

Architectural Frameworks for Scalable Digital Infrastructure and Secure Data Management in Resource-Constrained Organizations

Precious Nnamdi Ibe¹, Emmanuel Chukwuma Okeke², Ijeoma Mbonu³, Harouna Wendpanga Yann Christian Sankara^{4*}, Oluranti Ogundapo⁵, Olabode Michael Soneye⁶

¹ University of Port Harcourt, Port Harcourt, Nigeria

² IDEX Corporation, USA

³ Adeleke University, Nigeria

⁴ Independent Researcher, Dallas, TX, USA ORCID: <https://orcid.org/0009-0001-9263-8284>

⁵ NetBrain Technologies Inc., Canada

⁶ Ontario Health, Toronto, ON, Canada

* Corresponding author: Harouna Wendpanga Yann Christian Sankara, christiansankara@gmail.com

Abstract

Small and medium-sized enterprises, non-governmental organizations, public agencies in developing regions, community health providers, and educational institutions increasingly depend on digital infrastructure to deliver their core services. These organizations, however, operate under persistent constraints in budget, specialist skills, connectivity, and management attention. The acceleration of digital adoption during the COVID-19 pandemic widened their attack surface and exposed the fragility of improvised information technology arrangements. Established enterprise architecture frameworks such as TOGAF and Zachman, and security frameworks such as the NIST Cybersecurity Framework and ISO/IEC 27001, offer valuable guidance but presume organizational capacity that resource-constrained organizations rarely possess. This paper applies a design science research approach to develop the Tiered Adaptive Architecture Framework (TAAF), a layered and maturity-staged reference architecture that integrates scalable infrastructure design with secure data management. TAAF is organized around six layers (connectivity and endpoint; identity and access; compute and platform; data management; application and integration; and cross-cutting governance and operations) and three maturity tiers (Essential, Managed, and Optimized) that allow organizations to invest incrementally. The framework is grounded in seven design principles, including managed-first adoption, identity as the primary security perimeter, value-based data classification, and design for intermittent connectivity. Its utility is evaluated analytically through three illustrative scenarios and a comparative assessment against existing approaches. The analysis suggests that TAAF lowers the entry threshold for sound architecture practice, aligns security investment with data value, and preserves a credible path to scale. The paper concludes with implications for practitioners, policymakers, and researchers, and identifies the need for longitudinal empirical validation.

Keywords: enterprise architecture; scalable infrastructure; data security; zero trust; cloud computing; small and medium-sized enterprises; resource-constrained organizations; design science research

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1. INTRODUCTION

1.1 Background

Digital infrastructure has become the operating backbone of nearly every type of organization. Payment processing, patient records, donor management, student information systems, logistics, and internal communication now run on networked systems whose availability and integrity directly determine whether an organization can perform its mission. The World Bank (2021) argues that data has become a core development asset, capable of improving lives when it is governed well and of causing harm when it is not. At the same time, connectivity remains unevenly distributed. The International Telecommunication Union (2021) estimates that roughly a third of the world population remained offline in 2021, with the gap concentrated in least developed countries and rural areas.

Large enterprises address infrastructure and security through dedicated architecture teams, security operations centers, and multi-year transformation programs. Most organizations do not have these resources. Small and medium-sized enterprises (SMEs), which account for the majority of firms worldwide, as well as non-profit organizations, local government units, rural clinics, and schools, typically operate with a single generalist technician, an outsourced provider, or no designated IT staff at all. Their infrastructure is often assembled opportunistically: a consumer-grade router, a mix of personal and organizational devices, shared passwords, and a growing collection of cloud applications adopted without central oversight.

The COVID-19 pandemic accelerated this pattern. Organizations moved rapidly to remote work, online service delivery, and cloud collaboration tools, frequently without the architectural planning that such shifts would normally require. Threat actors exploited the resulting gaps. The European Union Agency for Cybersecurity (ENISA, 2021) reported that SMEs faced increased phishing, ransomware, and supply chain attacks during the pandemic while lacking the awareness, budget, and expertise needed to respond. The IBM Security (2021) Cost of a Data Breach Report found that average breach costs reached their highest level in the history of the study, with remote work a contributing factor.

1.2 Problem Statement

A substantial body of guidance exists for designing information systems and securing data. Enterprise architecture frameworks such as TOGAF (The Open Group, 2018) and the Zachman Framework (Zachman, 1987) provide comprehensive methods for aligning technology with business strategy. Security frameworks such as the NIST Cybersecurity Framework (NIST, 2018), ISO/IEC 27001 (ISO/IEC, 2013), and the CIS Critical Security Controls (Center for Internet Security, 2021) offer structured control

catalogs. Emerging models such as zero trust architecture (Rose et al., 2020) redefine how access should be granted in distributed environments.

These frameworks share a common limitation from the perspective of constrained organizations: they assume the presence of staff, budget, and governance structures capable of interpreting and operationalizing them. TOGAF, for example, describes an iterative Architecture Development Method with numerous phases, deliverables, and governance boards. An organization with three employees and an annual technology budget of a few thousand dollars cannot meaningfully execute it. Conversely, the informal practices that such organizations adopt in the absence of guidance tend to produce infrastructure that neither scales gracefully nor protects sensitive data adequately. There is, therefore, a gap between comprehensive but heavy frameworks and ad hoc practice. This paper addresses that gap.

1.3 Research Objectives and Questions

The objective of this study is to design and evaluate an architectural framework that enables resource-constrained organizations to build digital infrastructure that can scale with demand while managing data securely. The study is guided by three research questions:

- **RQ1:** What characteristics of resource-constrained organizations limit the applicability of existing architecture and security frameworks?
- **RQ2:** What design principles and architectural components should a framework include to support both scalability and secure data management under these constraints?
- **RQ3:** How does such a framework compare with existing approaches in terms of feasibility, security coverage, scalability, and cost proportionality?

1.4 Contributions

The paper makes three contributions. First, it synthesizes literature on information systems in constrained settings, cloud adoption, and security architecture into a multidimensional characterization of resource constraint. Second, it proposes the Tiered Adaptive Architecture Framework (TAAF), which combines a layered reference architecture with maturity tiers, a secure data lifecycle, and a control mapping to the NIST Cybersecurity Framework. Third, it provides an analytical evaluation of the framework through illustrative scenarios and a structured comparison with alternative approaches.

1.5 Structure of the Paper

Section 2 describes the research method, including the literature search and synthesis procedure and the design science approach. Section 3 presents the results and discussion: the literature synthesis, the conceptual model (the Tiered Adaptive Architecture Framework), its illustrative application and comparative assessment, and the implications and limitations of the study. Section 4 concludes and identifies directions for future research.

2. RESEARCH METHOD

This study adopts design science research (DSR), a paradigm in information systems research oriented toward creating and evaluating artifacts that solve identified problems (Hevner et al., 2004). The research follows the six-activity process model proposed by Peffers et al. (2007): problem identification and motivation, definition of objectives for a solution, design and development, demonstration, evaluation, and communication.

2.1 Literature Search and Synthesis

The literature base was assembled through two complementary routes. The first was a set of targeted keyword searches of scholarly indexes, publisher websites, and standards bodies, using terms that combined the core constructs of the study: enterprise architecture, cloud adoption, scalability, zero trust, identity and access management, data governance, data protection regulation, small and medium-sized enterprises, and developing countries. The second was a curated seed corpus of applied studies drawn from a consolidated peer reference collection, screened for relevance to digital infrastructure, cybersecurity, data management, and operations in resource-constrained settings.

Three inclusion criteria were applied. Sources had to address at least one of the study's constructs directly or offer a transferable practice from an adjacent domain; they had to be peer-reviewed articles, scholarly books, recognized standards, or authoritative institutional reports; and they had to be published in or before 2021, so that the synthesis reflects the state of knowledge at the time of writing. Bibliographic details of searched sources were checked against publisher records. The final corpus comprises 200 sources, 100 from each route.

The sources were analyzed through thematic synthesis. Each source was coded against five themes: organizational constraint, architecture and service management, cloud and edge infrastructure, security architecture, and data governance and resilience. The themes structure Section 3.1, and the gaps identified across them define the requirements for the conceptual model in Section 3.2. Applied seed studies were used mainly to ground the model's practices and illustrative scenarios, while searched sources supplied the theoretical and normative foundations.

2.2 Problem Identification and Objectives

The problem was identified through the literature synthesis presented in Section 3.1, which established both the practical need and the limitations of existing frameworks. From this analysis, five solution objectives were derived. The framework should be (O1) feasible for organizations without dedicated architecture or security staff; (O2) incremental, allowing value to be realized at each stage of investment; (O3) integrated, addressing infrastructure, security, and data governance together; (O4) scalable, supporting growth without requiring wholesale redesign; and (O5) standards-aligned, mapping to established frameworks so that organizations can later pursue formal compliance.

2.3 Design and Development

The artifact was developed through iterative synthesis. Design principles were extracted from the literature and from widely accepted practitioner guidance, including the CIS Controls, NIST SP 800-207, and NIST SP 800-63B. Architectural layers were derived by consolidating the domains common to TOGAF technology architecture, the NIST Cybersecurity Framework categories, and cloud reference models. Maturity tiers were defined by grouping practices according to their cost, required skill, and risk reduction, drawing on the prioritization logic of the CIS implementation groups.

2.4 Demonstration and Evaluation

Hevner et al. (2004) identify several evaluation methods for design artifacts, including observational, analytical, experimental, testing, and descriptive approaches. Given the scope of this paper, evaluation is analytical and descriptive. The framework is demonstrated through three illustrative scenarios constructed to represent common types of constrained organizations. These scenarios are composites informed by the literature rather than case studies of specific organizations, and their purpose is to test the internal coherence and applicability of the framework. The framework is then compared with three alternative approaches against criteria derived from the solution objectives. The limitations of this evaluation approach are discussed in Section 3.6.

3. RESULTS AND DISCUSSION

This section presents the results of the study in three parts. Section 3.1 reports the literature synthesis, Section 3.2 presents the conceptual model that was designed from it, and Sections 3.3 to 3.6 discuss the model through illustrative application, comparison, implications, and limitations.

3.1 Literature Synthesis

3.1.1 Characterizing Resource-Constrained Organizations

Resource constraint is frequently treated as a synonym for small size, but the literature suggests a more nuanced picture. Research on information systems in developing countries has long observed that systems designed in well-resourced contexts often fail when transferred to settings with different infrastructure, skills, and institutional conditions. Heeks (2002) described this phenomenon as a design-reality gap, in which the assumptions embedded in a system diverge from the realities of the environment in which it is deployed. Walsham and Sahay (2006) similarly emphasized the importance of local context, capacity building, and sustainability in technology interventions.

Studies of cloud adoption among SMEs further identify the specific constraints that shape technology decisions. Alshamaila et al. (2013) found that relative advantage, uncertainty, compatibility, firm size, top management support, and supplier capability all influence whether SMEs adopt cloud

services. Senyo et al. (2018), in a review of cloud computing research, noted that cost, security concerns, and limited expertise recur as barriers across contexts.

Studies of small and medium-sized enterprises, including those in developing economies, confirm that cybersecurity practices and security investment are shaped by size, resources, and owner perceptions (Gupta & Hammond, 2005; Heidt et al., 2019; Kabanda et al., 2018; Osborn & Simpson, 2017), and adoption research grounded in the technology-organization-environment framework identifies compatibility, cost, and top management support as decisive (Gangwar et al., 2015; Low et al., 2011; Oliveira et al., 2014; Tornatzky & Fleischer, 1990). Recent work on small business operations reinforces this characterization. Reviews of digital transformation in operations management describe how automation, analytics, and process redesign are reshaping smaller firms (Agboada et al., 2018), while lean process research shows that standard operating procedures, lightweight Six Sigma adaptations, and process re-engineering can be scaled down for organizations with limited capacity (Agboada et al., 2019; Ambali et al., 2021; Ebisi et al., 2021). Work on translating tax and regulatory requirements into SME compliance workflows and on coordinating governance across business partners illustrates the administrative load that small firms carry (Eyetsemitan et al., 2020; Eyetsemitan et al., 2021), and research on creator businesses shows that even solo enterprises must build operational infrastructure as they scale (Anyanwu, 2021). Studies of multi-branch SMEs show that IT support must balance cost against operational continuity, that maturity models can standardize support across distributed offices, and that first-contact resolution depends on workforce competency (Anyanwu, 2019; Anyanwu, 2020; Wikiri, 2021).

Financial and infrastructural contexts display similar patterns. Fintech-enabled transaction banking and digital lending have expanded the digital footprint of small firms (Okafor et al., 2021), and research on web-based payment portal adoption in Sub-Saharan Africa identifies the determinants that shape uptake (Agyei et al., 2019). Studies of high-throughput collections platforms show how payment infrastructure must scale as transaction volumes grow (Osuji et al., 2021). Infrastructure constraints are equally material: research on solar power for small-scale manufacturers, load distribution in hybrid solar installations, and affordable microgrids for underserved communities documents how unreliable grid power shapes technology choices in developing economies (Komi & Adeniji, 2020; Sunday & Omoegun, 2018; Sunday & Omoegun, 2019). Broader development research cautions that the benefits of information and communication technologies are uneven and depend on local institutional conditions (Avgerou, 2008; Brewer et al., 2005; Heeks, 2010). Drawing on these sources, this paper characterizes resource constraint along five dimensions, summarized in Table 1.

Table 1. Dimensions of Resource Constraint and Their Architectural Implications

Dimension	Typical Manifestation	Architectural Implication
Financial	Small, irregular, or grant-dependent IT budgets; preference for operating over capital expense	Favor pay-as-you-go and free-tier services; avoid large upfront hardware purchases

Dimension	Typical Manifestation	Architectural Implication
Human and skills	No dedicated IT staff, or one generalist; reliance on volunteers or vendors	Minimize operational complexity; prefer managed services and automation
Infrastructural	Unreliable power, limited or costly bandwidth, intermittent connectivity	Design for offline operation, synchronization, and graceful degradation
Governance	Informal policies, unclear data ownership, limited board oversight of technology	Provide lightweight, template-based policies and clear accountability
Attention and time	Technology competes with core mission for leadership attention	Offer prioritized, staged guidance rather than exhaustive control catalogs

Note. Synthesized from Heeks (2002), Walsham and Sahay (2006), Alshamaila et al. (2013), Senyo et al. (2018), and ENISA (2021).

3.1.2 Enterprise Architecture Frameworks

Enterprise architecture (EA) frameworks provide structured approaches for describing and governing the relationship between business processes, information, applications, and technology. The Zachman Framework (Zachman, 1987) offers a classification schema organized by stakeholder perspective and interrogative (what, how, where, who, when, why). TOGAF (The Open Group, 2018) provides both a content framework and a process, the Architecture Development Method, for iteratively developing and governing architecture. Software architecture literature complements these with attention to quality attributes such as performance, availability, modifiability, and security, and with tactics for achieving them (Bass et al., 2012).

EA frameworks are valuable because they encourage organizations to make architectural decisions deliberately and to document them. Their weakness for constrained organizations lies in their breadth and process overhead. They are designed as meta-frameworks to be tailored, but tailoring itself requires expertise. As a result, constrained organizations tend either to ignore EA entirely or to adopt fragments without the connective reasoning that makes them useful.

Practitioner-oriented EA literature emphasizes that architecture should create a foundation for execution rather than become a documentation exercise (Lankhorst, 2017; Ross et al., 2006), and standards such as ISO/IEC/IEEE 42010 and evaluation methods such as ATAM provide lighter ways to describe and assess architectures (ISO/IEC/IEEE, 2011; Kazman et al., 2000). Applied information systems research offers further guidance on how architecture is realized in practice. Studies of ETL design and data integration in CRM-centric enterprise architectures, CI/CD pipeline strategies, and comparative evaluation of DevOps tooling show how disciplined engineering keeps integrated systems maintainable (Badmus et al., 2018; Badmus et al., 2019a; Badmus et al., 2020), and platform governance frameworks for regulated healthcare environments illustrate how configuration and access must be controlled as platforms grow (Badmus et al., 2019b). Research on standardizing change management mechanisms in large organizations and on developing technology talent in emerging markets underlines that architecture

depends on people and processes as well as technology (Uzondu et al., 2021; Wikiri, 2019). DevOps and site reliability engineering research demonstrates that automation and measurement improve both delivery speed and stability (Beyer et al., 2016; Forsgren et al., 2018; Humble & Farley, 2010; Kim et al., 2016).

3.1.3 Cloud, Hybrid, and Edge Infrastructure

Cloud computing has transformed the economics of infrastructure. The NIST definition identifies on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service as essential characteristics, delivered through software, platform, and infrastructure service models (Mell & Grance, 2011). Armbrust et al. (2010) highlighted that cloud computing converts capital expenditure into operating expenditure and allows organizations to scale resources in response to demand without overprovisioning. For constrained organizations, these properties are especially attractive: they reduce the need to purchase and maintain hardware and shift routine operational work, such as patching physical servers, to the provider.

Cloud adoption also introduces dependencies. Reliable connectivity becomes a prerequisite, costs can grow unpredictably without governance, and organizations may become locked into proprietary services. Edge computing, which places computation close to where data is generated, offers a partial response to connectivity limitations by enabling local processing and later synchronization (Shi et al., 2016). Container orchestration platforms such as Kubernetes provide portability across environments (Burns et al., 2016), although their operational complexity is often disproportionate for small organizations. Data-intensive system design further reminds architects that distributed systems involve trade-offs among consistency, availability, and partition tolerance that must be chosen consciously (Brewer, 2012; Kleppmann, 2017).

Cloud adoption also has a business dimension: it changes cost structures, sourcing relationships, and the skills an organization needs (Marston et al., 2011), and in developing economies it offers particular promise alongside particular infrastructure risks (Kshetri, 2010). A growing body of applied research examines the mechanics of scalability. Auto-scaling techniques for elastic applications (Lorido-Botran et al., 2014), models for energy-efficient virtual machine placement and constraint-based network resource allocation (Ahmed & Odejebi, 2018b; Ahmed et al., 2019), approximation models for cloud database optimization (Odejebi et al., 2019), and machine learning approaches to resource scaling (Ahmed et al., 2020) all aim to align capacity with demand and cost. Serverless computing extends this logic by removing server management altogether and charging per execution (Baldini et al., 2017; Jonas et al., 2019). Frameworks for scalable and secure enterprise messaging and for multi-tenant productivity deployments under high concurrency show that scalability and security must be engineered together (Ahmed & Odejebi, 2018a; Odejebi & Ahmed, 2018b). Migration research emphasizes phased approaches and the risk of underestimating integration effort (Jamshidi et al., 2013), and vendor lock-in research addresses the tension between flexibility and dependency (Opara-Martins et al., 2016). Infrastructure as code governance and identity integration across hybrid and multi-cloud environments have emerged as key controls for cloud estates (Mbonu, Aliliele, et al., 2020; Mbonu, Iwuanyanwu, et al., 2020b; Morris, 2016), and data-driven cost management models support oversight of technology spending (Oduleye & Medon, 2021). Containers and microservices extend these patterns toward finer-grained, independently scalable

components (Dragoni et al., 2017; Newman, 2021; Pahl, 2015), while big data workloads on cloud platforms raise their own scalability questions (Hashem et al., 2015). Predictive maintenance models for e-commerce systems built on cloud analytics show how these capabilities can support operational reliability (Mayo et al., 2021).

For organizations with limited connectivity or power, fog and edge computing research shows how processing can move closer to users (Bonomi et al., 2012; Satyanarayanan, 2017), and field studies of rural wireless and telemedicine systems demonstrate that sustainability depends as much on local maintenance capacity as on technology (Brewer et al., 2005; Surana et al., 2008). An offline-first design framework for digital learning in low-connectivity environments offers a directly transferable pattern for synchronizing data when links are intermittent (Unamma et al., 2018), and data-informed digital learning platforms show that such systems can still support evidence-based decisions (Orise & Niniola, 2020). Telecommunications deployment studies and reviews of product strategy in mobile network rollouts across emerging markets address the connectivity on which these designs depend (Amayo & Popoola, 2017b; Sanni et al., 2020c). Reliability engineering, predictive maintenance, and condition monitoring research from critical power and energy infrastructure supplies methods for keeping local equipment available (Adaramola et al., 2018; Gideon et al., 2019; Sunday et al., 2020).

3.1.4 Security Architecture: From Perimeter to Zero Trust

Classical security design principles, including least privilege, economy of mechanism, fail-safe defaults, and complete mediation, remain foundational (Saltzer & Schroeder, 1975). Historically, many organizations implemented these principles through a network perimeter model that treated internal networks as trusted. The rise of cloud services, mobile devices, and remote work has eroded that perimeter. Kindervag (2010) proposed the zero trust model, which removes implicit trust based on network location. NIST Special Publication 800-207 formalized zero trust architecture as an approach in which access to resources is granted per session, based on identity, device posture, and policy, and in which all communication is secured regardless of network location (Rose et al., 2020).

Control frameworks provide catalogs of safeguards. The NIST Cybersecurity Framework organizes activities into five functions: Identify, Protect, Detect, Respond, and Recover (NIST, 2018). The CIS Controls version 8 introduced implementation groups that prioritize safeguards according to organizational capability, with Implementation Group 1 described as essential cyber hygiene for organizations with limited resources (Center for Internet Security, 2021). This prioritization is directly relevant to the present study. Digital identity guidance, particularly NIST SP 800-63B, provides evidence-based recommendations on authentication, including the use of multi-factor authentication and the abandonment of arbitrary password complexity and rotation rules (Grassi et al., 2017). Threat modeling offers a structured way to anticipate how systems may be attacked (Shostack, 2014). The Verizon (2021) Data Breach Investigations Report consistently identifies phishing, stolen credentials, and misconfiguration as leading causes of breaches, suggesting that identity controls and secure configuration deliver disproportionate value.

The BeyondCorp initiative demonstrated at scale that access can be decided by user and device rather than network location (Gilman & Barth, 2017; Ward & Beyer, 2014), and early surveys of cloud security identified the multi-tenancy and shared responsibility issues that motivate this shift (Subashini & Kavitha, 2011; Takabi et al., 2010). Applied studies have extended zero trust further, proposing identity-centric zero trust governance for enterprises (Ogbole, Okoruwa, Fadayomi, et al., 2021) and zero trust for operational technology in critical infrastructure (Ahmed et al., 2021). Identity and access management research addresses integration across hybrid and multi-cloud environments and federated systems (Mbonu, Aliliele, et al., 2020; Oshoba et al., 2019), and studies of Active Directory highlight both its centrality to enterprise networks and the lessons of offline security assessment (Ladapo et al., 2018; Ladapo et al., 2019). Comparative evaluation of authentication schemes explains why passwords persist despite their weaknesses (Bonneau et al., 2012). Privacy-centric security engineering and risk-based assurance models connect these controls to data availability and protection (Anderson, 2020; Fadayomi et al., 2019; Okoruwa et al., 2020).

A parallel stream of work focuses on detection, response, and validation. It covers insider threat modeling, security audit and enterprise risk assessment, intrusion detection, and incident response and forensics (Akeju et al., 2018; Cichonski et al., 2012; Dosunmu & Ogundele, 2019; Dosunmu & Ogundele, 2020; Dosunmu & Ogundele, 2021); adversary behavior models such as MITRE ATT&CK (Strom et al., 2018); the economics of security investment (Gordon & Loeb, 2002); and log analytics with SIEM platforms and automated incident response (Mbonu, Iwuanyanwu, et al., 2019). Applications of artificial intelligence to secure software testing and regression control, and forensic analytics for VoIP-enabled fraud, address specific technical exposures (Mbonu, Aliliele, et al., 2021b; Mbonu, Iwuanyanwu, et al., 2021). Ransomware research shows that many attacks rely on relatively simple techniques that sound backup and access controls can defeat (Kharraz et al., 2015), and malware targeting cloud-native microservices in edge architectures is an emerging concern (Idika et al., 2021). Analyses of cybercrime during the pandemic confirm the surge in phishing and ransomware that accompanied rapid digitalization (Dwivedi et al., 2020; Lallie et al., 2021).

Research on operational technology security, including NERC CIP compliance in electric utilities, shows that these concerns extend to the physical infrastructure that many small utilities and facilities operate (Adegbite et al., 2020). Integrated cybersecurity and anti-money laundering governance demonstrates how security can be embedded in wider compliance programs (Fadayomi et al., 2021). Catalog-based control baselines such as NIST SP 800-53 and small business guidance such as NISTIR 7621 represent two ends of the spectrum between comprehensiveness and accessibility (Joint Task Force, 2020; Paulsen & Toth, 2016).

Human behavior remains a decisive variable. Information systems research shows that policy compliance depends on employees' beliefs about costs and benefits (Bulgurcu et al., 2010), that violations are often rationalized through neutralization techniques (Siponen & Vance, 2010), and that users may rationally reject security advice whose burden exceeds its perceived value (Herley, 2009). Studies in Nigerian university registries document gaps in information security awareness and records confidentiality (Onche et al., 2020), and ethics and compliance training frameworks offer methods for producing measurable behavioral change (Anichukwueze et al., 2020).

3.1.5 Data Management and Governance

Secure data management encompasses the full lifecycle of data: creation or collection, storage, use, sharing, archiving, and destruction. Regulatory developments have raised the stakes. The European Union General Data Protection Regulation (Regulation (EU) 2016/679) established principles of lawfulness, purpose limitation, data minimization, accuracy, storage limitation, integrity, and confidentiality. Comparable instruments have appeared elsewhere, including the Nigeria Data Protection Regulation (NITDA, 2019) and South Africa's Protection of Personal Information Act, which came into full effect in 2021. These regimes apply to organizations regardless of size, although enforcement and penalty structures vary.

Practical data protection also depends on resilient backup. The widely cited 3-2-1 rule recommends keeping three copies of data, on two different media, with one copy off-site (Krogh, 2009). The prevalence of ransomware has led practitioners to emphasize that at least one copy should be immutable or offline. The Cloud Security Alliance (2021) Cloud Controls Matrix version 4 provides a control framework specifically for cloud environments, including data security and information lifecycle management domains.

Data governance research distinguishes decision domains such as data quality, metadata, access, and lifecycle, and assigns accountability for each (Abraham & Schneider, 2019; DAMA International, 2017; Khatri & Brown, 2010). Applied work provides detailed mechanisms for this lifecycle. Legal and ethical risk modeling for enterprise data protection governance (Mbonu et al., 2018), risk-based business intelligence architecture for financial technology platforms (Mbonu, Aliliele, et al., 2021a), and agile digital transformation with embedded IT risk and ISO compliance controls (Mbonu, Iwuanyanwu, et al., 2020a) illustrate how classification and control can be built into data platforms and processes. Comparative studies of data protection regulation and secure cloud implementation across jurisdictions (Mbonu, Aliliele, et al., 2019; Tankard, 2016; Voigt, 2017), work on embedding privacy by design in corporate restructuring (Ominyi, 2021), and privacy by design as a general philosophy (Cavoukian, 2009) highlight the compliance complexity facing organizations. Cyber risk maturity assessment against NAICOM and NDPR requirements offers a practical evaluation model from the Nigerian context (Fadero et al., 2021). In health contexts, research addresses interoperability and data quality as the backbone of health system transformation (Ilodigwe & Adesemoye, 2021), integrated laboratory information systems for infection detection (Abdulrazaq et al., 2019), diagnostic quality systems in resource-limited laboratories (Yusuf & Abdulrazaq, 2018), and multi-laboratory national reporting networks for surveillance (Yusuf et al., 2020).

Several integrity mechanisms have also been proposed. Blockchain-based audit trails for cloud configuration and tamper-proof regulatory recordkeeping aim to make records verifiable (Anichukwueze et al., 2021; Oshoba et al., 2020), and traceability and chain-of-custody frameworks from pharmaceutical supply chains show how provenance can be preserved across many parties (Aneke & Adesemoye, 2019). End-to-end visibility frameworks for complex supply chains apply similar principles to operational data (Nnabueze et al., 2021). Key management and media sanitization guidance provide the operational detail needed to make encryption and disposal effective (Barker, 2020; Kissel et al., 2014).

Resilience research supports the emphasis on recovery. Contingency planning guidance establishes the principles of business impact analysis and recovery strategy (Swanson et al., 2010), and studies of business continuity and disaster recovery in African financial services during the COVID-19 pandemic (Fadero et al., 2020) and of supply chain resilience after disruption (Anene, 2021) show that recovery capability has measurable value.

3.1.6 Synthesis and Research Gap

The literature reveals three gaps. First, architecture frameworks and security frameworks are largely developed and applied separately, even though infrastructure decisions and security outcomes are tightly coupled. Second, while some frameworks, notably the CIS Controls implementation groups, acknowledge differences in organizational capability, few provide an integrated, staged pathway that links infrastructure scalability, security controls, and data governance. Third, constrained-context research has documented the failure of transplanted designs but has offered relatively few prescriptive architectural artifacts. TAAF is designed to address these gaps.

3.2 Conceptual Model: The Tiered Adaptive Architecture Framework (TAAF)

TAAF is the conceptual model proposed by this study. It is a reference architecture composed of four elements: a set of design principles, a six-layer architectural model, three maturity tiers, and a secure data lifecycle with associated controls. Figure 1 presents the overall structure.

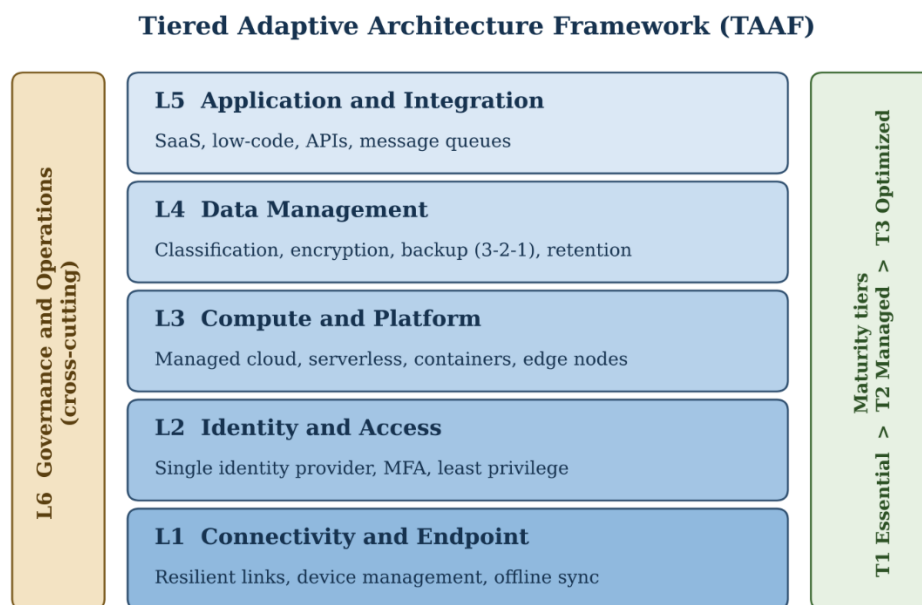


Figure 1. Structure of the Tiered Adaptive Architecture Framework

Note. Layers L1 through L5 are stacked by dependency. L6 spans all layers. Each layer is implemented progressively through tiers T1 to T3.

3.2.1 Design Principles

Seven principles guide decisions within every layer of the framework. They are intended to be memorable and actionable for a non-specialist decision maker.

- **P1. Managed first.** Prefer software-as-a-service and managed platform services over self-hosted systems whenever they meet functional and regulatory requirements. Managed services transfer patching, availability, and much of the physical security burden to providers whose scale allows them to perform these functions more reliably.
- **P2. Grow incrementally.** Choose components that can scale horizontally or by changing a subscription tier, rather than components that require replacement as demand grows. Avoid premature complexity; adopt advanced patterns only when a measured need arises.
- **P3. Identity is the perimeter.** Consolidate user accounts under a single identity provider, enforce multi-factor authentication, and grant access according to role and least privilege. This principle operationalizes zero trust in a form that constrained organizations can achieve.
- **P4. Protect data according to its value.** Classify data into a small number of categories and apply controls proportionate to sensitivity and regulatory obligation, rather than attempting uniform protection of everything.
- **P5. Automate the repetitive.** Automate updates, backups, account provisioning, and configuration wherever possible, since manual routines are the first to lapse when staff are overstretched.
- **P6. Design for failure and disconnection.** Assume that power, connectivity, and individual services will fail. Prefer applications that support offline operation and later synchronization, and ensure that recovery is tested.
- **P7. Favor open standards and portability.** Prefer services that support standard protocols and data export formats, such as SAML or OpenID Connect for identity and CSV, JSON, or SQL for data, so that the organization can change providers without losing its data.

3.2.2 Architectural Layers

Layer 1: Connectivity and Endpoint. This layer covers network access and the devices through which users interact with systems. In constrained settings, connectivity may be unreliable or expensive, and devices are frequently heterogeneous, including personally owned phones and laptops. Core practices include maintaining an inventory of devices, enabling automatic operating system updates, enforcing device encryption and screen locks, and, at higher tiers, enrolling devices in a mobile device management service. Where connectivity is poor, the architecture should incorporate redundant links, such as a primary fixed line and a cellular backup, and should prioritize applications that function offline.

Layer 2: Identity and Access. This layer establishes who can access what. At the Essential tier, the organization consolidates accounts in a single identity provider, which is often bundled with a

productivity suite, eliminates shared accounts, and enforces multi-factor authentication for all users, beginning with administrators and email. Password guidance follows NIST SP 800-63B, favoring length and password managers over forced complexity and periodic rotation (Grassi et al., 2017). At higher tiers, single sign-on is extended to all applications, access reviews occur periodically, and conditional access policies consider device health and location, approximating the policy decision point described in zero trust architecture (Rose et al., 2020).

Layer 3: Compute and Platform. This layer hosts workloads that cannot be satisfied by off-the-shelf applications. Following P1 and P2, the framework recommends a progression from pure SaaS, to managed platform services and serverless functions, to containers only where portability or workload characteristics justify the operational overhead. Serverless and managed database services scale automatically and charge according to use, which aligns cost with demand. For organizations with significant offline needs, a small edge node, such as a low-power local server or network-attached storage device, can provide local caching and processing, synchronizing with cloud services when connectivity permits (Shi et al., 2016).

Layer 4: Data Management. This layer governs how data is classified, stored, protected, retained, and disposed of. It is described in detail in Section 3.2.4.

Layer 5: Application and Integration. This layer comprises the business applications and the connections between them. Constrained organizations often accumulate disconnected tools, producing duplicate data entry and inconsistent records. The framework recommends selecting a small number of core systems of record, connecting them through vendor-supported integrations or low-code automation platforms, and, at higher tiers, adopting application programming interfaces and asynchronous messaging so that systems are loosely coupled and can scale independently (Kleppmann, 2017).

Layer 6: Governance and Operations. This cross-cutting layer provides the policies, roles, and routines that keep the other layers effective. It includes assigning an accountable owner for technology and data, maintaining a concise acceptable use policy, a data protection policy, and an incident response plan, monitoring costs, and reviewing third-party providers. Governance artifacts at the Essential tier should be short and template-based; the aim is clarity of responsibility rather than documentation volume.

Governance in TAAF draws on the observation that digital transformation is primarily an organizational change process rather than a purely technical one (Vial, 2019). Standard operating procedures make governance routines repeatable even when staff change (Agboada et al., 2019), and integrated data visualization, executive decision systems, and business intelligence dashboards support continuous monitoring of performance (Lawal & Oduleye, 2019b; Ogbole, Okoruwa, Babatope, et al., 2021; Sanni & Atima, 2021b). Research on standardized contract review, shared responsibility, and multi-jurisdictional compliance informs how vendor relationships should be governed (Ominyi & Anichukwueze, 2020; Ominyi & Anichukwueze, 2021; Ominyi et al., 2021; Ominyi, 2020; Uchechi et al., 2021), and procurement automation and vendor governance frameworks support transparent, cost-effective sourcing of managed services (Ahiake Patrick et al., 2020; Akinleye & Adeyoyin, 2021; Okonkwo et al., 2019).

3.2.3 Maturity Tiers

TAAF defines three tiers that allow organizations to adopt the framework progressively. **Tier 1 (Essential)** contains low-cost, high-impact practices that any organization can implement with limited skills, often within existing subscriptions. **Tier 2 (Managed)** introduces centralized management, automation, and formal routines, typically requiring modest additional spending or part-time specialist support. **Tier 3 (Optimized)** adds advanced capabilities such as conditional access, infrastructure as code, centralized logging, and automated recovery testing, appropriate for organizations that handle highly sensitive data or that have grown substantially. Table 2 summarizes representative practices for each layer and tier.

Table 2. Representative Practices by Layer and Maturity Tier

Layer	Tier 1: Essential	Tier 2: Managed	Tier 3: Optimized
L1 Connectivity and Endpoint	Device inventory; automatic updates; full-disk encryption; screen locks	Mobile device management; backup internet link; endpoint protection	Device compliance checks tied to access; network segmentation
L2 Identity and Access	Single identity provider; MFA for all; no shared accounts; password manager	Single sign-on for major apps; role-based access; joiner-mover-leaver process	Conditional access; phishing-resistant MFA; periodic access reviews
L3 Compute and Platform	SaaS for core functions; avoid self-hosted servers	Managed databases and serverless functions; budget alerts	Infrastructure as code; containers where justified; multi-region options
L4 Data Management	Three-level classification; automated cloud backup; encryption at rest	3-2-1 backup with immutable copy; retention schedule; data sharing rules	Data loss prevention; key management; automated restore testing
L5 Application and Integration	Few core systems of record; vendor integrations	Low-code automation; data export routines	APIs and message queues; event-driven integration
L6 Governance and Operations	Named owner; one-page policies; incident contact list	Incident response plan; vendor review; cost reviews	Centralized logging and alerting; tabletop exercises; metrics

Note. Practices are cumulative. An organization at Tier 2 is expected to maintain Tier 1 practices.

3.2.4 Secure Data Management Lifecycle

Layer 4 is organized around a seven-stage data lifecycle. Each stage is linked to specific controls whose intensity depends on data classification. TAAF recommends a three-level scheme that is simple enough for non-specialist staff to apply consistently: **Public** (information intended for open release), **Internal**

(operational information whose disclosure would cause limited harm), and **Restricted** (personal data, financial records, health information, credentials, and any data subject to regulatory obligations).

- **Classify.** Identify the main data sets the organization holds, where they are stored, who owns them, and which classification applies. A simple data register, maintained as a spreadsheet, is sufficient at Tier 1.
- **Collect and minimize.** Collect only the data needed for a defined purpose, consistent with the data minimization principle of the GDPR and comparable laws. Unnecessary data is a liability that consumes storage and expands breach impact.
- **Store and encrypt.** Store Restricted data only in approved systems that provide encryption at rest and in transit. Avoid storing Restricted data on removable media or personal accounts.
- **Use and process.** Grant access on a least-privilege basis through the identity layer. Log access to Restricted data where the platform supports it.
- **Share.** Define approved channels for sharing data with partners, prefer time-limited links over attachments, and execute data processing agreements with service providers.
- **Retain and back up.** Apply a retention schedule aligned with legal requirements. Back up according to the 3-2-1 rule, ensure at least one copy is immutable or offline, and test restoration periodically. Note that SaaS providers typically operate under a shared responsibility model and may not protect against accidental deletion or account compromise, so independent backup of critical SaaS data is advisable.
- **Dispose.** Securely delete data at the end of its retention period and sanitize or destroy devices before disposal or reuse.

3.2.5 Scalability Patterns

Scalability in TAAF is understood in three senses: technical scalability, the ability of systems to handle increased load; organizational scalability, the ability to add users, sites, and functions without proportionate increases in administrative effort; and financial scalability, the ability of costs to grow in line with value rather than ahead of it. The framework encourages five patterns.

The first is *elastic managed services*, in which capacity is adjusted by the provider or by a configuration change rather than by procurement. The second is *stateless application design*, which allows additional instances to be added behind a load balancer when custom applications are needed. The third is *caching and content delivery*, which reduces bandwidth demand and improves performance for users on slow connections. The fourth is *asynchronous processing*, in which tasks are placed on queues and handled independently, so that temporary spikes do not overwhelm systems. The fifth is *template-driven provisioning*, in which new users, devices, or sites are configured from standard templates, supporting organizational scalability. Each pattern is accompanied by a financial guardrail: budget alerts, monthly cost review, and periodic removal of unused resources, since elastic resources can generate unexpected charges if left unmonitored (Armbrust et al., 2010).

Forecasting research on demand, revenue, and cash flow provides methods for anticipating these costs (Aifuwa et al., 2020; Lorigo-Botran et al., 2014; Tonoyan et al., 2021a; Tonoyan et al., 2021b).

3.2.6 Alignment with the NIST Cybersecurity Framework

To satisfy objective O5, TAAF practices are mapped to the five functions of the NIST Cybersecurity Framework. This mapping allows organizations to communicate their posture to funders, partners, or auditors in a widely recognized vocabulary and to use TAAF as a stepping stone toward fuller adoption of the NIST framework or ISO/IEC 27001. Table 3 provides a summary.

Table 3. Mapping of TAAF Practices to NIST Cybersecurity Framework Functions

NIST CSF Function	Primary TAAF Layers	Representative TAAF Practices
Identify	L4, L6	Device and data inventories; data classification; named owners; vendor review
Protect	L1, L2, L3, L4	MFA; least privilege; encryption; automatic updates; managed services; secure configuration
Detect	L1, L2, L6	Provider security alerts; sign-in anomaly alerts; endpoint protection; centralized logging at Tier 3
Respond	L6	Incident contact list; incident response plan; tabletop exercises
Recover	L4, L6	3-2-1 backups with immutable copy; restore testing; continuity procedures

3.2.7 Conceptual Relationships and Propositions

The conceptual model links three groups of constructs. Organizational constraints (financial, human, infrastructural, governance, and attention) act as antecedents that limit which practices an organization can adopt. Architectural practices, organized by layer and tier, are the mechanisms through which the organization responds. Outcomes are expressed in three dimensions: security and data protection, scalability, and cost proportionality. Governance (Layer 6) moderates the relationship between practices and outcomes by ensuring that practices are maintained and reviewed rather than implemented once and neglected. From these relationships, four propositions are derived for future empirical testing.

- **Proposition 1.** Adoption of Tier 1 identity and access practices (Layer 2) is associated with a lower incidence of credential-based security incidents, independent of organizational size.
- **Proposition 2.** Organizations that follow the managed-first principle achieve greater scalability per unit of IT staff effort than organizations that self-host comparable workloads.

- **Proposition 3.** Value-based data classification (Layer 4) improves cost proportionality by concentrating protective spending on Restricted data.
- **Proposition 4.** The positive effect of architectural practices on security and scalability outcomes is stronger where a named owner and periodic review routines (Layer 6) are in place.

3.3 Illustrative Application and Evaluation of the Model

This section discusses the conceptual model by applying it to three illustrative scenarios and comparing it with alternative approaches.

3.3.1 Evaluation Criteria

The framework is evaluated against five criteria derived from the solution objectives: feasibility (O1), incremental value (O2), integration of infrastructure, security, and data governance (O3), scalability (O4), and standards alignment (O5). An additional criterion, cost proportionality, reflects the financial constraint emphasized throughout the literature.

3.3.2 Illustrative Application Scenarios

Scenario A: A community non-governmental organization with intermittent connectivity. Consider an NGO with fifteen staff working across a head office and several field locations, collecting beneficiary data on mobile devices. Connectivity in the field is intermittent, and the organization relies on grant funding with no dedicated IT staff. Applying TAAF at Tier 1, the organization consolidates staff accounts in a single identity provider bundled with its existing productivity subscription, enables MFA, and eliminates shared logins. It selects a mobile data collection application that supports offline entry and encrypted synchronization, addressing P6. Beneficiary records are classified as Restricted and stored only in the approved platform, with automated exports to a second cloud storage location. A one-page data protection policy assigns ownership to the operations manager. These steps require little new spending and address the most common breach vectors identified in the literature, namely stolen credentials and data stored on unmanaged devices (Verizon, 2021). As funding grows, a move to Tier 2 adds mobile device management, allowing lost devices to be wiped remotely.

This approach is consistent with research on scaling mobile health solutions and on district health information systems, which identifies data quality and connectivity as recurring obstacles (Braa et al., 2004; Ekemezie et al., 2018; Oparah, Gado, et al., 2021). AI-based risk stratification for public health emergencies illustrates how such field data may later feed wider planning systems (Oparah, Ezech, et al., 2021).

Scenario B: A regional network of primary health clinics. Consider five clinics sharing a patient record system, subject to health data confidentiality obligations. Power outages are frequent. Applying TAAF, the network begins at Tier 1 but moves rapidly to Tier 2 for Layers 2 and 4 because patient records are highly sensitive. A cloud-hosted electronic medical record service is selected over a self-hosted server in each clinic (P1), while each clinic maintains a low-power edge device with an uninterruptible power

supply to cache scheduling data during outages (P6). Role-based access ensures that clerical staff cannot view clinical notes. Backups follow the 3-2-1 rule with an immutable copy, and restoration is tested quarterly. The framework helps the network sequence its investments, protecting the highest-value data first rather than spreading a limited budget evenly across all areas.

This sequencing is consistent with global guidance on digital interventions for health system strengthening (World Health Organization, 2019), with experience from rural telemedicine deployments (Surana et al., 2008), and with research on health data governance and interoperability (Ilodigwe & Adesemoye, 2021). Studies of infrastructure-driven expansion of diagnostic access in rural regions and of sustainable laboratory infrastructure for resource-constrained settings show how such networks typically grow (Aminu-Ibrahim et al., 2018; Aminu-Ibrahim et al., 2020), and research on digital transformation and Lean Six Sigma in pharmaceutical distribution illustrates the operational gains available from better data flows (Obukadata et al., 2021a; Obukadata et al., 2021b).

Scenario C: A growing small retail enterprise. Consider a retailer that began with a single shop and a social media presence and now operates an online store with growing transaction volumes. Customer payment data is handled by a third-party payment processor, reducing the organization's direct exposure. TAAF guides the retailer to keep its storefront on a managed e-commerce platform (P1, P2), integrate inventory and accounting through vendor-supported connectors (Layer 5), and add budget alerts as it adopts additional cloud services. As order volumes rise, the retailer moves toward Tier 3 for Layer 5, introducing an event-driven integration so that inventory updates, order notifications, and accounting entries are processed asynchronously. This allows the business to absorb seasonal spikes without redesigning its core systems.

As transaction volumes rise, the retailer's exposure to fraud and its data protection obligations grow, which is why Tier 3 practices such as centralized logging and continuous control validation become relevant. Studies of churn prediction, geomarketing analytics, and predictive anti-money laundering detection illustrate the analytical and monitoring workloads that a growing customer base generates (Atakpa, 2021; Oziri et al., 2020; Seyi-Lande et al., 2020).

Across the three scenarios, TAAF produced coherent and differentiated recommendations. The tier structure allowed each organization to set different maturity levels for different layers according to its risk profile, which is consistent with the risk-based approach of the NIST Cybersecurity Framework (NIST, 2018).

3.3.3 Comparative Assessment

Table 4 compares TAAF with three alternative approaches commonly encountered in constrained organizations: ad hoc practice, a comprehensive enterprise architecture framework (TOGAF), and the stand-alone application of a security control framework (the NIST Cybersecurity Framework or CIS Controls). The ratings are qualitative judgments based on the analysis in Sections 3.1 and 3.2 and should be read as indicative.

Table 4. *Qualitative Comparison of TAAF With Alternative Approaches*

Criterion	Ad Hoc Practice	TOGAF	Security Framework Alone	TAAF
Feasibility for non-specialists	High	Low	Medium	High
Incremental value	Low	Medium	Medium to high (CIS IGs)	High
Integration of infrastructure, security, and data	Low	Medium	Low to medium	High
Scalability guidance	Low	High	Low	Medium to high
Standards alignment	Low	High	High	Medium to high (via mapping)
Cost proportionality	Medium	Low	Medium	High

Note. IGs = Implementation Groups. Ratings reflect the authors' analytical assessment and require empirical confirmation.

The comparison suggests that TAAF occupies a useful middle ground. It retains much of the accessibility of ad hoc practice while introducing the structure, integration, and standards alignment that ad hoc practice lacks. It does not replace TOGAF or the NIST Cybersecurity Framework; rather, it offers an on-ramp to them. Its scalability guidance is less comprehensive than that of a full EA framework, which reflects a deliberate trade-off in favor of feasibility.

3.4 Trade-offs and Risks

The managed-first principle involves trade-offs. Reliance on large cloud providers concentrates dependency, may raise data sovereignty questions where data protection laws restrict cross-border transfers, and can lead to lock-in. P7 mitigates lock-in by emphasizing export capability and open standards, but cannot eliminate it. Cost unpredictability is another risk, particularly where organizations pay in currencies that fluctuate against the currencies in which cloud services are priced. The framework's financial guardrails address this partially. Finally, a framework that simplifies architecture may create a false sense of security if organizations treat Tier 1 as a destination rather than a starting point. The governance layer, through periodic review, is intended to counteract this tendency.

Research on vendor lock-in confirms that data portability and standard interfaces are the most practical mitigations available to smaller organizations (Opara-Martins et al., 2016).

3.5 Implications

3.5.1 Implications for Practice

For practitioners, including managers, IT generalists, and consultants serving constrained organizations, TAAF offers a prioritized pathway rather than an exhaustive checklist. The most important practical implication is that substantial risk reduction is achievable at low cost. Identity consolidation, multi-factor authentication, automatic updates, and tested backups address the attack patterns most frequently observed in breach reports (Verizon, 2021) and are frequently available within subscriptions that organizations already pay for. The framework also encourages managers to treat technology decisions as architectural decisions with long-term consequences, particularly regarding data portability and vendor dependence.

3.5.2 Implications for Policy and Funders

Policymakers and funders influence the technology environment of constrained organizations through regulation, procurement rules, and grant conditions. Data protection laws such as the GDPR, the Nigeria Data Protection Regulation, and the Protection of Personal Information Act impose obligations that apply regardless of organizational size, yet small organizations often lack the guidance to comply. Frameworks such as TAAF could be incorporated into sector-specific guidance, capacity-building programs, or grant conditions that fund baseline security as a legitimate operating cost rather than an overhead to be minimized. Funders could also support shared services, such as pooled identity, backup, or security monitoring arrangements for networks of small organizations, which would extend Tier 2 and Tier 3 capabilities to organizations that could not afford them individually.

Studies of data protection regulation across jurisdictions and of compliance regimes in emerging and developed markets suggest that regulators increasingly expect technology controls to be demonstrable (Mbonu, Aliliele, et al., 2019; Ominyi & Anichukwueze, 2021; Republic of South Africa, 2013).

3.5.3 Implications for Theory and Research

For research, the study contributes a design artifact that integrates two literatures, enterprise architecture and security frameworks, which have largely developed in parallel. It extends the design-reality gap perspective by translating it into prescriptive architectural guidance, and it reframes zero trust as an incrementally attainable model rather than an end state available only to large enterprises. The propositions in Section 3.2.7 provide a basis for theory testing, and the maturity tier structure offers a measurable construct that future studies can operationalize.

3.6 Limitations

This study has several limitations. The evaluation is analytical and relies on illustrative composite scenarios rather than field deployments, so the framework's effectiveness in practice has not yet been demonstrated empirically. The comparative ratings are qualitative and reflect the authors' judgment. The framework focuses primarily on organizations that can access commercial cloud services; organizations operating in fully offline environments or under strict data localization requirements may need substantial

adaptation. Finally, the threat landscape and technology market evolve rapidly, so specific practices within each tier will require periodic revision.

4. CONCLUSION

Resource-constrained organizations face the same threats and many of the same regulatory obligations as large enterprises, but with a fraction of the resources. Existing architecture and security frameworks provide valuable knowledge but are often too heavy to be applied directly in these settings, leaving many organizations to rely on improvised arrangements that neither scale nor adequately protect data. This paper has proposed the Tiered Adaptive Architecture Framework, which integrates scalable infrastructure design and secure data management in a layered and staged form. Seven design principles guide decisions; six layers organize the architecture; three maturity tiers allow incremental investment; and a data lifecycle and NIST Cybersecurity Framework mapping connect the framework to established practice.

In response to the research questions, the study found that financial, human, infrastructural, governance, and attention constraints jointly limit the applicability of existing frameworks (RQ1); that principles emphasizing managed services, identity-centric security, value-based data protection, automation, and resilience to disconnection provide a sound basis for an integrated framework (RQ2); and that, on analytical comparison, such a framework offers greater feasibility and cost proportionality than comprehensive alternatives while retaining a credible path to standards compliance (RQ3).

4.1 Future Research

Future research should validate TAAF empirically through longitudinal case studies and action research in organizations of different types and regions, measuring outcomes such as security incidents, recovery times, administrative effort, and cost. Development of a self-assessment instrument would allow organizations to determine their current tier for each layer. Further work could also examine shared-service models for networks of small organizations, the adaptation of the framework to fully offline and data-localized contexts, and the integration of emerging capabilities, such as passwordless authentication and automated configuration assessment, into the tier structure as they become accessible to smaller organizations.

Future work should also apply established design science evaluation frameworks and maturity model development procedures to strengthen the rigor of TAAF's validation. Research on data-driven operations management in educational institutions and on supply chain talent development suggests that such validation should also measure organizational outcomes.

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