

Affordable Health Technology in Sub-Saharan Africa: Lessons and Opportunities for Sustainable Healthcare Delivery

Melkamu Hunegnaw Asmare, Lucca Geurts

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Affordable Health Technology in Sub-Saharan Africa: Lessons and Opportunities for Sustainable Healthcare Delivery

Melkamu Hunegnaw Asmare^{1*} PhD; Lucca Geurts^{2*} PhD

¹13 Andreas Vesaliusstraat Leuven Center for Affordable Health Technology KU Leuven LEUVEN BE

²13 Andreas Vesaliusstraat eMedia Research Lab, Human-Computer Interaction KU Leuven LEUVEN BE

*these authors contributed equally

Corresponding Author:

Melkamu Hunegnaw Asmare PhD

13 Andreas Vesaliusstraat

Leuven Center for Affordable Health Technology

KU Leuven

Andreas Vesaliusstraat 13 - box 2600

LEUVEN

BE

Abstract

Background: Sub-Saharan Africa (SSA) continues to grapple with severe healthcare disparities, including high disease burdens, insufficient medical personnel, and fragmented infrastructures. Although modern technologies promise transformative potential, high costs and mismatched solutions often limit their viability in low-resource environments.

Objective: This study addresses how “affordable health technology” can serve as a catalyst for improving access, reducing costs, and enhancing care quality in SSA.

Methods: Employing a narrative literature review, we synthesized insights from academic publications, policy documents, technical reports, and illustrative case studies. We examined on technology-driven interventions across telemedicine, mobile health, supply-chain optimization, micro-insurance platforms, health-related e-learning, electronic medical records, 3D printing, and medical automation. We also identified common themes in successful and failed interventions to formulate a set of core requirements for truly affordable solutions.

Results: Our findings reveal that while telemedicine and mobile health tools can significantly extend care to remote communities, their success hinges on robust infrastructure, supportive policies, and sustainable funding. Micro-insurance initiatives effectively reduce financial barriers but demand broad stakeholder collaboration. E-learning and 3D printing have proven valuable for capacity-building and cost-effective customization. In addition, the paper presents a comprehensive definition of “Affordable Health Technology” proposing essential requirements for designing, developing, and deploying such interventions: affordability, accessibility, scalability, sustainability, and deep market understanding. Finally, it reflects on lessons from both successful and failed interventions across SSA, offering crucial insights into how impactful, affordable health technology solutions can be designed and sustained in resource-constrained environments.

Conclusions: This review highlights the strong promise of affordable user-centered health technologies to improve healthcare delivery in SSA. Key enablers include a deep understanding of the market, scalable design, innovative distribution, robust local engagement, commitment beyond profit, and strategic task sharing. By embedding these principles into policy and practice, governments and innovators can foster affordable and impactful healthcare solutions throughout the region.

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Original Manuscript

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Abstract

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Methodology: Employing a narrative literature review, we synthesized insights from academic publications, policy documents, technical reports, and illustrative case studies. We examined on technology-driven interventions across telemedicine, mobile health, supply-chain optimization, micro-insurance platforms, health-related e-learning, electronic medical records, 3D printing, and medical automation. We also identified common themes in successful and failed interventions to formulate a set of core requirements for truly affordable solutions. **Results:** Our findings reveal that while telemedicine and mobile health tools can significantly extend care to remote communities, their success hinges on robust infrastructure, supportive policies, and sustainable funding. Micro-insurance initiatives effectively reduce financial barriers but demand broad stakeholder collaboration. E-learning and 3D printing have proven valuable for capacity-building and cost-effective customization. In addition, the paper presents a comprehensive definition of “Affordable Health Technology” proposing essential requirements for designing, developing, and deploying such interventions: affordability, accessibility, scalability, sustainability, and deep market understanding. Finally, it reflects on lessons from both successful and failed interventions across SSA, offering crucial insights into how impactful, affordable health technology solutions can be designed and sustained in resource-constrained environments.

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Keywords: affordable health technology, Sub-Saharan Africa, innovative health technology, health technology

1 Introduction

1.1 Healthcare Challenges in SSA

Sub-Saharan Africa (SSA) continues to shoulder a disproportionate burden of global disease, partly due to its unique environmental and socio-political landscape [1]. Reports indicate that the region accounts for about a quarter of the world's disease burden, but has access to only a small fraction of the global healthcare workforce [2].

[3] Key indicators such as life expectancy remain significantly lower than global averages, and childhood immunization rates lag far behind high-income regions [5]. This situation is exacerbated by severe shortages of healthcare providers and facilities. According to the World Health Organization (WHO), the number of healthcare workers in SSA falls short of recommended minimums, necessitating more than a 140% increase in the current workforce to meet essential service coverage [7][8]. Moreover, this shortage is further exacerbated by a workforce concentration in urban areas, leaving rural regions severely underserved. This is indeed a very serious problem for the population as the majority of the people in the region live scattered in a rural area that are unreachable and inaccessible by healthcare workers with traditional methods. As of the period between 2014 and 2021, SSA continued to have a significantly lower density of healthcare workers compared to more developed regions. The data indicates that there are only 2.3 medical doctors and 12.6 nursing and midwifery personnel per 10,000 population in SSA. In stark contrast, Europe boasts a higher density with 39.4 doctors per 10,000 population, and North America has 152 nursing and midwifery personnel per 10,000 population [9].

Another pressing concern is the persistent "brain drain" where SSA-trained healthcare professionals emigrate to other continents in pursuit of better opportunities [10]. In addition, the region struggles with inadequate infrastructure and limited financial resources for equipping hospitals [11]. Inflation in medical device costs, combined with weak governance and, in some cases, conflict or natural disasters, directly threatens the functionality of entire health systems [12]. The result is a healthcare environment that is both fragmented and under-resourced. These economic pressures, alongside mismanagement of resources, conflicts, and natural disasters, threaten to collapse the already depleted healthcare system.

The average life expectancy at birth in SSA is 61 years, more than 10 years lower than the global average, and 18 years lower than the average in the European and Northern American region [13]. Immunization coverage, access to clean water and sanitation, healthcare expenditure, and the density of healthcare workers relative to the population are all crucial metrics that underscore the pressing need for improvement. As of recent data, the overall full vaccination coverage across 25 SSA countries was found to be around 56.5%, with significant disparities ranging from as low as 24% in some

countries to as high as 93% in others like Rwanda [14]. The global vaccine coverage is about 83% [15].

In SSA, health expenditure varies but is generally lower in comparison to developed nations averaging at 4.92% of the GDP [16]. Given that their respective GDP is low, the expenditure will also be very low. In contrast, developed countries, particularly those within the Organisation for Economic Co-operation and Development (OECD),



have higher health care expenditures relative to their GDP. The United States was at the higher end, spending 16.8% of its GDP on health care, followed by Germany at 11.7%. Other high-income countries like France, Canada, Japan, and the United Kingdom also spent more than 10% of their GDP on health care [17].

1.2 Conceptualizing “Affordable Health Technology”

With regard to the aforementioned health indicators, it is evident that the SSA is facing significant challenges. These challenges highlight the importance of developing a cohesive and well-planned strategy for systemic improvement. Addressing these involves increasing health funding, improving health worker recruitment and training, and enhancing health service delivery. The need for a significant overhaul of the health care system is clear. Traditional approaches have not adequately addressed the growing demands and rising costs. Technology-enabled interventions could play a crucial role in this transformation, enabling wider access to preventive and treatment measures, and contributing to lower disease burden and mortality rates. Taking all this into account, at the launch of the global initiative on digital health, the WHO Director-General declared “The future of health is digital”, advocating for integrated national systems over standalone products and emphasizing quality technical support [18].

The WHO defines Health Technology as the “application of organized knowledge and skills in the form of devices, medicines, vaccines, procedures, and systems developed to solve a health problem and improve quality of lives” [19]. However, a clear and operational definition of what constitutes an affordable health technology is lacking. The concept of frugal innovation is often traced back to the “appropriate technology” movement [20], which advocated for technologies suited to low-income countries specifically, those that are labor-intensive, simple to operate and repair, and produce good targeting low-income consumers [21]. However, this viewpoint falls short of recognizing the broad potential of affordable health technologies. As a result, a more integrated and comprehensive definition of affordable health technology is needed.

1.3 Why Affordability Matters?

Affordability is crucial because it determines who can access and benefit from technological advances. While recent decades have witnessed incredible leaps in medical technology, many of these innovations such as sophisticated imaging machines and robotic surgical systems are largely out of reach for the majority of health care facilities and patients in SSA [22][23]. Although some technologies can theoretically reduce costs if they replace more expensive processes, the overall trend is that advanced medical developments increase health care expenditures for low-resource nations [24][25].

Moreover, focusing on the price tag of a device or app alone is insufficient; even nominally “frugal” or “low-cost” devices might fail if they require expensive consumables,

have short lifespans, or lack sufficient training and support frameworks. The other complicated reality is that purchasing or receiving donated high-tech equipment without a strategy for local maintenance, electricity reliability, or skilled operators



frequently lead to idle or prematurely broken devices [26][27][28]. As a result, the broader concept of affordability must integrate not only cost per unit but also maintenance obligations, distribution logistics, user-friendliness, and cultural acceptance [29].

On average, new medical technologies tend to enhance the quality of care by improving health outcomes, though this is not universally true for all technologies in every context. Many new technologies prove to be ineffective or redundant, not improving health outcomes significantly [30]. Distinguishing between effective and ineffective technologies during their introduction is a complex challenge. Furthermore, while certain technologies can reduce costs by replacing more expensive alternatives or averting costly health issues, the overall impact of new technologies is an increase in healthcare costs [31]. The healthcare sector's incentives and regulations often lead to inappropriate diffusion of technology, with both underutilization of effective, cost-efficient options and overuse of ineffective or cost-inefficient ones [30].

Additionally, there is a strong public demand for the latest and best medical technologies, and healthcare providers generally strive to meet this demand, further driving the adoption and diffusion of new medical technologies. Unfortunately, few of these high-tech and expensive medical innovations have the potential to significantly reduce costs and increase access to healthcare to the general public in SSA. Because a significant segment of the population resides in remote areas far from urban centers equipped with the infrastructure to support advanced medical devices and because there remains a shortage of qualified specialists to operate such technology effectively, alternative solutions are crucial. This underscores the need for accessible and affordable health technology. Affordable health technology will also assist the nation to be self-reliance in health care delivery.

1.4 The Need for Self-reliance

Historically, SSA countries have relied heavily on foreign aid and multilateral donors to fund healthcare. For example, Ethiopia, once the largest recipient of USAID in SSA, is thrust into crisis when a sudden freeze on US assistance halted vital food and healthcare programs that served millions [32]. This endangered critical efforts to combat malaria, HIV, and malnutrition. Nearly 16 million Ethiopians relied on USAID, and thousands of health workers along with NGOs providing sexual violence support and refugee aid have been forced to discontinue services, exacerbating an already dire humanitarian situation and derailing long-term development plans such as Ethiopia's Health Sector Transformation Plan II.

Recognizing the volatile global politics and economy, many are now reevaluating this reliance, exploring a combination of South-South partnerships and public-private ventures that could foster greater local resilience [33][34][35][36]. This reassessment may lead to a greater focus on South-South collaborations and public-private partnerships. Improving healthcare in SSA is crucial, and there is a growing recognition of this need among investors and entrepreneurs [37]. Governments are trying to shift

from relying solely on foreign aid to using technology and market knowledge to innovate [38]. Various types of literature proposed diverse methods and approaches in the creation of technology-based innovation to address healthcare challenges in SSA.



A central pillar of this self-reliance is the development of affordable health technologies that address SSA's unique conditions. Efforts must address a wide spectrum of social, economic, and infrastructural challenges. Health outcomes cannot be enhanced by the health sector alone, given how deeply issues like education, sanitation, and economic development intertwine with public health [39][40]. A report from the African Development Bank Group indicated that over the coming 50 years, a more comprehensive approach to enhancing health is anticipated, focusing on both preventive and curative measures [41]. A shift toward more collaborative approaches has therefore gained traction, emphasizing the need for strong linkages between government institutions, private investors, local communities, and non-governmental organizations (NGOs).

1.5 Scope of the Paper and Research Questions

The goal of this paper is to highlight several healthcare challenges and the potential impact of health technology innovation. Underpinning the importance of affordable health technology, we have been researching this domain in close partnership with collaborators from the Global South. The insights presented in this paper are drawn from the collective experience of the authors, investigation of existing reports of health technology companies active in SSA, case studies on which we have worked directly, and a comprehensive examination of the academic and policy literature. By blending empirical evidence with practical lessons from real-world interventions, we aim to offer a balanced perspective on affordable health technology's challenges and opportunities in SSA. It also proposes a comprehensive definition of affordable health technology, distinguishing it from mere "low-cost" solutions, and clarifies the elements that must be in place to make these technologies both practical and sustainable. The paper also proposes theoretical constructs that can guide practical explorations of what constitutes a 'good' digital health solution and lists core enablers of success. The paper also details the common causes of failures.

Summarized, in this paper, we answer the following three research questions:

- RQ1: What is affordable health technology, and how can it become truly impactful, particularly in SSA countries?
- RQ2: What are the core requirements for the design, development, implementation, and operation of affordable health technologies?
- RQ3: What does a 'good' solution look like, and why do some solutions fail?

1.6 Outline of the Paper

The rest of this paper is organized into four key sections. Section 2 (Related Works) presents a synthesis of existing literature and relevant conceptual frameworks that underpin affordable health solutions in resource-limited contexts. It covers key

theories such as convergent innovation, frugal innovation, stakeholder engagement, and user-centered design approaches that previous scholars and practitioners have applied in SSA settings. Section 3 (Methodology) details the narrative review design, describing the selection of relevant sources, screening procedures, data extraction, and synthesis.



Section 4 (Results and Discussion) consolidates the core findings from the reviewed literature and illustrative case studies, focusing on technical themes and affordable health technology in SSA. It interprets these results in a broader context, and highlights the challenges and solutions critical to advancing these interventions. It also provides a comprehensive definition of affordable health technology and key requirements for the design, development, and deployment of such technologies. Finally, Section 5 (Conclusion) underscores the paper's main insights, emphasizing how impactful, affordable health technology innovations can be designed and sustained in resource-constrained environments.

2 Related Works

2.1 Foundational Perspectives on Affordable Health Technology

Affordable technological interventions face significant hurdles. Clifford [42] explores why, despite rapid advancements, many healthcare technologies fail to benefit low-resource communities. He emphasizes that true affordability hinges on more than just lower costs; solutions must also suit local infrastructure, cultural norms, training needs, and business models that allow long-term sustainability. In particular, he highlights comprehensive needs assessment to ensure that interventions match genuine user requirements rather than assumptions, as well as thoughtful supply-chain design so devices are properly maintained and consumables remain accessible. Key insights include the importance of user-centered design, open-source approaches, and crowdsourced diagnostics to reduce bias and expand reach. Clifford also addresses data ownership and privacy, noting that interoperability and transparent governance over patient data are critical for scaling solutions effectively. Throughout, he critiques “plague of pilots” or short-term projects that lack sustainable revenue models, urging a shift toward ecosystem-based planning where technology is introduced alongside business incentives, maintenance plans, and community engagement. This approach fosters an environment in which healthcare technologies can truly empower health workers, meet patient needs, and remain operable well after initial external funding phases.

Dube et al. [43] have introduced a term called convergent innovation (CI) as a meta-innovation that merges technological and social innovation for sustainable prosperity and affordable universal healthcare. They claim that by fostering collaboration and bridging siloed efforts, CI delivers scalable, resilient solutions that simultaneously address economic growth and human development.

The paper by Moleka et al. [44] highlights how frugal innovation prioritizing affordability, simplicity, and resourcefulness can tackle Africa's unique constraints and empower marginalized communities. It explores foundational frameworks (e.g., Jugaad,

Bottom of the Pyramid, Reverse Innovation), and examines key enablers such as policy support and collaborative ecosystems. Ultimately, it underscores the transformative potential of frugal innovation in driving inclusive growth, sustainable development, and alignment with global goals across the continent.



Segarra-On˜a et al. [45] investigate how stakeholder engagement drives innovation outputs in the healthcare industry, with a special focus on co-creation between health-care firms and their surrounding ecosystem. Key insights include the need for closer collaboration with end users, suppliers, competitors, and institutional partners, as well as the importance of clearly aligning organizational objectives toward innovation. Ultimately, their results show that while stakeholder engagement does foster innovative activity, its real impact is mediated by a well-defined strategic focus on innovation. This highlights the managerial relevance of nurturing user input and social co-creation as a powerful route to developing more effective and wide-reaching innovations in healthcare.

Bekele et al. [46] developed a healthcare software platform in rural Ethiopia, following user-centered design methods tailored to low-resource, culturally diverse settings. Their process involved iterative prototypes, frequent user feedback, and on-site evaluations to ensure the platform's relevance, particularly for semi-literate health-care workers with limited connectivity. They incorporated simple icons, robust offline functionality, and a community-oriented rollout that included training and plans for long-term upkeep. The case study underscores how close engagement with local end users, coupled with an iterative design process, can yield more sustainable and culturally appropriate healthcare solutions in developing countries. Designing for local contexts also reduces the risk of products becoming underutilized [47] [48].

Chakravarty [49] explores how small and medium manufacturing firms in South Africa develop medical devices suited for resource-constrained environments, typically dominated by Western multinationals. Using case studies of six firms, the author applies an adapted global health framework (the "4A" lens of Availability, Accessibility, Appropriateness, and Affordability) to identify what makes these devices "frugal." While some products specifically target low-resource healthcare settings (e.g., simpler, low-cost designs meeting local needs), others have universal appeal yet still lower costs through lean R&D and manufacturing. These firms tackle institutional voids (unavailable local testing labs, high import costs) by leveraging internal design capabilities, forging multiple collaborations (often with universities or global nonprofits), and adopting vertical integration (in-house testing, parts fabrication) to reduce reliance on underdeveloped services. Despite challenging regulatory processes and competition from imports, success is driven by strong engineering, strategic local partnerships, and sometimes differential pricing or cross-subsidization for public-sector buyers. The study underscores the role of government and international NGOs in scaling these "frugal" innovations, suggesting that supporting local SMEs in emerging markets can help fill healthcare gaps worldwide. Success also hinges on financial models that reduce out-of-pocket costs for end-users, especially given that many SSA populations have limited disposable income [50] [44] [49]. This strategy can include subscription models that

mitigate catastrophic health spending [51] [52].

Considering the fact that the people in SSA are scarcely populated and live in vast areas, designers, developers, and businesses must emphasize the importance of innovative distribution strategies to reach remote and hard-to-access areas. Traditional distribution methods often don't work for these regions [53]. Local supply chain

integration can reduce both logistics costs and service disruptions, supporting more reliable access to products and spare parts [54].

Engaging local communities in the design, production, and distribution processes of health technologies is essential. This ensures cultural relevance and fosters local entrepreneurship [55]. The paper [56] highlights the crucial role of strong, systematic community engagement in improving health equity and informing policy-making. Another very important element there is strong training and supervision, which ensures that technologies are appropriately operated and fosters trust in new systems [57].

Polak and Warwick's book "The Business Solution to P o v e r t y" [58] challenges traditional notions of aid and development, advocating for a market-driven, entrepreneurial approach to uplift the world's poorest, highlighting the intertwined nature of profitability and positive social impact. The book discusses the potential of the bottom of the economic pyramid; a market of approximately three billion people who live on less than \$2.50 a day. Rather than viewing this demographic as merely a group in need of aid, they see them as a vast untapped market. If businesses can create products and services tailored to the needs and constraints of these individuals, they can achieve significant profitability while simultaneously improving the quality of life for millions. For many years, the medical sector in these regions has been dependent on direct aid and donations, which failed to bring the required impact, hence there should be a business end to it. However, the ethos should be profit with a purpose [59]. Task Sharing / Task Shifting (TSTS) in healthcare involves delegating routine activities like disease screening to non-experts. This strategy requires easy-to-use technologies to ensure safe and accurate operations without expert supervision. Because Sub-Saharan Africa's population skews toward younger age groups, there is a substantial pool of young adults who can be rapidly trained to handle routine clinical tasks. Advances in artificial intelligence and machine learning can further automate many of these tasks such as screening; thus allowing scarce, highly skilled clinicians to concentrate on more complex and critical responsibilities [60]. The study in Kenya [61] concludes that well-structured task sharing and task shifting can expand healthcare access and strengthen health systems in resource-limited settings.

Scaling up health initiatives requires not only expanding proven interventions but also ensuring a supportive policy environment at every level of the health system [62]. Successful scale-up demands deliberate attention to the full policy landscape from macro-level strategies and budget to facility-level guidelines and training so proven health interventions become routine, high-quality services accessible to all.

2.2 GapAnalysis

Existing research on affordable health technology in SSA has addressed topics like user-centered design, stakeholder engagement, and frugal innovation. Clifford, for instance, highlights the importance of sustainability and local ownership, while others discuss convergent innovation or frugal design. However, several gaps remain:

- **Fragmented Coverage of the Technology Landscape:** Most studies concentrate on a single domain—telemedicine, supply chain, or e-learning—without synthesizing a broad array of interventions into a unified concept of “affordable health technology”.

- **Insufficient Consolidation of Lessons from Both Successes and Failures:** Many analyses describe best-practice interventions or case studies where solutions scaled effectively. Yet relatively few systematically address how and why certain initiatives fail. This hampers the ability of practitioners and policymakers to anticipate pitfalls such as misaligned design choices, insufficient infrastructure, or stakeholder disengagement.
- **Narrow or Incomplete Definitions of 'Affordability':** While "frugal innovation" has been extensively discussed, much of the literature tends to reduce affordability to cost-saving measures or simpler technology. Few incorporate broader, comprehensive criteria like sustainability, deep market understanding, and community engagement in a single operational framework. Hence, there is limited guidance on how best to embed local cultural, infrastructural, and governance factors in the product life cycle to ensure sustained affordability.
- **Lack of a Roadmap to Scale:** Existing literature provides broad recommendations for scale-up (e.g., seeking policy support), but little detail on linking design principles to operational expansion, such as supply chain innovations and continuous financing.
- **Limited Cross-Comparison of Companies and Research Projects:** Much of the published literature looks at a single intervention or a short list of them. Studies that comprehensively compare a wide array of initiatives from telehealth to 3D printing to digital insurance are relatively scarce. This lack of cross-initiative analysis reduces our ability to pinpoint universal success factors or recurring challenges relevant to multiple domains.

2.3 Contribution

The present paper addresses these gaps by conducting a narrative literature review that weaves together a broader ecosystem of health-technology interventions. We analyze commercialized solutions (e.g., Waspito, Zipline, mPharma), research-level innovations (e.g., AI-based medical automation), and instructive failures or partial-failures, identifying shared success factors as well as recurrent stumbling blocks. Crucially, we propose a comprehensive, operational definition of "affordable health technology" that goes beyond low cost, incorporating affordability, accessibility, scalability, sustainability, and deep market understanding as interdependent design requisites. By integrating insights from multiple domains, multiple initiatives, multiple countries, and spotlighting practical exemplars, our paper seeks to offer a more holistic roadmap for innovators, policymakers, and donors aiming to deploy or scale impactful health solutions in SSA.

In doing so, we not only expand on prior conceptual frameworks (e.g., frugal innovation, convergent innovation) but also showcase how task sharing, commitment beyond profit, and innovative distribution combine to overcome structural barriers. This extensive cross-

pollination of success and failure stories based on tangible case studies, marks a distinctive contribution, filling a recognized gap in the literature by delivering an integrated, context-sensitive advantage on designing and operationalizing affordable health technologies across the SSA.



3 Methodology

The principal methodology employed in this paper is a narrative literature review [63], a qualitative approach that synthesizes evidence and perspectives from diverse sources to present a coherent, contextualized understanding of the research topic. In this case, the broad focus on healthcare challenges in SSA and the role of affordable health technology necessitated a flexible and iterative method, allowing for an inclusive exploration of academic publications, policy documents, and organizational reports.

A narrative literature review differs from a strictly systematic review in that it does not necessarily follow a tightly prescribed protocol for article selection and appraisal

[63]

[64]. Instead, it aims to provide depth of contextual insight, especially useful when investigating a multi-faceted issue such as the intersection of resource constraints, public health indicators, and technological innovation across geographically and socially diverse regions like SSA. This approach, therefore, facilitated the integration of findings from various disciplines, including public health, health economics, and technology development.

3.1 Rationale for the Chosen Method

Given the scope and complexity of healthcare challenges in SSA, a narrative review was deemed most suitable for revealing the layered, interdependent factors at play. A narrowly scoped systematic review might risk overlooking important contextual insights, while a meta-analysis would likely be hindered by heterogeneous study designs and data metrics. In contrast, a narrative approach facilitated a broad exploration of the literature encompassing epidemiological trends, case studies of start-up interventions, reviews of government-led health programs, and emerging theoretical frameworks around affordable health technology. This method thereby allows the paper to offer both a comprehensive overview of existing knowledge and a conceptual synthesis that points to critical gaps and future research directions.

By adopting a narrative literature review, this paper aspires to spark a more nuanced understanding of how affordability, accessibility, scalability, and sustainability can collectively bolster healthcare delivery in SSA. It integrates rich contextual perspectives that could inform researchers, practitioners, and policymakers aiming to develop or scale affordable health solutions in resource-limited environments.

3.2 Search Strategy and Sources of Information

The initial stage of the review involved conducting targeted searches across major academic databases, including PubMed, Scopus, and Web of Science, as well as regional databases such as African Journals Online. Broad search terms were com-

binned with region-specific keywords to capture literature relevant to SSA. For instance, key terms included “Sub-Saharan Africa”, “affordable health technology”, “health-care challenges”, “frugal health technology”, “Low-cost medical devices”, “Healthcare innovations for low-resource settings”, “Cost-effective healthcare solutions”, “Point-of-care diagnostics”, “Affordable healthcare delivery models”, “Health technology assessment in low-income countries”, “Sustainable healthcare technologies”, “Health-care technology for developing regions”, “Task shifting and task sharing for healthcare

affordability”, “Automation and AI for healthcare affordability”, “Digital Healthcare” and “health technology innovation in Africa”. This approach ensured coverage of both global frameworks and context-specific interventions.

To enrich the dataset, gray literature was also included. This encompassed official reports from organizations like the WHO, the World Bank, and regional governmental or non-governmental bodies. Conference proceedings, policy briefs, company websites, and online technical reports were examined for detailed accounts of healthcare interventions. Given the evolving nature of health technology, these non-peer-reviewed materials often contained up-to-date data and case studies that had not yet appeared in academic journals.

3.3 Inclusion and Exclusion Criteria

In the narrative review process, inclusion and exclusion criteria were applied flexibly, guided by the paper’s central aims. Publications were included if they meet one or more of the following criteria:

- Discusses healthcare challenges or health technology interventions in SSA.
- Presents technical information about a currently functional health technology product in SSA.
- Provides an analysis or substantial description of technology-driven solutions (e.g., telemedicine, mobile health, drug verification, electronic health records, supply-chain innovations, 3D printing, micro-insurance, AI and automation, or e-learning).
- Offers insights into frugal innovation, affordability, sustainability, or scalability of health technologies.
- Describes about the barriers and challenges for failures or partial failures of proposed interventions.

Papers focusing solely on high-income settings or lacking clarity regarding cost and scale-up potential were excluded unless they presented conceptual frameworks or theoretical models relevant to resource-constrained contexts. Studies published in languages other than English were excluded.

From an initial exploration from all 49 Sub-Saharan African countries [65], we identified 69 health technology companies and selected 19 initiatives (17 successful and 2 failed initiatives), and 8 research-level initiatives were fit our criteria for further analysis. Throughout this review, we consulted and summarized about 120 sources, including websites, reports, and peer-reviewed publications.

3.4 Data Extraction and Synthesis

A qualitative data extraction process was carried out. The authors initially screened titles and abstracts to verify their relevance, followed by a full-text review of the selected papers. During the full-text review, key points were recorded in an overview

table under the following categories to respond to the overarching research questions posed in this study:



- **Healthcare indicators in SSA:** These references primarily focus on the health status of populations in SSA, including maternal and child health, disease burden, mortality rates, health workforce gaps, and overall system capacity.
- **Types of technology innovations:** These references document or analyze technical solutions grouped into nine domains: telemedicine, digital health records, mobile health (mHealth), supply chain, digital health insurance, e-learning platforms, 3D printing, drug verification system, and medical automation.
- **Implementation factors:** These sources delve into training, infrastructure, policy/regulatory frameworks, governance, and other conditions that facilitate or hinder the uptake of health technologies in SSA. Several discuss the roles of stakeholders, local ownership, and user-centered design processes.
- **Affordability and funding models:** References here emphasize creating cost-effective solutions that maintain essential functionality. Approaches like public-private partnerships, donor-based or market-based mechanisms, and cost-containment strategies that seek to make health technologies viable for low-income populations in SSA.
- **Outcomes and lessons learned:** These references evaluate real-world interventions, reporting on effectiveness, barriers, facilitators, and sustainability. Some papers highlight partial or outright failures (e.g., donated equipment falling into disrepair, EHR or telemedicine pilots discontinued post-funding).

Drawing from these categories, a narrative synthesis was then developed. This process involved iteratively grouping similar findings, reconciling or explaining any contradictory results, and identifying overarching patterns. The flexible nature of a narrative review allowed for new themes (such as task shifting, local entrepreneurship, or local government regulatory support) to emerge organically during synthesis, ensuring that the complex interplay between technologies, economic constraints, and healthcare infrastructures in SSA was adequately captured.

3.5 Validation

To strengthen the reliability of the findings, the authors undertook informal triangulation by comparing data from peer-reviewed research with grey literature sources and expert commentaries as much as possible. Where possible, multiple references were used to validate specific data points such as the measured impact of a telemedicine pilot or the reported success rates of micro-insurance platforms.

3.6 Ethical Considerations

Since this study did not involve direct human subjects research, no formal ethical approval was required. Nonetheless, the authors adhered to scholarly standards by accurately citing all sources of information and avoiding unwarranted generalizations. When detailing program outcomes, particular care was taken to represent each intervention's context, geographical, economic, and cultural, so as not to overstate transferability across different SSA settings.

3.7 Positionality Statement

In writing this paper, the authors acknowledge the importance of positionality: the way in which personal values, backgrounds, and professional affiliations shape inquiry, data interpretation, and conclusions [66]. One of the authors is originally from SSA country and has maintained close, ongoing collaborations with local healthcare institutions, offering a grounded perspective on the societal and infrastructural realities of low-resource settings. The other author is based in an institution in Europe with a strong research focus on affordable health innovation. While this dual vantage point enriches the study by combining insider understanding with outsider academic rigor, it also necessitates reflexivity to prevent inadvertently reproducing assumptions that may not reflect local contexts [67][68]. Throughout the research process, the authors remained attentive to how their distinct positionalities could shape the framing of issues and the emphasis on certain interventions over others. By regularly revisiting and discussing these potential biases, the team aimed to maintain integrity and inclusivity in both the methods and the conclusions of this paper.

4 Results and Discussion

This section integrates our findings on how affordable health technology is transforming healthcare in SSA with a broader discussion of what constitutes “affordability” in these contexts. It begins by highlighting specific interventions, from telemedicine platforms and mHealth services to micro-insurance models and supply-chain innovation that have measurably improved care access and quality. We then examine the definition and core requirements of affordable health technology, reflecting on how these solutions align with such criteria in practice. In doing so, we address our key research questions. This section also offers both data-driven insights into ongoing successes and critical lessons on challenges that must be overcome for long-term impact.

4.1 Examples of Successes and Failures

4.1.1 Success Stories from Commercially Available Initiatives in SSA

Technology has emerged as one of the most promising ways to tackle structural deficiencies in SSA's healthcare sector. Technology-enabled healthcare services can be found in multiple forms. This approach, known as technology-enabled healthcare services, encompasses the enhancement of hospitals, pharmacies, and laboratories through the application of advanced technology. A variety of health technology solutions have emerged across SSA to tackle pressing challenges such as limited healthcare resources, disease burdens, and geographic barriers. Each success story illustrates how local engagement, thoughtful design, and context-

specific delivery models can dramatically improve access to services, reduce costs, and enhance patient outcomes. Table 1 highlights 17 companies and initiatives currently operational in SSA, each focusing on a particular challenge within the region's healthcare landscape and employing distinct technological models. The variety of approaches ranging from telehealth and digital health records to supply-chain optimization and micro-insurance showcases

how technology can target specific system gaps such as specialized-care shortages, logistical bottlenecks, or unaffordable healthcare costs. Many of these solutions thrive on partnerships with governments, NGOs, or telecom providers, underscoring the value of local ownership and policy support. They also emphasize user-centered or context-aware design, as seen in telemedicine and e-learning platforms that account for limited bandwidth or digital literacy.

Several ventures like mPharma and M-TIBA exemplify how creative funding models, including micro-insurance and subscription options, reduce out-of-pocket costs for low-income users. Despite these gains, connectivity shortfalls, staffing and training gaps, and complex regulatory environments persist as obstacles. The range of successes, however, suggests that well-tailored interventions, robust infrastructure, and sustained stakeholder engagement can promote affordability and scalability. Thus, readers can learn that although no single solution applies universally, multiple business and technical innovations coupled with collaboration and regulatory backing can effectively mitigate healthcare disparities and optimize service delivery in SSA's resource-constrained settings. Their success factors, challenges, and key lessons learned are explored further in Section 4.2.

4.1.2 Success Stories from Initiatives at Research Level in SSA

Table 2 presents 8 research-level successes all in the domain of “medical automation”, a term encompassing any AI-driven or algorithm-based system that reduces reliance on specialized personnel for tasks like screening and monitoring. Each showcased initiative seeks to automate a particular clinical or diagnostic process ranging from low-cost VR solutions for glaucoma to machine learning software that detects rheumatic heart disease from audio signals. By removing time-intensive workloads from limited specialists, these automation tools enable mid-level health workers or community health workers to conduct initial assessments and identify at-risk patients who can then be quickly referred to specialized care. The initiatives uniformly highlight the importance of iterative design, where local user feedback and accuracy validation were critical for building trust and ensuring that the software's outputs were clinically reliable. Additionally, they illustrate the need for partnerships with local hospitals, regulators, and donors to fund technology updates, integrate with existing workflows, and facilitate training. Even though most examples remain in pilot or proof-of-concept phases, they underscore the broad value of deploying simplified, AI-enabled platforms for routine diagnoses in underserved areas. From this, we can learn that automated diagnostics when carefully adapted, validated, and supported locally have strong potential to scale up, expand healthcare reach, and alleviate the region's chronic workforce shortages. The reported challenges and lessons learned from these research initiatives are analyzed

in further in Section 4.2.

4.1.3 Failure(orPartialFailures)Stories

While some “failure” or “partial failure” cases did not originate from a specific company, they represent widely documented challenges in SSA healthcare technology deployments. Table 3 summarizes cases of complete or partial failures. Obtaining concrete data on failed initiatives is difficult, as these cases are rarely publicized. However,



Table 1 Illustrative Success Stories: Commercially Available Products in SSA

No.	Company/ Initiative	Country	Brief Description	Domain
1	WellNewMe [69][70]	Nigeria		Telehealth
2	Waspito [71][72]		A digital health platform focusing on preventive care and chronic disease management using online health risk assessments	Telehealth
3	Rocket Health [73][75]	Cameroon	A p-p-based telehealth that connects healthcare providers with patients, offering teleconsultations, prescriptions, and lab links	Telehealth
4	Ghana Telemedicine [76][77]	Uganda	Operates licensed teleconsultation, lab sample collection, and medication delivery, integrated with licensed pharmacy	Telehealth
5	mPharma [78][79]	Ghana	Telemedicine to improve healthcare delivery, especially for women and children in remote communities—used in educating health workers, diagnosing, and offering care	Telehealth
6	Helium Health [80][81]	Ghana	Provides prescription drug inventory management, e-record integration, and better access to affordable medicines	
7	Baobab Health Trust [82][83]	Nigeria	Offers EHR, hospital management software, and telemedicine integration, streamlining billing and patient data	Digital Health Records
8	Toto Health [84][85]	Malawi	Specializes in low-cost digital tools for patient records, workflow optimization, and disease tracking in under-resourced clinics	Digital Health Records
9	Medstore [87][88]	Kenya	Uses mobile (SMS/voice) to educate parents and expectant mothers on maternity, child health, and immunization	Digital Health Records
		Ethiopia	An online marketplace that digitally connects healthcare providers with suppliers of medical devices and equipment	mHealth
10	Zipline [89][90]	Rwanda, Ghana	Uses drones for rapid delivery of blood products, vaccines, and medication to remote hospitals and clinics	Supply Chain Supply Chain
11	Health[e]Foundation [91][92]	Multi-SSA	Delivers offline-friendly learning modules for health professionals and community workers in Ethiopia, Rwanda, Uganda, etc.	Health E-learning
12	Prothea [93]	Kenya	3D-prints affordable custom prosthetic limbs, reducing cost from ~\$3500 to \$1400, with faster turnaround (24 hours)	3D Printing
13	Casava [94]	Nigeria	By leveraging technology and partnering with reputable healthcare providers, Casava streamlines the insurance process, offering affordable and accessible health insurance solutions	Digital Insurance

- | | | | | |
|----|---|---|---|-----------------------|
| 14 | Turaco[95] | Multi-SSA Africa -
focuse d insurtechdedicatedtomakinginsur- | ance simple, affordable, and accessible for low-income communities, covering needs such as health, life, andpersonal accident | DigitalInsuranc
e |
| 15 | M-PESA
+M-TIBA
[96] | Kenya | Mobilemoneyplatform(M-PESA)+micro-insurance(M-TIBA)thathelpslow-incomepopulationsinsure and save for healthcare costs | DigitalInsuranc
e |
| 16 | NucleusIS
[99] | Nigeria
,Ghana | Digitallyautomatesprocessesbetweeninsurers,hos-pitals, and enrollees, boosting efficiency and insurancecoverage | DigitalInsuranc
e |
| 17 | Sproxil
[100]
[101][102]
[103] | Multi-SSA | Fights counterfeit drugs via scratch-off labels andfreeSMSverificationcodesforauthenticitychecks | DrugVeri-
fication |

Table 2 Illustrative Success Stories: Research Level Initiatives in SSA

No.	Company/Initiative	Country	Brief Description
1	Glaucoma Easy Screener (GES) [104]	Ethiopia	smartphone + VR headset solution for low-cost visual field screening, validated with 85-90% diagnostic accuracy
2	RHD Screening via PCG+ML [105]	Ethiopia	Automated Rheumatic Heart Diseases screening using machine learning on phonocardiogram data, enabling non-expert usage
3	CAD4TB [106] [107]	Multi-SSA	AI-powered chest X-ray analysis for TB screening, improving rapid detection in Kenya, Tanzania, Zambia, Nigeria
4	EyeArt AI System [108] [109]	South Africa	AI-driven retinal imaging that detects diabetic retinopathy automatically, often deployed in primary care settings
5	Malaria Phone Microscopy [110] [111] [112]	Uganda, Sudan	Smartphone-based microscopy + AI to detect malaria parasites, reducing lab tech workload and improving diagnostic speed
6	CardioPad [113]	Cameroon	Tablet-based ECG capturing and interpretation device for rural communities, integrated with rural cardiologists remotely
7	POC Analyzers for HIV [114] [115]	South Africa, Kenya, Uganda	Automated portable machines for HIV screening/viral load, requiring minimal user input and enabling real-time decisions
8	Digital Triage Tools [116] [117] [118]		Algorithm-based symptom checkers for community health workers, standardizing initial assessment and referrals

we identified a few examples: the donation of high-end medical equipment that did not account for local infrastructure, maintenance, or training; a Tanzania-based electronic health record initiative that did not succeed; and telemedicine kiosks that fell short of their potential in multiple SSA countries. We then examined the primary contributors to failure in these settings and the lessons learned.

4.2 Challenges and Success Factors

From the detailed analysis of the companies and initiatives mentioned in the three

Tables 1, 2, and 3, certain patterns emerged that underpin success and challenges. Table 4 presents a matrix that indicates which solutions fall under each success factor or challenge theme, followed by an overview of common themes, both challenges and success factors. This allows a quick look at where solutions share similar hurdles and which enablers drive their success. By grouping the solutions under these common themes, it becomes clearer how each intervention shares certain struggles (e.g., connectivity and training) and benefits from certain strengths (e.g., local partnerships, and user-friendly design).

This subsection synthesizes the key themes from the successes and setbacks outlined in the tables above, offering a closer look at the elements that either facilitate or constrain impactful, affordable health technology in SSA. We identified seven main

Table 3 Failure Stories (or Partial Failures) in SSA

No.	Company/ Initiative	Country	Brief Description	Domain
1	Donated or Shipped Advanced Equipment [119][120]	Multi-SSA	High-end devices (e.g., MRI, CT scanners) delivered to facilities lacking stable power, parts, or skilled staff; quickly became nonfunctional	Equipment Donation
2	EHR Pilot [121]	Tanzania	Initially promising EHR system stalled post-funding due to low local stakeholder buy-in, poor training, unclear data maintenance strategy	Digital Health Records
3	Telemedicine Kiosks [122][123][124]	Multi-SSA	Complex kiosk interfaces unsuited for community health workers; sporadic connectivity, unclear operational model led to disuse	Telehealth

challenges (A1–A7) and six main success factors (B1–B6). Although each intervention is unique, the patterns discussed here highlight shared experiences, enabling a more nuanced understanding of how technology projects can thrive—or falter—in resource-constrained environments.

Table 4 Thematic Matrix: Success Factors or Challenges

No. Solution	A. Challenges ¹							B. Success Factors ²					
	A1	A2	A3	A4	A5	A6	A7	B1	B2	B3	B4	B5	B6
1. WellNewMe	✓							✓	✓	✓	✓		✓
2. Waspito	✓				✓			✓	✓		✓		✓
3. RocketHealth	✓							✓	✓		✓		✓
4. GhanaTeleM	✓	✓						✓	✓	✓		✓	✓
5. mPharma				✓			✓	✓	✓		✓		✓
6. HeliumHealth		✓				✓		✓	✓	✓	✓		✓
7. BaobabHealth	✓	✓						✓	✓	✓	✓		✓
8. Totohealth					✓	✓		✓	✓		✓		✓
9. Medstore	✓			✓				✓	✓		✓		✓
10. Zipline			✓					✓	✓			✓	✓
11. Health[e]Fou		✓						✓	✓	✓	✓		✓
12. Prothea		✓	✓				✓	✓	✓	✓			✓
13. Casava					✓			✓	✓		✓		✓
14. Turaco			✓	✓				✓	✓		✓		✓
15. M-TIBA				✓	✓			✓	✓	✓	✓	✓	✓
16. NucleusIS		✓		✓				✓	✓		✓		✓
17. Sproxil			✓				✓	✓	✓		✓		✓

4.2.1 Challenges

- A.1 Unreliable Connectivity & Power: In many SSA regions, power outages and suboptimal internet coverage frequently disrupt electronics systems and hamper real-time data exchange. Telemedicine apps (e.g., Waspito) require stable internet for video consultations, but face periodic connection dropouts in rural Cameroon. Likewise, any cloud-based solution such as Helium Health's EHR needs both adequate internet and a backup power supply. Without such reliability, even well-designed platforms fail to deliver consistent services.
- A.2 Staffing & Training Gaps: Constraints on staff availability and skills can undermine a project's success. Some solutions demand specialized installation or usage steps that local personnel may find overwhelming without robust support. For instance, Baobab Health Trust's digital tools in Malawi thrived only after a sustained training regimen for clinic workers who were unfamiliar with electronic recordkeeping. Where training remains superficial or one-off, projects revert to paper-based methods.
- A.3 High Infrastructure Requirements: Certain interventions rely on sophisticated equipment or distribution hubs, incurring significant capital outlay and maintenance costs. Zipline, for example, gains prominence by leveraging drones for blood product delivery but needs dedicated launch facilities, capable drones, and

¹A. Challenges

1. Unreliable Connectivity & Power: Frequent internet outages, limited bandwidth, or unstable electricity hinder implementation and real-time data usage.
2. Staffing & Training Gaps Inadequate onboarding or continuous training can lead to user resistance and underutilization.
3. High Infrastructure Requirements Advanced equipment (drones, 3D printers) and distribution hubs (Zipline drone launch sites) often entail substantial upfront or maintenance costs.
4. Multi-Stakeholder Coordination Aligning incentives among government, donors, clinicians, pharmacists, and patients can be complex, slowing adoption or raising costs.
5. Payment & Affordability Barriers Many uninsured or low-income users can't afford even small fees without creative financing models or subsidies.
6. Older Demographic / Local Resistance to Digital Tools Technology skepticism and lower digital literacy, especially among older adults, can limit adoption.
7. Specialized Partnerships Required Some solutions (Sproxil, Prothea) need ongoing collaboration with pharma or local tech teams, creating reliance on external or specialized partners.

²B. Success Factors

1. Local Ownership & Partnerships Involvement of governments, telecoms, NGOs, local clinics, or community leaders ensures stronger buy-in and easier scaling.
2. Technology as an Enabler, Not the Goal Solutions that tackle a concrete local need (rather than introducing tech for tech's sake) show higher uptake and better outcomes.

3. Scalability & Training Telemedicine, EHR, or micro-insurance platforms thrive when staff and end-users receive thorough, ongoing training and support.
4. Affordability Beyond Upfront Cost Effective models minimize maintenance, supply-chain overhead, and usage fees, ensuring continued affordability over time.
5. Regulatory/Policy Support Government endorsement, regulatory clarity, or policy incentives have proven critical for full-scale launches (Zipline drones, M-TIBA).
6. Context Adaptation & User-Friendliness Seamless interfaces, local-language support, offline modes, and simplified sign-up processes help solutions reach more users.

a specialized operation team. While the service offers immense value, the initial infrastructure can be daunting if not properly planned with reliable funding.

A.4 Multi-Stakeholder Coordination: Many solutions particularly in supply chain or micro-insurance necessitate alignment among government bodies, private clinics, donors, telecom operators, and more. mPharma's inventory system had to build trust with pharmacies, distributors, and hospital administrators. Conflict - ing incentives or bureaucratic hurdles slow down expansions; thus, structured communication channels and clear contractual obligations become critical.

A.5 Payment & Affordability Barriers: In contexts where out-of-pocket expenses dominate, even modest fees can dissuade patients. Micro-insurance platforms like M-TIBA help mitigate this but rely on large enrollment to remain solvent. When buy-in lags (due to skepticism or limited disposable incomes), the scheme can struggle financially. This barrier often merges with other challenges like local resistance to digital payments.

A.6 Resistance to Digital Tools: Innovative technologies sometimes face pushback from older patients or less tech-savvy populations. Whether it's teleconsultations or e-wallet-based insurance, a subset of potential users might distrust digital channels. Rocket Health in Uganda worked around this by running a wariness campaign and simplifying enrollment, yet older demographics demanded phone-based (rather than app-based) consultations.

A.7 Specialized Partnerships Required: Certain solutions hinge on continuous collaboration with a single manufacturer or specialized vendor, for instance, Sproxil's drug verification system depends on pharmaceutical partners willing to adopt unique scratch-codes. If that partner withdraws or encounters regulatory pressures, the service's entire model may be jeopardized.

4.2.2 Success Factors

B.1 Local Ownership & Partnerships: Deep engagement with government entities, NGOs, and local businesses fosters a sense of shared responsibility reducing the likelihood of pilot abandonment. Ghana's national backing of telemedicine expansions, for instance, allowed for widespread policy support, streamlined funding channels, and stronger local staff morale.

B.2 Technology as an Enabler, Not the Goal : Effective solutions pinpoint a real, localized issue, for example, maternal mortality in remote clinics, then build the simplest or most appropriate tech around it. Zipline's drone deliveries stand out: their impetus was timely access to blood and medicine, not to showcase

drone

technology. By prioritizing that core need, Zipline's model resonates with health workers and local leadership, gaining faster acceptance.

- B.3 Scalability & Training: Sustained impact usually requires robust training and user support over time. Baobab Health Trust trains clinic workers repeatedly, ensuring new hires also gain the necessary skills. Similarly, Helium Health's EHR rollout includes ongoing help-desk services and refresher sessions. This investment in human resources boosts user confidence and fosters long-term system uptake.

- B.4 Affordability Beyond Upfront Cost: True cost-effectiveness isn't just about a low sticker price. mPharma, for example, lowers overall drug expenses through centralized inventory management, passing savings on to both pharmacies and patients. Its model relies on controlling recurrent costs, stock-out risks, and overheads. This synergy keeps healthcare more consistently affordable, a critical element to sustaining patient trust.
- B.5 Regulatory/Policy Support: Government endorsement especially in licensing, data governance, or expedited approvals can make or break a project. Rwanda's embrace of drone-based logistics exemplifies how official buy-in helps mitigate bureaucratic delays, fosters public awareness, and arranges necessary infrastructure or airspace approvals. Without such policy green lights, even well-funded innovations often stall.
- B.6 Context Adaptation & User-Friendliness: Adapting interfaces and workflows to the local environment ensures faster adoption. Sproxil's scratch-code verification system can be used on basic phones with no need for data plans. This method is simple enough that millions of ordinary citizens can verify drugs quickly, filling a critical gap in counterfeit medication control. When combined with multi-lingual support, these solutions can reach diverse populations more effectively.

By highlighting these specific challenges and success factors, the paper underscores the practical lessons obtained from both successful and failed initiatives. The main information is that scaling affordable health technology in SSA demands more than just innovative code or flashy hardware. Rather, it requires a calibrated approach that addresses infrastructure, culture, local ownership, and sustainable funding, all orchestrated around real, pressing needs.

4.2.3 Lessons from Failed Initiatives

The history of international health interventions in SSA also contains numerous cautionary tales. One recurrent problem is the donation or shipment of sophisticated diagnostic equipment, such as high-end MRI or CT scanners, to facilities lacking the basics to run them (stable electricity, specialized technicians, or funds for maintenance contracts).

Table 5 presents a concise overview of the common themes (challenges or missed opportunities as presented in Section 4.2.1) behind the partial or failed interventions, with an at-a-glance matrix showing which solution experienced each theme. By identifying which theme caused the stalls or failures, future interventions can proactively address core issues, namely,

ensuring feasible infrastructure, continuous training, meaningful stakeholder buy-in, robust funding, and technology that truly fits local needs. Below is an extended discussion of what we can learn from each row and how the listed themes intersect.

- **Donated or Shipped Advanced Equipment:** High-end imaging devices like MRI or CT scanners were delivered to rural or underserved facilities without ensuring stable electricity, a supply of consumables, or staff trained to operate and maintain them. Over time, these machines became idle or prematurely broke down, wasting

resources and eroding community trust. The shortfall emphasizes the importance of infrastructure alignment and ongoing maintenance planning.

- **EHR Pilot in Tanzania (Stalled Pilot):** Initially promising, this electronic health

records system lost momentum when external pilot funding ended. Local staff who never fully adopted or took ownership went back to paper-based methods. Contributing factors included insufficient training, the lack of a long-term plan for data storage, and difficulties gaining buy-in from frontline clinicians.

- **Telemedicine Kiosks:** In several SSA countries, kiosk-style telemedicine stations were introduced to provide remote consultations. While conceptually beneficial, connectivity issues, overly complicated user interfaces for community health workers, and a lack of an operational funding model led these kiosks to fall into disuse. Local trust waned as repeated outages or error messages plagued early adopters.

It is not enough to secure an initial pilot grant or donation; one must ensure genuine local ownership and an adaptable, context-appropriate model. By referencing these partial or complete failures, future innovators can proactively mitigate such pitfalls, ensuring that well-intentioned efforts do not unintentionally waste resources or undermine confidence in digital health solutions. Taking this into account, the following section presents why affordability is important and it also presents a new definition of affordable health technology with requirements in designing one.

Table 5 Concise Overview of Common Themes Behind Partial or Failed Interventions

No. Initiative	A. Challenges ¹						
	1)	2)	3)	4)	5)	6)	7)
Donation of High-End Imaging Equipment	✓	✓	✓	✓			✓
EHR Pilot in Tanzania		✓		✓	✓		✓
3. Telemedicine Kiosks	✓	✓		✓		✓	

4.3 Defining Affordable Health Technology

Section 4.1 highlighted how technology is increasingly being leveraged to improve healthcare access, affordability, and quality across SSA, a trend mirroring the broader push for innovative, tech-driven solutions in the continent's healthcare sector. Yet,

implementing these digital health initiatives remains challenging. We first start with a proper

definition of affordable health technology.

As per our investigation, a clear and operational definition of what constitutes an affordable health technology is lacking. Merely considering low-cost as an affordable technique is insufficient to determine the value and affordability of a given health technology. Therefore, in this section, we present the first more comprehensive and practical definition of affordable health technology:

Affordable Health Technology is an integrated set of cost-effective, accessible, sustainable, scalable, and context-appropriate technological solutions designed to improve health care delivery and outcomes in resource-constrained settings without imposing undue burdens on individuals, communities, or health systems.

A truly affordable health technology must combine multiple characteristics. It should be cost-effective by providing comparable or better health outcomes at lower overall cost than conventional solutions; it must be accessible to people in remote or underserved communities; it must be sustainable, taking into account environmental impacts and long-term usage patterns; and it should be readily scalable to benefit wider populations without exponentially increasing costs. This expansive concept can incorporate digital platforms, devices, and systems or combinations that are integral in delivering medical care and managing health economically. This holistic approach to defining affordability is more likely to produce solutions that can thrive in the often rugged and diverse contexts found across SSA.

4.4 Core Requirements for Designing Affordable Health Innovation

Drawing on the successes and challenges outlined in Tables 4 and 5 and their related discussions, six fundamental requirements emerge for medical technologies to be both effective and truly affordable in SSA. Below, each requirement is described with some examples from the results section:

1. **Deep Understanding of the Market:** Developers must conduct immersive field-work and partner closely with local stakeholders to ensure technologies fit daily realities. For example, Baobab Health Trust spent significant time understanding Malawi's rural clinic workflows and offline needs before implementing low-cost digital tools for disease tracking. Similarly, Wasipito in Cameroon targeted user-friendly mobile interfaces after recognizing spotty internet access and limited smartphone familiarity among patients and providers. Such ground-level insight ensures solutions are not just technologically sound but also culturally and infrastructurally appropriate.
2. **Affordability and Scalability:** The product must remain both low-cost in operation and readily expandable across regions. mPharma achieves this by providing centralized inventory management to pharmacies and hospitals, reducing medication prices without losing quality, and easily replicating the model in new locations. Likewise, M-TIBA harnesses existing mobile money networks to deliver micro-insurance at scale; minimal overhead and pay-as-you-go options lower financial barriers for end users. These examples show how controlling recurrent expenses (e.

g., maintenance, consumables) and tapping larger markets help make solutions simultaneously economical and scalable.

3. Innovation in Distribution: Because large segments of SSA populations live in remote or hard-to-reach areas, distributing products or services effectively can be a major obstacle. Zipline exemplifies a creative response by using drones to deliver blood products and medications to rural hospitals, drastically cutting transport

time. The success of Zipline hinges on integrating with each country's regulatory

framework and placing drone hubs strategically. This approach underscores that well-chosen distribution methods, whether drones, mobile apps, or marketplaces like Medstore, are vital to bridging geography-based disparities in care.

4. **Local Engagement:** Gaining community trust and involving local actors at every stage fosters meaningful adoption. Rocket Health partners with Uganda health-care staff for teleconsultations and invests in training both licensed pharmacists and home-visit lab technicians. By embedding technology in established community practices, the service garners acceptance and smooth day-to-day operations. Local stewardship has similarly proven essential for the AI-based RHDS Screening via PCG, where Ethiopian community health workers accept the tool because of ongoing training and collaboration with local cardiologists.
5. **Commitment Beyond Profit:** While financial sustainability is crucial, solutions must also serve a genuine social purpose. Sproxil, for instance, addresses counterfeit drug risks without imposing hefty fees on end users; basic scratch-and-text mechanisms are virtually free for patients. Meanwhile, Turaco focuses on cost-effective insurance policies that truly protect the low-income segment, rather than just maximizing returns. Embedding social impact objectives into the business model helps maintain affordable pricing, attract community trust, and enable long-term viability.
6. **Task Sharing/Task Shifting:** Designers and developers should prioritize automating routine, repetitive tasks in a way that allows staff with minimal training to operate the technology safely. For instance, CAD4TB applies AI to chest X-rays, letting nurses or community health workers screen for TB with minimal specialist oversight. In resource-limited settings, where highly skilled medical professionals are scarce, these tools free up experts to focus on more complex and critical interventions. Building medical technologies that enable non-specialists to confidently perform basic screening or data collection significantly expands service capacity, thus ensuring more people receive timely care while specialized clinicians handle advanced procedures.

4.5 Limitations of the paper

While the narrative literature review method provided in-depth contextual understanding, it is not without limitations. First, it relies heavily on the availability of existing literature, which is very low in SSA. This is mainly evident in the list of failure (or partial failure) section where very few publications or reports were found. Second, the absence of a rigid systematic screening may introduce selection bias, as studies with less prominent publication venues or those focusing on negative results

could be underrepresented. Third, there is a risk of subjectivity in the thematic grouping and interpretation of results. To mitigate these limitations, the authors maintained detailed records of search strategies and actively sought out gray literature to capture a more holistic view of healthcare interventions in SSA.



5 Conclusion

SSA continues to bear a disproportionate disease burden, with shortages of qualified workers and under-resourced infrastructure intensifying the region's healthcare challenges.

However, targeted, “affordable” health technologies demonstrate that major strides can be made; mPharma slashes medication costs, M-TIBA broadens financial protection, Ziplines swiftly delivers critical supplies, and telemedicine expansions reduce mortality in remote communities.

The three research questions have thus been answered:

1. RQ1 asks “What is affordable health technology, and how can it become truly impactful?” This paper presents that an affordable health technology must be cost-effective, sustainable, accessible, scalable, and context-appropriate, delivering health improvements without imposing undue financial burdens on individuals or health systems. Merely labeling something as “low-cost” is insufficient; it must also include maintenance, support, and distribution strategies suitable for local constraints. The true impact of health technology in SSA depends on user-centered design (to ensure acceptance), a strong local ecosystem (government, telecoms, NGOs, etc.), and continued alignment with resource realities. This includes using simpler, more robust equipment, building telemedicine solutions that can run on basic connectivity, or micro-insurance models that offer low premiums but real coverage for the uninsured.
2. RQ2 explores “What core requirements must be met to design and implement an affordable solution?” Based on common themes and the paper's evidence, six essential elements emerged: (1) Deep Market Understanding: Designers/developers should conduct immersive fieldwork to grasp local needs, cultural dynamics, and logistical hurdles, (2) Affordability and Scalability: Solutions must keep ongoing costs (maintenance, consumables) low and offer modular or tiered pricing for broader reach, (3) Innovation in Distribution: Whether it's drones (Zipline) or a cloud-based system (Helium Health), distribution must overcome vast distances and remote settings, (4) Local Engagement: Project buy-in from community health workers, local businesses, or government fosters trust, adoption, and smooth scale-up, (5) Commitment Beyond Profit: Impact-driven businesses ensure sustainability in low-income markets—frugal innovation and micro-insurance highlight this, and (6) Task Sharing/Task Shifting: Simplify technology usage so that mid-level cadres (CHWs or nurses) can perform tasks normally handled by specialists.

3. RQ3 focuses on “What does a good solution look like, and why does some fail?” The following points summarize the distinguishing traits: “Good” solutions should align with local context (infrastructure, workforce skills, patient habits), provide tangible cost-savings or improved service for end-users, feature long-term maintenance/IT support and continuous training, showcase co-creation: early involvement of local stakeholders, and integrate well with existing systems (tele-coms, clinic workflows). The Common Causes of failure were infrastructure gaps, lack of local ownership, insufficient training, and no business model, i.e. if the

solution is purely grant-funded, it often halts upon project completion and Technology mismatch where solutions are too advanced (MRI in remote clinic) or misaligned (complex kiosk interfaces for CHWs).

Taken together, these findings highlight the potential for technology-driven transformations in SSA's healthcare landscape, provided solutions are rooted in local realities and follow the key enablers laid out above. By systematically addressing infrastructure gaps, co-creating with end-users, and ensuring sustainable financial models, future interventions can promote lasting impact and help close persistent healthcare disparities across the region.

Declarations

- Conflict of interest/Competing interests: There is no conflict of interest.
- Ethics approval and consent to participate: Not Applicable
- Consent for publication: Not Applicable
- Data availability: Not Applicable
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- Code availability: Not Applicable
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