget integration; health insurance linkage; cybersecurity framework; ECOWAS peer-learning network	Domestic budget line established; cybersecurity framework enacted; pre-service curricula revised; sustainability financing operational	Normalized digital health practice; financially sustainable ecosystem; digitally competent incoming workforce; regulatory-compliant data governance	Digital health curricula at all training institutions; domestic budget line operational; cybersecurity regulations enacted; ECOWAS network formalized
Phase 5 Advanced Analytics and Intelligent Health Systems (Months 72+)	Leverage interoperable EHR for population health analytics, AI-assisted decision support, and regional disease surveillance	Population health dashboards; clinical decision support modules; AMR surveillance; outbreak detection algorithms; MCH outcome analytics; ECOWAS data exchange; AI governance framework	Phase 4 normalization achieved; domestic analytics capacity established; AI regulatory framework adopted; data quality standards met	Real-time disease surveillance; AMR monitoring; improved MCH outcomes; evidence-based resource allocation; regional health security leadership	AI governance framework enacted; AMR surveillance operational; ≥90% national facility EHR coverage; real-time outbreak detection demonstrated

5.3.1 Phase 1: Paper System Optimization (Months 0–18)

Objectives: Establish governance architecture; conduct national infrastructure and workforce baseline assessments; standardize paper-based record systems; mandate interoperability standards; formalize hybrid workflow policy.

Infrastructure requirements: National infrastructure audit capacity; data collection platforms for facility-level electricity and connectivity assessment.

Workforce requirements: National digital literacy assessment team; governance body technical secretariat with dedicated staffing.

Governance requirements: National Digital Health Governance Coordination Body legally constituted with statutory enforcement authority; Ministry of Health political commitment at Cabinet level; donor coordination MoU framework.

Implementation risks: Political resistance to governance centralization; donor reluctance to subordinate programme preferences to national standards; institutional capacity constraints in the Ministry of Health.

Health system outcomes: Phase 1 directly improves disease surveillance capability through standardized paper recording; supports maternal and child health monitoring through consistent

data capture; and establishes the governance foundation for equity-oriented digital health expansion.

Progression indicators: Governance body constituted; infrastructure audit published; FHIR mandate enacted; donor MoU signed; National eHealth Strategy revised.

5.3.2 Phase 2: Hybrid Paper-Digital Operations (Months 12–36)

Objectives: Deploy offline-capable EHR modules at pilot facilities in parallel with paper; build digital health champion cadre; validate interoperability architecture.

Infrastructure requirements: Offline-capable EHR software; local data storage and backup; solar power integration at pilot sites; mesh connectivity where feasible.

Workforce requirements: Digital health champions (task-shifting model) at pilot facilities; peer-learning support structures; structured in-service digital training curriculum.

Governance requirements: Readiness verification process for pilot facilities; phase governance milestone monitoring; county digital health coordinator deployment.

Implementation risks: Technical failures at pilot facilities generating normalization-damaging experiences; champion attrition through emigration; connectivity disruption; insufficient parallel workflow documentation.

Health system outcomes: Phase 2 begins generating longitudinal patient records at pilot facilities, directly improving continuity of care and patient safety through accessible clinical history and medication records.

Progression indicators: ≥80% of target champions trained; FHIR architecture validated at pilots; parallel paper-digital workflows operational; infrastructure readiness verified.

5.3.3 Phase 3: Department-Level Digitization (Months 30–60)

Objectives: Expand EHR to county health systems meeting readiness criteria; activate national health information exchange; enforce FHIR compliance across all health system actors.

Infrastructure requirements: National HIE server infrastructure (domestically hosted); county-level connectivity; DHIS2-EHR integration middleware; expanded solar and backup power at county facilities.

Workforce requirements: County digital health coordinators; expanded champion cadre; health informatics technical team for HIE management; DHIS2-EHR integration specialists.

Governance requirements: Readiness criteria framework formally adopted; non-FHIR-compliant deployment restriction legally enforceable; county performance accountability for digital health integration.

Health system outcomes: National HIE activation in Phase 3 enables real-time disease surveillance and outbreak detection — directly addressing the surveillance gaps exposed by the Ebola epidemic. County-level EHR deployment improves equity of access to digital health services and enables population-level monitoring of maternal and child health indicators.

Progression indicators: National HIE live; DHIS2-EHR integration operational; ≥70% county facilities at readiness threshold; non-compliant deployment restriction enforced.

5.3.4 Phase 4: Interoperable Electronic Health Records (Months 48–84)

Objectives: Achieve national EHR coverage in facilities meeting readiness criteria; establish domestic sustainability financing; institute digital health regulatory framework; achieve ECOWAS regional integration.

Infrastructure requirements: National data centre with redundancy; cybersecurity regulatory infrastructure; domestic EMR hosting independent of international vendors; ECOWAS regional data exchange connectivity.

Workforce requirements: Digital health competencies integrated in all pre-service health professional training; domestic health informatics specialist cadre; national EHR helpdesk; regulatory staff for data governance.

Governance requirements: Domestic budget line for health information systems; cybersecurity regulatory framework enacted; health insurance integration with EHR; ECOWAS peer-learning network formalized.

Health system outcomes: Phase 4 normalization of digital health practice directly improves service quality through clinical decision support, reduces medication errors through allergy and interaction alerts, and strengthens antimicrobial resistance monitoring through linked laboratory and pharmacy data.

Progression indicators: Domestic budget line operational; digital health curricula at all training institutions; cybersecurity framework enacted; ECOWAS network formalized.

5.3.5 Phase 5: Advanced Analytics and Intelligent Health Systems (Months 72+)

Objectives: Leverage interoperable EHR ecosystem for population health analytics, clinical decision support, antimicrobial resistance surveillance, and real-time outbreak detection.

Infrastructure requirements: AI-ready computing infrastructure; regional data exchange protocols; AMR laboratory-EHR integration; population health analytics platform.

Workforce requirements: Health data scientists; AI model governance specialists; AMR programme digital coordinators; clinical informaticists for decision support integration.

Governance requirements: AI governance framework with ethical oversight; AMR national action plan digital integration; regional health data sovereignty agreements.

Health system outcomes: Real-time disease surveillance and outbreak detection directly strengthen health security and epidemic response capacity. AMR surveillance enables evidence-based stewardship. Maternal-child health analytics identify high-risk pregnancies, improving outcomes in a context with among the world's highest maternal mortality ratios. AI-assisted diagnostic support improves service quality equity by extending specialist-equivalent decision support to rural and community facilities.

Progression indicators: AMR surveillance operational; AI governance framework enacted; ≥90% national facility EHR coverage; real-time outbreak detection demonstrated.

5.4 Governance Architecture

The HIDTF's governance architecture is specifically designed to address the fragmentation dynamics foundational to Liberia's digital health failure cycle. At the national level, a National

Digital Health Governance Coordination Body operating under Ministry of Health statutory authority serves as the apex coordination institution, with mandate to enforce interoperability standards, coordinate donor alignment, approve technology deployments, and monitor national implementation progress. This body's composition explicitly includes frontline health worker representatives and civil society organizations, operationalizing NPT's cognitive participation mechanism at the governance level.

At the sub-national level, county digital health coordinators — embedded within county health teams and accountable to both national governance structures and county health leadership — provide decentralized governance capacity to translate national policy into locally appropriate implementation action. The governance architecture also specifies enforcement mechanisms: no digital health system deployment by any actor — including donor-funded programmes — may proceed without compliance with the national FHIR interoperability mandate. This enforcement authority is the critical structural innovation absent from all predecessor frameworks.

5.5 Interoperability Strategy

The HIDTF's interoperability strategy follows a sequenced architecture: foundational standards adoption in Phase 1; point-to-point integration between pilot facilities in Phase 2; county-level integration and DHIS2 linkage in Phase 3; national HIE activation in Phase 4. The strategy mandates HL7 FHIR as the foundational interoperability standard, with OpenHIE architecture providing the health information exchange framework — open-source, internationally validated standards that reduce vendor lock-in risk and can be implemented and maintained by domestic technical teams with appropriate training. A critical governance element is the legally enforceable restriction on new non-FHIR-compliant deployments by any health system actor.

5.6 Resilience Integration

The HIDTF integrates resilience mechanisms at three nested levels. At the infrastructure level: offline-capable system design with local data storage and periodic synchronization; local data backup protocols with redundant storage; solar power integration; mesh connectivity. At the operational level: maintained paper-digital parallel workflows during transition phases; facility-level digital system management protocols; cross-trained backup personnel; contingency protocols for system failure. At the governance level: institutional contingency planning for donor withdrawal; domestic financing diversification strategies; regional technical assistance networks providing system support independent of individual donor organizations. Together, these mechanisms ensure that digital health infrastructure can maintain function under the conditions of infrastructural and institutional stress that characterize Liberia's health system operating environment.

6. Digital Transformation as a Public Health Intervention

Digital health transformation is frequently conceived as an administrative or informatics reform. This framing fundamentally underestimates its public health significance. HIDTF positions digital transformation as a public health intervention with direct, measurable consequences for health outcomes across multiple domains. The following analysis makes explicit the health outcome linkages that justify the sustained political and financial investment that HIDTF requires.

Continuity of care is impossible without longitudinal patient records that follow patients across facility and programme boundaries. In Liberia, patients with HIV, tuberculosis, hypertension, or pregnancy complications attend multiple facilities without any mechanism for shared clinical information — resulting in duplicated investigations, missed diagnoses, medication errors, and clinical discontinuity directly contributing to poor outcomes. Interoperable EHRs activated through HIDTF Phases 3 and 4 close this clinical information gap.

Patient safety depends fundamentally on accurate, accessible clinical records. Paper-based records are vulnerable to loss, degradation, and transcription error; they cannot provide allergy alerts, drug interaction warnings, or clinical decision support. EHR integration with clinical decision support modules in HIDTF Phase 5 directly improves medication safety and diagnostic accuracy — delivering patient safety gains analogous to those documented in high-income EHR contexts but under Liberia's specific clinical burden profile.

Disease surveillance and outbreak detection — as the Ebola epidemic demonstrated — require real-time, facility-linked data flows that paper-based systems structurally cannot provide. HIDTF's national HIE architecture creates the surveillance infrastructure necessary for early detection of infectious disease outbreaks, enabling rapid public health response that paper-based systems prevent.

Antimicrobial resistance monitoring requires linked laboratory, pharmacy, and clinical data across facilities and time — precisely the data integration that interoperable EHRs enable. Liberia's National Action Plan on AMR cannot be operationalized without digital infrastructure capable of generating the epidemiological data AMR surveillance requires.

Maternal and child health outcomes are directly improved by EHR-enabled continuity of antenatal care, delivery records, and postnatal follow-up. Liberia's maternal mortality ratio — among the highest globally — reflects in part the clinical information fragmentation preventing providers from identifying high-risk pregnancies, tracking complications across facilities, and ensuring postnatal follow-up. HIDTF's MCH analytics module in Phase 5 directly addresses this clinical gap.

Health equity is both a driver and an outcome of digital health transformation. The infrastructural inequities generating digital exclusion for rural populations also generate health service inequities: facilities without digital health systems cannot access clinical decision support, remote specialist consultation, or community health worker coordination platforms that improve equity of care. HIDTF's solar integration, offline-capable design, and county-level deployment directly advance health equity alongside digital access.

Service quality monitoring, resource allocation, and public health accountability all depend on the reliable, timely health data that interoperable EHRs generate. Without digital infrastructure, the Ministry of Health cannot monitor service delivery performance at facility level, identify underperforming facilities for targeted support, or generate the evidence base for evidence-informed health policy. HIDTF's population health analytics in Phase 5 closes this governance information gap.

7. Comparative African Lessons for HIDTF Transferability

The HIDTF's transferability claims require grounding in comparative African evidence. Four national experiences offer analytically instructive contrasts that validate the framework's core logic

and specify the contextual conditions determining which elements transfer directly and which require adaptation.

7.1 Rwanda: Governance Coherence as the Prerequisite of Success

Rwanda's digital health trajectory represents the strongest African evidence for the HIDTF's central proposition: that governance coherence is the prerequisite, not the product, of successful digital health implementation. Post-genocide governance reconstruction produced unusually strong central Ministry of Health authority, a coherent national eHealth strategy enforced from above, and a deliberate decision to standardize on a single national EHR platform with mandatory adoption across public facilities. Near-universal EHR coverage by the mid-2010s reflected not superior technology but superior governance: a central authority capable of coordinating donor alignment, enforcing technical standards, and sustaining institutional commitment across funding cycles. The transferable lesson for Liberia is not that Rwanda's political consolidation is replicable but that the HIDTF's Phase 1 governance architecture requirement reflects precisely the structural prerequisite that Rwanda had and Liberia currently lacks.

7.2 Ethiopia: Tiered Deployment and Domestic Capacity Investment

Ethiopia's SmartCare and iHRIS experience illustrates the importance of phased, tiered deployment sequenced by facility readiness and the necessity of domestic technical capacity investment. Ethiopia's Federal Ministry of Health adopted a tiered rollout strategy — beginning with referral hospitals before progressing to health centres — mirroring the HIDTF's criteria-based Phase 3 logic. Ethiopia also invested in training domestically employed health informatics cadres capable of providing sustained technical support independent of international advisors. Where Ethiopia struggled was interoperability: multiple vertical disease programmes deployed parallel systems that resisted integration and imposed documentation burdens analogous to those documented in Liberia, confirming that tiered deployment without concurrent interoperability enforcement reproduces fragmentation at scale.

7.3 Kenya: The Cost of Interoperability Governance Failure

Kenya's digital health experience provides the most direct cautionary parallel for Liberia. Kenya invested substantially in health information systems over two decades — deploying DHIS2 nationally and OpenMRS across hundreds of facilities — yet by the mid-2010s, the ecosystem exhibited precisely the fragmentation dynamics documented here: multiple incompatible EHR deployments, negligible interoperability, patient data trapped in vertical silos, and DHIS2 aggregate data disconnected from facility-level clinical records. The Kenya Health Information System Interoperability Framework, developed in 2017, represented belated recognition that governance-enforced interoperability standards needed to precede — not follow — platform proliferation. HIDTF's Phase 1 FHIR mandate directly applies this Kenyan lesson.

7.4 Ghana: Offline-First Design as Non-Negotiable at Community Tiers

Ghana's community health information system experience illustrates the specific challenge of extending digital systems to the lowest facility tiers. Ghana's pragmatic adoption of offline-capable mobile data collection tools for community health workers, accepting intermittent connectivity and delayed synchronization as design features rather than deficits, directly mirrors the HIDTF's

Phase 2 offline-capability requirement and hybrid legitimacy premise. Ghana's experience confirms that offline-first design is not a compromise but a prerequisite for digital health at community facility tiers across sub-Saharan Africa.

Taken together, these four cases provide empirical grounding for the HIDTF's three foundational premises: Rwanda confirms sequential conditionality; Ethiopia illustrates phased deployment sequencing; Kenya demonstrates the cost of interoperability governance failure; and Ghana validates offline-first design as non-negotiable at community tiers. The contextual differences across these systems — particularly varying degrees of post-conflict institutional fragility and donor dependency — confirm that HIDTF's most operationally distinctive features — enforcement-backed interoperability governance and prolonged hybrid legitimization — are most critical in the most fragile contexts.

8. Operationalizing HIDTF in Liberia: National Implementation Roadmap

Table 5 presents a realistic national implementation roadmap for HIDTF in Liberia across three time horizons, providing concrete and achievable recommendations that acknowledge institutional constraints while specifying progressive milestones across governance, infrastructure, workforce, financing, technology, and health outcome domains.

Table 5. National Implementation Roadmap: Operationalizing HIDTF in Liberia Across Short-, Medium-, and Long-Term Horizons

Domain	Short-Term (1–2 Years)	Medium-Term (3–5 Years)	Long-Term (5–10 Years)
Governance	Establish National Digital Health Governance Coordination Body by legislative instrument; revise National eHealth Strategy; enact FHIR mandate; sign donor MoU framework; deploy county digital health coordinators	Operationalize HIE governance; enact health data privacy legislation; integrate digital health KPIs into county performance frameworks; establish data quality monitoring function	Achieve national governance coherence; sustain institutional independence from any single donor cycle; establish Liberia as a regional ECOWAS digital health governance resource
Infrastructure	Complete national infrastructure audit; pilot solar integration at 10–15 facilities; deploy offline-capable EMR at pilots; establish local data backup protocols	Expand solar and generator-backup to all district hospitals; establish domestic server infrastructure; activate national HIE; achieve county-level connectivity	Achieve reliable electricity at ≥90% of health facilities; establish nationally redundant data centre; connect all community health posts to HIE through intermittent synchronization
Workforce	Complete national digital literacy assessment; train digital health champion cadre at all pilot facilities; develop in-service digital health curriculum	Scale champions to all county facilities; integrate digital health competencies into pre-service training at all health professional institutions; establish continuous professional development pathway	Achieve digitally competent entry-level health workforce across all cadres; sustain domestic health informatics specialist cadre; eliminate dependence on international advisors for routine HIS maintenance
Financing	Identify domestic and international sustainability	Establish dedicated Ministry of Health HIS budget line;	Achieve domestic financing covering ≥60% of HIS operational

Domain	Short-Term (1–2 Years)	Medium-Term (3–5 Years)	Long-Term (5–10 Years)
	financing sources; engage National Health Insurance Authority on EHR integration; begin advocacy for domestic HIS budget line	integrate EMR costs into facility operational budgets; develop public-private partnership models for technology maintenance	costs; transition donor role from implementation to innovation investment; establish HIS maintenance reserve fund
Technology	Mandate FHIR compliance for all new deployments; adopt open-source national EMR standard; configure offline-capable pilot EMRs; establish local IT support cadre	Activate national HIE on OpenHIE architecture; integrate DHIS2-EMR data flows; deploy disease-specific modules (HIV, TB, malaria, MCH); establish national EMR helpdesk	Deploy population health analytics dashboards; integrate clinical decision support; operationalize AMR surveillance; introduce AI-assisted diagnostic support with governance framework; connect to ECOWAS health data exchange
Health Outcomes	Establish disease surveillance baseline; pilot EMR linkage to maternal-child health reporting; document paper-digital parallel workflow performance metrics	Demonstrate improved continuity of care indicators at county level; operationalize outbreak detection algorithm on HIE; link EMR data to National Health Accounts reporting	Demonstrate measurable improvements in patient safety indicators, maternal mortality documentation, AMR monitoring coverage, and outbreak response time through digital health infrastructure

The short-term horizon (1–2 years) is dominated by governance and assessment activities creating the institutional architecture and baseline evidence necessary for all subsequent implementation. The medium-term horizon (3–5 years) focuses on expanding infrastructure, activating interoperability, and achieving county-level EHR deployment in compliant facilities. The long-term horizon (5–10 years) pursues full national normalization, advanced analytics, and regional health security leadership.

Critically, sustainability financing development begins in the short-term horizon, not as a Phase 4 consideration. The pilot-to-collapse cycle cannot be broken if domestic financing is treated as a post-implementation concern. This front-loading of sustainability planning is the most operationally distinctive feature of the roadmap relative to conventional digital health implementation approaches — reflecting the core lesson that HIDTF draws from two decades of implementation failure in Liberia and comparable fragile health systems.

9. Sustainability Considerations

Sustainability is not the final phase of HIDTF but a design principle embedded across all phases. Four sustainability dimensions require dedicated, coordinated attention from Phase 1 onward.

9.1 Financial Sustainability

The pilot-to-collapse cycle is fundamentally a financial sustainability failure: digital systems deployed through bounded donor funding lack the domestic financing for sustained operation after donor withdrawal. HIDTF's financial sustainability strategy begins in Phase 1 with advocacy for a dedicated Ministry of Health HIS budget line, engagement of the National Health Insurance Authority on EHR integration costs, and development of public-private partnership models for technology maintenance. The medium-term target is domestic financing covering at least 60% of HIS operational costs. Maintenance costs, software updates, hardware replacement cycles, and

connectivity fees must be projected and budgeted from Phase 1 planning. Donor withdrawal scenarios — partial and complete — should be modelled with contingency financing provisions embedded in the national digital health governance framework.

9.2 Workforce Sustainability

Workforce sustainability requires addressing both supply and retention of digitally competent health workers. HIDTF's integration of digital health competencies into pre-service training at all health professional institutions — from community health worker training to medical school curricula — ensures that the incoming workforce is equipped for digital health practice without dependence on in-service training for fundamental competencies. Retention strategies must address the digital literacy premium rendering trained health informatics staff vulnerable to NGO sector absorption: salary supplementation, career pathway development, and institutional recognition for digital health champions are necessary components that HIDTF Phase 4 embeds institutionally.

9.3 Technological Sustainability

Technological sustainability requires adoption of open-source platforms (OpenMRS, DHIS2, OpenHIE) not dependent on commercial licensing fees or vendor continuity; domestically hosted infrastructure eliminating reliance on international cloud vendors for EHR data access; local IT support capacity capable of hardware maintenance and software updates without international technical assistance; and software upgrade governance protocols maintaining system functionality without creating upgrade-dependent technical debt. The technology refresh cycle — hardware lifecycle of three to five years, software update cycles — must be budgeted within the domestic HIS financing framework from Phase 1.

9.4 Governance Sustainability

Governance sustainability requires that the National Digital Health Governance Coordination Body's legal authority, funding, and mandate survive political cycles and post-election policy changes. This requires constitutional or legislative entrenchment of the governance body's mandate beyond individual ministerial commitment; transparent public accountability mechanisms generating civil society oversight; and regional integration through ECOWAS peer-learning networks creating international accountability for Liberia's digital health governance commitments. Institutional ownership of the national EHR architecture by the Ministry of Health — rather than any donor or NGO partner — must be legally and contractually established from the earliest implementation phase, with data sovereignty provisions ensuring that patient data remains under national institutional control regardless of technical partnership arrangements.

10. Policy Implications for Liberia and Similar LMICs

10.1 Digital Health Governance

The Ministry of Health must establish the National Digital Health Governance Coordination Body by legislative instrument with clear statutory authority, cross-sectoral representation, and a dedicated secretariat. Digital health governance must be treated as a health system governance

function — not an informatics project — with commensurate political priority and budget allocation. County-level digital health coordination capacity must be embedded within county health team structures with defined accountability relationships to national governance architecture.

10.2 Interoperability Standards

HL7 FHIR compliance must be mandated as a condition of operation for all digital health systems deployed in Liberia's health system, including donor-funded programmes, without exception or waiver. Interoperability enforcement requires a technically competent governance body empowered to reject non-compliant systems — not merely issue guidance. All technology procurement processes for health system digital tools must include FHIR compliance as a mandatory technical specification.

10.3 Sustainable Financing

Domestic government budget allocation for health information system operation and maintenance must be established as a recurrent budget line, not a project-specific expenditure. Health insurance reform should integrate EHR-based billing and data requirements, creating institutional alignment between health financing reform and digital health implementation. Public-private partnerships for technology maintenance should be developed with contractual provisions for technology transfer and domestic capacity development.

10.4 Workforce Development

Digital health competencies should be integrated into the training curriculum of all health professional cadres, from community health workers through medical school graduates. A national health informatics specialist cadre — including EHR system administrators, HIE technical managers, and data quality officers — should be established as a recognized government employment category with defined salary scales, career pathways, and retention incentives.

10.5 Public-Private Partnerships

Technology partnerships should require data sovereignty provisions ensuring national institutional ownership of patient data; open-source platform commitments preventing vendor lock-in; long-term technical support contracts extending beyond project funding cycles; technology transfer obligations building domestic maintenance capacity; and participation in the national governance coordination framework. Mobile network operators should be engaged for rural connectivity expansion with regulatory incentives for extending affordable mobile data to health facility locations.

10.6 County-Level Implementation Structures

Digital health implementation must be governed at county level through dedicated county digital health coordination structures with authority to conduct readiness assessments, manage county-level implementation, and escalate technical and governance problems to national level. HIDTF readiness criteria should be applied at county level to determine implementation sequencing, with no county bypassing readiness assessment on the basis of political visibility or donor preference.

10.7 Data Governance

A national health data privacy and cybersecurity regulatory framework must be enacted specifying patient data rights, institutional stewardship obligations, breach notification requirements, and enforcement mechanisms. Data sovereignty — the principle that Liberian patient data is governed by Liberian institutions under Liberian law — must be embedded in all technology partnership agreements. Community trust in digital health systems must be built through transparent communication about data use and culturally appropriate privacy protection measures.

10.8 Implications for Other LMICs

The HIDTF's conceptual architecture is transferable to analogous fragile and resource-constrained health systems facing similar intersections of post-conflict reconstruction, donor dependency, infrastructure constraints, and EHR implementation failure. Sierra Leone, South Sudan, the Central African Republic, and the Democratic Republic of Congo share structural conditions with Liberia that render conventional digital health implementation models equally inappropriate. HIDTF offers these contexts a theoretically grounded alternative centring governance reform, resilience, phased transition, and hybrid workflow legitimization. Regional adaptation will require contextual modification of phase timelines, governance body configurations, and interoperability standards adoption sequences — but the framework's foundational premises and sequencing logic are generalized to the structural conditions these contexts share.

11. Discussion

11.1 Interpreting the Findings: Recursive Implementation Failure as a Structural Dynamic

This paper advances three analytical contributions that collectively address what the existing literature has described but not explained. Consider what two decades of digital health implementation reviews have produced: Heeks (2006) identified the design-reality gap; Fraser and colleagues (2005) catalogued infrastructure and training barriers; Fritz and colleagues (2015) synthesized success criteria across low-resource EHR implementations. Each is analytically rigorous. None explains why the same barriers recur across successive implementation cycles in the same countries, why documenting them does not interrupt the failure pattern, or why institutional conditions deteriorate rather than improve with each attempt. The literature knows what the barriers are. It does not know why the system that produces them is self-sustaining. The first contribution of this paper is the concept of recursive implementation failure as a structural dynamic: each failed intervention depletes absorptive capacity without disrupting the structural couplings between governance fragmentation, donor dependency, and interoperability failure, generating a ratchet effect of progressive institutional hardening. This is not a restatement of barriers — it is an explanation of the system that reproduces them.

The mechanism-based analysis presented here explains this precisely: the barriers constitute a mutually reinforcing system, and the system is recursive because each failed intervention depletes absorptive capacity without disrupting the structural coupling between governance fragmentation, donor dependency, and interoperability failure. The ratchet effect — progressive institutional hardening against digital adoption — is not incidental but is the predictable

consequence of a system in which the incentive structures governing implementation are misaligned with sustainability outcomes.

11.2 Theoretical Contribution: Reliability Asymmetry and Hybrid Legitimacy

The second contribution is the reliability asymmetry concept as an analytical reframing of what the literature has consistently misdiagnosed. The standard framing — visible in CFIR's inner-setting constructs, NPT's cognitive participation mechanism, and diffusion theory's compatibility attribute — treats health worker maintenance of paper systems as a barrier: as resistance, inadequate training, or insufficient organizational readiness. This framing generates implementation responses of more training, more change management, and stronger normalization investment. The reframing offered here is different in kind, not in degree: under Liberian operating conditions, paper genuinely outperforms digital systems. Health worker behaviour is not a problem to correct but information about the operating environment. The correct implementation response is not to overcome the behaviour but to design systems that accommodate it — governing hybrid paper-digital coexistence as a legitimate, designed steady state rather than treating it as a transitional deficiency. This reframing has direct prescriptive consequences. It produces HIDTF's hybrid legitimacy premise — a design principle that no existing framework explicitly generates — and it explains why implementation approaches premised on overcoming health worker resistance are structurally misaligned with fragile-state operating realities regardless of their technical quality.

11.3 Political Economy Analysis: Why Failure Persists Despite Documentation

The third contribution is the political economy analysis of implementation persistence — an explanatory register that implementation science frameworks have largely avoided. CFIR, NPT, and NASSS treat implementation failure as a diagnostic problem: identify barriers, design responses, improve outcomes. This assumes that implementing organizations want sustainability and are failing to achieve it. The political economy analysis offered here questions that assumption. Donor organizations are not uninformed about the pilot-to-collapse cycle; they are embedded in incentive systems that make collapse structurally predictable. Output-based accountability, short budget cycles, and inter-donor competition for visibility are not individual failures of commitment — they are institutional features that make sustained domestic ownership incompatible with standard donor programme architecture. This has a direct prescriptive implication that barrier-focused implementation science has not generated: changing implementation outcomes requires changing institutional incentive structures, not improving technical quality within unchanged incentive systems. HIDTF's governance architecture responds to this specifically — not by appealing to donor goodwill, but by creating a national coordination body with statutory enforcement authority that makes compliance with national standards obligatory and non-compliance institutionally costly.

11.4 Comparison with Existing Frameworks

HIDTF's comparison with CFIR, NPT, and NASSS is detailed in Table 3 and in Section 5.1. The critical comparative insight is that HIDTF does not supplement existing frameworks' diagnostics — it provides the operational pathway that those diagnostics imply but do not specify. CFIR

identifies governance as a critical outer-setting factor but provides no governance architecture roadmap. NPT identifies normalization mechanisms but no pathway for building their preconditions where these are structurally absent. NASSS predicts non-adoption with precision but provides no operational alternative for fragile-state contexts. HIDTF fills this collective prescriptive gap. The framework should be understood as complementing, not replacing, existing frameworks: CFIR, NPT, and NASSS retain diagnostic value for implementation determinant assessment, normalization monitoring, and complexity mapping — functions that HIDTF's empirical validation phases will require.

11.5 Implications for Implementation Science

The HIDTF's theoretical contribution to implementation science extends beyond Liberia and digital health. The recursive failure concept offers a generalizable analytical lens for understanding persistent implementation failure in complex adaptive systems where barriers are structurally coupled, failed interventions deplete rather than restore institutional capacity, and conventional barrier-removal strategies consistently fail to produce durable outcomes. This applies beyond digital health: persistent implementation failure in vaccination programmes, community health worker scale-up, and supply chain modernization in fragile health systems may reflect analogous recursive dynamics.

The HIDTF provides a diagnostic template for identifying whether failure is recursive rather than merely persistent, and for designing systems-level interventions targeting the structural couplings generating recursion. The framework's governance-first, phased, readiness-conditioned approach represents a distinct implementation logic — one that prioritizes institutional precondition-building over technology deployment — applicable across implementation domains in fragile and resource-constrained health systems.

11.6 Implications for Liberia and Fragile Health Systems

For Liberia, the HIDTF's most fundamental implication is the inversion of prevailing implementation logic: governance, infrastructure, and workforce preconditions must be established before technology deployment, not developed in parallel with or after it. This inversion requires political commitment to deferred gratification — investing in eighteen months of governance architecture development before any technology deployment occurs — that donor accountability frameworks and political cycles currently discourage. Making the case for this investment requires demonstrating that the cost of continued implementation failure exceeds the cost of front-loaded governance reform.

For other fragile health systems, HIDTF offers an implementation framework that explicitly accounts for the political economy of donor-funded implementation, the structural consequences of post-conflict institutional fragility, and the genuine resilience value of hybrid paper-digital workflows. The framework's recognition that digital health transformation is a public health intervention — with measurable consequences for continuity of care, patient safety, outbreak response, and health equity — reframes the political case for sustained investment and provides the outcome linkages necessary to engage ministries of finance and health insurance authorities as implementation partners.

11.7 Limitations of the Analysis

The political economy analysis presented here risks overstating the uniformity of donor behaviour: some donor organizations have adopted country-ownership principles, support government-led implementation, and invest in domestic capacity building. The argument is not that all donors always reproduce fragmentation but that the structural incentive architecture of donor-funded implementation tilts implementation logic toward the pilot-to-collapse pattern — and individual commitment to national ownership is insufficient without a national governance authority capable of specifying and enforcing what alignment means technically.

12. Limitations

This paper is subject to several limitations that should inform interpretation and application of its findings.

As a conceptual implementation science paper, the analysis is not based on primary empirical data from Liberia but synthesizes available peer-reviewed literature, grey literature, WHO reports, and country-specific health system data. Liberia-specific peer-reviewed research on EHR implementation is limited, requiring reliance on the broader LMIC literature and careful extrapolation from analogous contexts. Empirical validation of the HIDTF through prospective implementation research in Liberia is essential before the framework's prescriptive recommendations can be applied with full confidence.

The HIDTF has not been developed through formal stakeholder co-design processes involving Liberian health workers, Ministry of Health officials, donor representatives, or county health teams. The framework reflects conceptual analysis of documented structural conditions rather than participatory stakeholder validation. Delphi consensus methods engaging Liberian implementation science and digital health expertise would strengthen the framework's contextual grounding and stakeholder legitimacy.

The paper's theoretical synthesis integrates frameworks developed in diverse epistemological traditions and institutional contexts. The coherence of theoretical integration reflects conceptual judgment rather than empirical synthesis, and alternative theoretical framings might generate different analytical conclusions. The paper's theoretical architecture should be understood as one analytically coherent interpretation of available evidence, not as the exclusive framework for understanding digital health in fragile health systems.

The paper necessarily generalizes about Liberia's health system context, which encompasses significant intra-national variation across counties, facility levels, and health system actors. The framework's readiness criteria architecture in Phase 3 is designed to accommodate this variation, but the national-level analysis cannot fully capture the contextual specificity that implementation will require at facility and county levels.

Rapidly evolving digital health technologies — including low-earth orbit satellite connectivity, AI-assisted EHR, and distributed data governance architectures — may shift the technical constraints informing some HIDTF design specifications. The framework should be understood as a conceptual architecture requiring iterative technical updating as technological conditions and the evidence base evolve.

The context-specific assumptions embedded in the HIDTF — including Liberia's particular donor dependency, governance fragmentation dynamics, and post-conflict institutional conditions — limit direct transferability to contexts with different structural profiles, even within the fragile-state category. Cross-country adaptation requires systematic contextual alignment assessment before application.

13. Future Directions

Several research directions would substantially strengthen the evidence base for HIDTF and for digital health implementation in fragile health systems more broadly.

Pilot implementation studies represent the highest priority: prospective mixed-methods evaluation of HIDTF Phase 1 and Phase 2 activities at a defined set of Liberian health facilities would generate the empirical evidence base needed to validate, refine, and operationalize the framework's prescriptions. Such studies should employ implementation science frameworks for measurement, including CFIR-based determinant assessment, NPT normalization mapping, and outcome measures spanning adoption, fidelity, sustainability, and health impact.

Delphi consensus validation engaging Liberian and broader sub-Saharan African digital health expertise — including implementation practitioners, Ministry of Health officials, donor representatives, health worker union leaders, and implementation science researchers — would strengthen HIDTF's contextual validity and generate the stakeholder legitimacy that conceptual frameworks developed without primary consultation require.

Stakeholder co-design processes involving Liberian health workers in framework refinement — particularly in developing readiness criteria, digital health champion competency frameworks, and hybrid workflow protocols — would address the participatory design gap that the current conceptual development process necessarily leaves.

Cost-effectiveness analysis of HIDTF implementation compared with conventional digital health deployment models would generate the economic evidence base needed to justify front-loaded governance investment and make the case for multi-cycle donor commitment.

Cross-country validation studies examining HIDTF applicability in other post-conflict, donor-dependent health systems — Sierra Leone, South Sudan, the Central African Republic — would generate the comparative evidence needed to assess the framework's generalizability and specify contextual conditions determining which elements transfer directly and which require adaptation.

Longitudinal implementation research tracking the institutional consequences of recursive implementation failure — measuring implementation fatigue, absorptive capacity depletion, and organizational trust dynamics across successive implementation cycles — would provide the empirical foundation for the recursive failure concept that this paper develops theoretically but has not yet been validated at scale.

14. Conclusion

Digital health implementation in Liberia has failed repeatedly — not because of inadequate technology, insufficient ambition, or lack of investment, but because three self-reinforcing mechanisms have remained unaddressed. Recursive implementation failure means each

unsuccessful attempt worsens the institutional conditions for the next, generating a compounding ratchet effect that cannot be interrupted by single-domain interventions however well-designed. Reliability asymmetry means that under Liberian operating conditions paper genuinely outperforms digital systems, so health worker maintenance of paper is rational professional judgment rather than resistance — and treating it as resistance produces implementation strategies that are structurally misaligned with the environment they are meant to change. The political economy of donor dependency means the pilot-to-collapse cycle is not a technical failure but a structurally predictable consequence of incentive systems that reward deployment activity over sustainability outcomes — systems that no amount of technical quality improvement will alter. These three mechanisms interact: the political economy of donors reproduces governance fragmentation; governance fragmentation enables interoperability failure; infrastructure unreliability generates reliability asymmetry; each failed cycle deepens recursive failure. Together, they constitute a self-sustaining system that barrier-focused implementation approaches cannot disrupt.

Existing implementation frameworks — CFIR, NPT, NASSS — diagnose the components of this cycle with analytical precision but converge on no operational pathway for governing the transition from paper-based to digital health practice in fragile, post-conflict, donor-dependent health systems. They are diagnostic where Liberia requires prescriptive guidance; they identify what normalization needs without specifying how to build its structural preconditions; and they provide no logic for governing prolonged hybrid paper-digital coexistence as a legitimate resilience strategy. This prescriptive gap is what HIDTF fills.

HIDTF explains why digital health implementation repeatedly fails in resource-constrained health systems and proposes a phased, readiness-based pathway for overcoming those failures through sustainable digital transformation. By establishing governance architecture, infrastructure stability, and workforce competency as sequenced preconditions for technology deployment; by legitimizing hybrid paper-digital workflows as designed resilience rather than transitional deficiency; by embedding interoperability enforcement authority in governance architecture before any technology is deployed; and by integrating domestic sustainability financing from Phase 1 rather than treating it as a post-implementation consideration — the HIDTF offers a theoretically grounded, practically oriented alternative to the technology-first models that have consistently failed.

Digital health transformation in Liberia is not an administrative reform. It is a public health intervention with direct consequences for continuity of care, patient safety, disease surveillance, antimicrobial resistance monitoring, maternal and child health outcomes, service quality, and health equity. The Ebola epidemic demonstrated, at catastrophic cost, what the absence of interoperable health information infrastructure means for population health security. The HIDTF provides an evidence-informed, implementation-science-grounded pathway for building that infrastructure sustainably — not as a technological aspiration, but as a health system governance imperative.

Empirical validation through prospective pilot implementation, stakeholder co-design, and cross-country comparative research remains essential. No conceptual framework — however analytically rigorous — substitutes for the implementation knowledge generated through systematic empirical engagement with Liberian health system realities. The HIDTF is offered as

a theoretically grounded starting point for that empirical journey, and as a contribution to the implementation science knowledge base supporting digital health transformation in fragile and resource-constrained health systems globally.

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Conflict of Interest

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