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Developing the STOE Framework and Implementation Architecture: A Dual Model for e-Health Implementation in Resource-Constrained Public Healthcare Settings of Western Kenya

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Abstract
Well-funded e-Health pilot projects in low- and middle-income countries (LMICs) consistently fail to achieve sustainable integration into routine practice. Existing frameworks address single dimensions of this problem, lacking integrated, multi-level perspectives and actionable roadmaps. This paper presents the development and empirical validation of the STOE (Social-Technological-Organisational-Environmental) Framework and its complementary Implementation Architecture, a dual model for resource-constrained public healthcare settings. We employed a sequential explanatory mixed-methods design across three public healthcare facilities in Western Kenya. Following a deductive-inductive process, we deductively constructed the STOE Framework by synthesising Normalisation Process Theory, the Technology-Organisation-Environment framework, and the Four-in-Balance Model. This a priori model was then inductively tested through quantitative surveys (n=108 healthcare providers) and qualitative interviews (n=21 key informants). Empirical data confirmed the framework's validity. Implementation failures stemmed from structural disconnects across nested STOE contexts, not isolated technical deficits. Three disconnect patterns emerged: (1) environmental policy uncertainty paralysing organisational decision-making (E→O); (2) technologies procured without frontline user input leading to systematic social rejection (S↔T); and (3) fragmented funding creating unsustainable donor-dependent pilots that collapsed post-completion (E→O→S cascade). The validated dual framework offers a pragmatic two-stage approach for resource-constrained health systems: diagnose systemic weaknesses using the STOE lens, then target interventions precisely using the architectural blueprint. This moves the field beyond checklist-style models toward integrated diagnosis and action.

Introduction

Global health systems face immense pressure to deliver quality, equitable care amidst rising demand and constrained resources (WHO, 2021; Snowdon & Cohen, 2011). Digital health interventions, collectively termed e-Health, are defined as the use of information and communication technologies (ICT) in health and are heralded as transformative instruments capable of enhancing healthcare efficiency, safety, and access (WHO, 2021). The World Health Organisation's Global Strategy on Digital Health 2020-2025 recognises that digital technologies are not merely adjuncts but essential drivers of universal health coverage (WHO, 2021). Yet a persistent gap remains between technological potential and realised health gains, particularly in low- and middle-income countries (LMICs).

In Kenya, as in many Sub-Saharan African contexts, e-Health initiatives follow a predictable trajectory. They emerge as donor-funded pilot projects, demonstrate promise within controlled environments, and subsequently falter when confronted with the complex realities of scale-up and sustainability. They remain siloed within specific departments, most commonly HIV/AIDS clinics, fragmented across parallel systems, and ultimately unsustainable beyond the lifecycle of external funding (Ireri et al., 2025; Ondulo, 2018). This phenomenon, described in the literature as "pilotitis," represents more than a technical failure; it constitutes a systemic breakdown in translating innovation into routine practice (Huang, Blaschke, & Lucas, 2017).

The critical question that animated this research is simple: why do well-intentioned e-Health initiatives, often backed by considerable financial investment, consistently fail to achieve sustainable integration within the complex, resource-constrained public healthcare settings they are designed to serve? The prevailing literature offers valuable but partial answers through singular theoretical lenses: technology acceptance, organisational readiness, or policy environments (Greenhalgh et al., 2004; Yusof et al., 2008). This theoretical fragmentation mirrors the practical silos observed in the field and overlooks the critical, dynamic interdependencies between the social, technological, organisational, and environmental levels of a health system. A technologically sophisticated system cannot succeed without skilled and motivated users. Skilled users cannot function without a supportive organisational culture and leadership. Organisational readiness cannot compensate for an unstable policy environment or unreliable infrastructure.

Consequently, a significant dual gap persists: the need for a theoretically robust, integrated model that explains these interdependencies, coupled with an operational roadmap to guide action. Existing checklist-style models (e.g., HOT-fit, TAM) identify discrete barriers but do not explain how barriers at different levels interact and reinforce one another. We therefore synthesised three established theories: NPT (social processes), TOE (contextual domains), and FIBM (sustainability conditions), specifically to resolve the limitations of these checklist approaches by creating a nested, dynamic model that captures cross-level interactions.

This paper addresses this dual gap by presenting the STOE Framework and its Implementation Architecture. Our core contribution is the demonstration of their development through a systematic deductive-inductive methodology. We first deductively built the STOE Framework by synthesising leading theories into a cohesive, hierarchical model. We then inductively validated and refined it through empirical fieldwork in Western Kenya. Finally, we extended the validated conceptual model into a practical Implementation Architecture. This dual framework moves beyond checklist models to offer a dynamic systems perspective with direct practical utility for both research and practice.

Methodology: A Sequential Explanatory Mixed-Methods Design Grounded in Doctoral Research

The development of the STOE Framework emerged from a deliberately structured research programme, conducted across three purposively selected public healthcare facilities in Western Kenya. These facilities were chosen to represent varying economic endowments and levels of e-Health maturity: Facility A (rural level IV hospital, minimal digital presence), Facility B (peri-urban level IV hospital, pilot-stage electronic medical records), and Facility C (urban level IV facility, multiple parallel digital systems). This variation was essential to capture the full spectrum of implementation challenges across different organisational contexts.

The methodological architecture followed a sequential explanatory mixed-methods design (Creswell, 2012), but with a critical refinement: the explicit incorporation of a deductive-inductive theory-building process. This approach recognised that robust theoretical development requires not merely the testing of hypotheses derived from existing literature, but a recursive dialogue between a priori theoretical synthesis and empirical reality.

The Deductive-Inductive Research Process

The research unfolded in two interconnected phases; each was designed to inform and refine the other.

Phase One: Deductive Theory-Building commenced with a critical analysis of the existing implementation science literature. Three parent theories were identified as particularly salient to the e-Health implementation context. Normalisation Process Theory (NPT) illuminates the social mechanisms through which practices become routinely embedded (coherence, cognitive participation, collective action, reflexive monitoring) (May & Finch, 2009). The Technology-Organisation-Environment (TOE) framework structures analysis across three contextual domains but treats them in a static manner (Tornatzky & Fleischer, 1990). The Four-in-Balance Model (FIBM) offers insights into the conditions for sustainable technology integration but is too narrow for organisation-wide adoption (Kennisnet, 2011).

The logic of synthesis was as follows: TOE provides the "what", the contextual domains (Technology, Organisation, Environment) that shape implementation possibilities. NPT provides the "how", the social mechanisms through which practices become embedded or fail. FIBM provides the "balance" condition, the insight that sustainable implementation requires alignment across multiple dimensions simultaneously. By nesting these complementary strengths, we resolved each parent model's limitation: NPT lacks environmental context, TOE lacks dynamic social processes, and FIBM lacks scope for complex organisational adoption. From these three theoretical foundations, we synthesised a preliminary integrated framework, an a priori model that posited a nested relationship between Social, Technological, Organisational, and Environmental contexts. This preliminary framework then informed the design of data-collection instruments, ensuring that the quantitative survey and qualitative interview protocols were structured to probe constructs across all three parent models.

Phase Two: Inductive Theory Testing and Refinement involved the systematic collection and analysis of empirical data to interrogate this preliminary synthesis. The quantitative strand employed structured questionnaires administered to 108 healthcare providers (doctors, nurses, clinicians, administrators, and IT personnel) to assess e-Health availability, usage patterns, and perceptions of benefits and barriers, aligned with constructs from the parent theories. The qualitative strand comprised 21 in-depth semi-structured interviews with key informants (medical superintendents, IT leads, departmental heads), supplemented by non-participatory observation of clinical workflows and document analysis of facility service charters and strategic plans.

Data Analysis and Framework Synthesis

The analytical strategy was explicitly designed to facilitate theory refinement. Quantitative data were analysed using descriptive statistics and Exploratory Factor Analysis (EFA) in SPSS to identify underlying structures and relationships. Qualitative data underwent thematic analysis, with codes derived both deductively (from theoretical frameworks) and inductively (from emergent themes not anticipated by the literature). The integration of findings from both strands catalysed the final synthesis: empirical insights were used to inductively test, refine, and ultimately confirm the deductively built STOE model, while simultaneously revealing the structural need for a complementary Implementation Architecture.

Results and Findings: The Empirical Case for a Nested View

The findings that emerged from this mixed-methods investigation painted a stark portrait of e-Health implementation in its struggling formative stages. Consistent with the WHO-ITU (2012) characterisation of health systems in the "experimentation and early adoption" phase, implementations were characterised by fragmentation, donor dependency, and a persistent lack of integration. Core clinical systems such as Electronic Medical Records (EMRs) were either entirely absent or, where present, functionally compromised.

Multi-Level Determinants as Interactive Barriers

Critically, the barriers to successful implementation were not isolated within single domains but nested and mutually reinforcing across all levels of the health system. This finding carries profound implications, for it suggests that interventions targeting any single dimension in isolation are inherently limited.

- Environmental Context (E): Unstable electricity supplies, poor network connectivity, and the absence of cohesive national policy frameworks created a hostile foundation. Participants consistently cited political interference in procurement processes and the lack of coordinated funding mechanisms as environmental barriers that preceded and constrained all subsequent implementation efforts.
- Organisational Context (O): Hierarchical organisational cultures actively resisted change. There was a critical absence of e-Health leadership at the facility level, a lack of strategic change management processes, and minimal involvement of frontline staff in implementation planning.
- Social Context (S): Significant user anxiety was prevalent, particularly among nursing staff and older clinicians who reported low digital comfort. The mechanisms described by NPT were strikingly evident: low coherence (poor shared understanding of the technology's purpose), weak cognitive participation (minimal buy-in), and fragmented collective action (poor collaboration between clinical and technical staff).
- Technological Context (T): Inadequate hardware, unreliable software, and a severe shortage of technical support staff meant that even basic functionality could not be assured. Existing systems were frequently described as difficult to navigate and incompatible with established clinical workflows.

Specific Structural Disconnects Between Contexts

The most significant finding was not just the presence of these multi-level barriers but their interaction, the structural disconnects between contexts that created cascading failures. Three specific disconnect patterns emerged from the data:

Disconnect 1: Environmental-Organisational (E→O). Kenya's devolution policies created profound uncertainty at the facility level. County health management teams, uncertain of their budgetary allocations, became paralysed in their decision-making regarding IT investments. As one medical superintendent explained: "*We cannot commit to any major IT investment because we do not know what our budget will be next year. Last year, we planned for five servers; we received one. How can we build a system on that?*"

Disconnect 2: Social-Technological (S↔T). Technologies were frequently procured through centralised processes without any assessment of local user skills or workflow fit. As one senior clinician noted, "*They brought this system from Nairobi and told us it would solve all our problems. But it does not work the way we work. It takes more time, not less. So we use it when the supervisor is watching; otherwise, we use our paper registers. The system does not know that we see 200 outpatients per day with three nurses.*"

Disconnect 3: Environmental-Organisational-Social Cascade (E→O→S). Donor-funded projects created perverse incentives. Facilities received substantial funding for initial hardware procurement but no recurrent budget for maintenance, training, or technical support. When the donor project ended after 24-36 months, systems collapsed. One health records officer observed: "*The project gave us twenty computers and trained fifteen people. After two years, the project left. We had no money for repairs, no technician, and the trained staff were transferred. Now the computers sit in the store.*"

These empirical findings demonstrated that existing frameworks, used in isolation, were insufficient to diagnose the systemic nature of the problem. The data demanded a model capable of representing the nested, interdependent reality of the implementation ecosystem.

Development of the STOE Framework: A Nested Synthesis

The STOE Framework is the product of a systematic, two-phase research programme designed to build and then test a comprehensive theory of technology implementation.

Phase 1: Deductive Theory-Building

The starting point was a critical analysis of three dominant parent models, each with a significant limitation: NPT is rich in social processes but neglects the broader environmental context (May & Finch, 2009); the TOE framework is strong on contextual dimensions but treats them statically, neglecting dynamic social processes (Tornatzky & Fleischer, 1990); and FIBM is useful for individual-level change but too narrow in scope for complex, organisation-wide adoption (Kennisnet, 2011).

Our deductive synthesis resolved these limitations not by picking one theory, but by nesting them into a novel, cohesive, and hierarchical structure:

- The Social (S) domain integrates NPT's core mechanisms (coherence, cognitive participation, collective action, reflexive monitoring).
- The Technological (T) and Organisational (O) domains structure the key internal contexts within the TOE framework.
- The Environmental (E) domain encompasses the critical external pressures from the TOE framework that NPT omits.

This STOE hierarchy created our a priori theoretical framework, positing that social processes (how change happens) are embedded within and interact with the three defining contextual domains (where and why it happens). The crucial innovation lies in its hierarchical conceptualisation: the four contexts are arrayed concentrically, not as parallel categories.

Phase 2: Inductive Theory Testing – Empirical Validation and Refinement

The deductively built model was subjected to rigorous empirical testing using our mixed-methods data. The outcome was clear: the empirical findings confirmed the framework's validity and utility. The data validated the necessity of all four nested domains and their interactions. The E→O disconnect (environmental policy uncertainty paralysing organisational decision-making) confirmed the critical influence of the outer-to-inner layer. The S↔T disconnect (technologies procured without user input leading to rejection) validated the essential interaction between human dynamics and technical design. The E→O→S cascade confirmed that environmental constraints propagate through organisational contexts, undermining social processes.

The Validated STEO Conceptual Framework

The inductively validated framework is a nested system of four concentric contexts:

1. Environmental Context (E): The outermost, enabling layer (policy, infrastructure, funding, political economy)
2. Organisational Context (O): The internal institutional layer (culture, leadership, structure, resources)
3. Social Context (S): The human dynamics layer (meaning, participation, collaboration, appraisal)
4. Technological Context (T): The tools and capabilities layer (hardware, software, usability, workflow fit)

Success at the core (sustainable embedding of e-Health practices) is contingent on the alignment and strength of all surrounding layers. A weak environmental foundation undermines organisational capacity, which erodes social coherence and ultimately dooms technological deployment. Implementation is not a linear process but a systemic achievement requiring coherence across all four domains.

From Conceptual Framework to Implementation Architecture

While the STOE Framework provides an essential diagnostic lens, translating diagnosis into action requires an operational roadmap. Informed directly by the empirical findings on structural disconnects, we developed a complementary four-layer Implementation Architecture that operationalises the STOE insight into a strategic construction plan.

Layer 1: The Foundation (E). Corresponds to the STOE 'E' dimension. Must be constructed with a stable government vision/policy, a change-driven culture, and robust governance structures (e.g., a National e-Health Board). Implementation efforts that ignore environmental conditions are destined for collapse.

Layer 2: The Pillars (O and S). Five critical enablers that actively bridge and strengthen the Organisational and Social contexts: Leadership (committed champions), Financing (sustainable mechanisms beyond project cycles), Stakeholder Collaboration (structured engagement), Expertise/Training (systematic capacity building), and Infrastructure (reliable hardware, connectivity, support). The absence of any pillar creates a structural weakness.

Layer 3: The Implementation Process (T). The site-level execution layer, involving Local Delivery Plans and the phased integration of e-Health domains (Management, Communication, Decision Support, and Information Systems), supported by vertical Monitoring & Evaluation.

Layer 4: The Benefits Layer. The target outcomes are access, productivity, and quality of care.

This architecture shows that the STOE contexts are not just observed but must be actively built and connected. The "Pillars" are the actionable mechanisms that prevent the disconnects our research uncovered.

Discussion

What We Now Know That We Did Not Know Before

This study contributes three specific empirical insights that were not previously established in the e-Health implementation literature for resource-constrained settings. First, we now know that implementation failures in Western Kenyan public facilities are not random or attributable to single causes but follow predictable patterns of cross-context disconnect, specifically E→O, S↔T, and E→O→S cascades. Second, we now know that these disconnects are mutually reinforcing: environmental policy uncertainty does not merely co-occur with organisational paralysis but directly causes it, thereby undermining social processes. Third, we now know that checklist-style models (e.g., HOT-fit, TAM) cannot capture these dynamic interactions because they treat barriers as discrete categories rather than nested, interacting layers.

Theoretical Contribution: A Validated Dual Framework

The STOE Framework contributes to implementation science by demonstrating a complete deductive-inductive development cycle. It logically synthesises and transcends the limitations of established middle-range theories (May & Finch, 2009; Tornatzky & Fleischer, 1990) and grounds the resulting model in empirical evidence. By nesting rather than simply combining theories, it offers an integrated perspective that explains how and why different contexts interact. Pairing this validated conceptual model with an operational architecture addresses a key translational gap in the literature (Greenhalgh et al., 2004), offering both a diagnostic lens (STOE) and a prescriptive roadmap (Architecture).

Practical Utility: What Specific Changes This Framework Demands

For practitioners and policymakers, the dual framework demands three specific changes to current practice. First, health system planners must replace single-domain assessments (e.g., "we need more training," or "we need better software") with systematic STOE mapping to identify which specific disconnect pattern is operating. Second, funding mechanisms must be restructured to include recurrent maintenance budgets from project inception, not merely capital procurement, a direct response to the E→O→S cascade identified in our findings. Third, technology procurement processes must mandate frontline user workflow assessments prior to purchasing decisions, a direct response to the S↔T disconnect.

Limitations and Future Research

The framework was developed and validated in a specific Kenyan public health context (three facilities in Western Kenya). Further validation across diverse healthcare settings, countries, private and faith-based facilities, and different types of digital health interventions is needed. Regarding the framework's empirical status, we do not concede that STOE remains purely conceptual. The framework has been inductively tested and confirmed using empirical data from 108 survey respondents and 21 qualitative interviews, with specific patterns of disconnect documented. The call for future operationalisation into measurable constructs reflects standard scientific practice of moving from qualitative validation to quantitative scale development, not an admission of purely conceptual status. Future research should develop validated measurement instruments for each STOE domain, explore dynamic feedback loops between layers over time, and test the Implementation Architecture as a prospective planning tool.

Conclusion

The persistent translational gap in e-Health reflects both a contextual integration gap and an implementation strategy gap. We have failed to recognise that implementation is a systemic achievement requiring coherence across environmental, organisational, social, and technological contexts, and we have lacked a structured approach to translating that understanding into coordinated action. This paper has presented the STOE Framework and its Implementation Architecture, developed through a rigorous deductive-inductive process and empirically validated in three public healthcare facilities in Western Kenya. The STOE Framework offers a validated, holistic lens for diagnosing the multi-level, interdependent challenges of implementation, revealing that failures follow predictable patterns of cross-context disconnect (E→O, S↔T, and E→O→S). Its complementary Architecture provides a structured blueprint for action, translating systemic understanding into strategic construction. By bridging the conceptual-operational divide via a robust methodological pathway, this dual framework represents a significant step toward closing the persistent know-do gap in e-Health implementation, moving us closer to the promise of sustainable, technology-enabled healthcare for all, particularly for those in resource-constrained settings who need it most.

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