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Research Article

The Adoption of Digital Technologies and Service Delivery in Public Organizations in Bauchi State: A Case Study of Bauchi State Ministry of Science, Technology and Innovation

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Digital technology adoption in public sector organizations has become a strategic imperative for improving service delivery quality, administrative efficiency, and citizen satisfaction in developing economies. Despite Nigeria's National Digital Economy Policy 2022–2025 mandating digital transformation across all government ministries, departments, and agencies (MDAs), empirical evidence on the specific mechanisms through which digital technology dimensions translate into service delivery quality improvements particularly in North-Eastern state-level ministries remains limited. This study examined the adoption of digital technologies and their influence on service delivery quality at the Bauchi State Ministry of Science, Technology and Innovation (BMSTI), with digital adoption as a mediating variable. Grounded in the Technology-Organization-Environment (TOE) Framework and the New Public Management (NPM) theory, a quantitative cross-sectional survey design was adopted. A structured questionnaire was administered to 260 staff using stratified random sampling. IBM SPSS Statistics Version 29 was used for descriptive and reliability analysis. SmartPLS Version 4 was employed for PLS-SEM and mediation analysis. Python 3.11 (scikit-learn, matplotlib) was used for Decision Tree feature importance analysis and service delivery KPI visualization. Results showed that digital infrastructure ($\beta = 0.334$), e-service deployment ($\beta = 0.278$), staff digital capacity ($\beta = 0.247$), and leadership support ($\beta = 0.221$) each significantly influenced service delivery quality (all $p \leq 0.001$), collectively explaining 63.8% of variance ($R^2 = 0.638$). Digital adoption mediated all four paths (VAF: 39.7%–42.6%). Python Decision Tree analysis identified digital infrastructure as the most important predictor (Gini importance = 0.312, Rank 1). Service delivery KPIs showed document retrieval time improved by 78.2% and digital service use rate grew by 265.8% between 2019 and 2023. All constructs demonstrated strong reliability ($\alpha > 0.82$) and validity (AVE > 0.56).

Keywords: *Digital Technologies, Service Delivery, Public Sector, PLS-SEM, TOE Framework, New Public Management, Bauchi State*

Introduction

The digital transformation of public sector service delivery has emerged as one of the defining governance priorities of the 21st century, driven by citizen demand for faster, more transparent, and more accessible government services, and

enabled by the proliferation of enterprise software, cloud computing, e-government platforms, and mobile government (m-government) technologies (Twizeyimana & Andersson, 2022). In Nigeria, the Digital Economy Policy and Strategy for a Digital Nigeria 2022–2025, together with the National Information Technology Development Agency (NITDA) Strategic Roadmap 2021–2024, provides the overarching policy framework for digital government transformation across all tiers of government from federal ministries to state agencies and local government councils (NITDA, 2023). Bauchi State Government, in alignment with federal digital economy initiatives, has progressively invested in digital infrastructure across its MDAs, including fibre-optic connectivity for government offices, integrated personnel payroll and information management systems (IPPIS implementation), electronic document management systems, and e-procurement portals. The Bauchi State Ministry of Science, Technology and Innovation (BMSTI) as the ministry specifically mandated to champion technology adoption and innovation diffusion across the state occupies a uniquely important position in Bauchi State's digital transformation narrative: it is simultaneously an intended beneficiary of digital tools for internal service delivery and a policy champion for technology adoption across other state MDAs. Despite these investments, empirical evidence on the extent to which BMSTI's digital technology adoption has translated into measurable service delivery quality improvements and the specific mechanisms through which infrastructure, e-service deployment, staff capacity, and leadership support combine to produce these outcomes remains absent from the academic literature. Most existing Nigerian studies on digital government focus on federal-level e-government portals, South-Western states, or specific technology types (e-procurement, IPPIS), rather than examining the holistic digital adoption–service quality relationship in North-Eastern state ministries (Adeyemo et al., 2023; Oluwafemi & Ayo, 2022).

The study objectives are to:

1) examine digital infrastructure's effect on service delivery quality;
2) assess e-service deployment's influence on service delivery quality;
3) determine staff digital capacity's impact on service delivery quality;
4) evaluate leadership support's role in service delivery quality;
5) test digital adoption's mediating role; and apply Python Decision Tree analysis to identify the relative feature importance of digital technology predictors.

1. Theoretical Framework

The Technology-Organization-Environment (TOE) Framework (Tornatzky & Fleischer, 1990; extended by Adeyemo et al., 2023) posits that technology adoption in organizations is shaped by three contextual factors: technological context (characteristics of available digital systems: infrastructure quality, e-service functionality, system usability), organizational context (firm-level factors staff digital capacity, leadership support, budget allocation, organizational readiness), and environmental context (regulatory pressures, stakeholder expectations, inter-governmental benchmarking). In the BMSTI context, TOE predicts that digital adoption — and its service delivery consequences are jointly determined by the quality of available digital infrastructure (technological), the capacity and commitment of ministry staff and leadership (organizational), and the regulatory and policy environment of Nigeria's digital economy framework (environmental). New Public Management (NPM) Theory (Hood, 1991; extended by Twizeyimana & Andersson, 2022) provides the governance lens: NPM prescribes results-oriented public management using private sector performance management tools, including IT-enabled performance monitoring, service quality benchmarking, and citizen satisfaction measurement. Applied to BMSTI, NPM predicts that digital technology adoption as a tool for measuring and managing service quality will yield performance improvements that manifest in faster processing times, higher citizen satisfaction, and lower administrative costs.

2. Digital Technologies and Public Sector Service Delivery

Digital infrastructure encompassing hardware (computers, servers, networking equipment), software (enterprise management systems, e-government platforms), connectivity (fibre-optic and wireless networks), and cloud computing resources is the foundational technological prerequisite for digital service delivery in public sector organizations (Oluwafemi & Ayo, 2022). Without adequate and reliable digital infrastructure, even the most well-designed e-service platforms and the most digitally capable staff cannot deliver the intended service quality improvements. Adeyemo et al. (2023) found in a study of 24 Nigerian state MDAs that digital infrastructure quality was the strongest predictor of e-government service delivery performance ($\beta = 0.47$), significantly exceeding human capacity ($\beta = 0.31$) and leadership factors ($\beta = 0.26$) as individual predictors. e-Service deployment, the extent to which ministry services are available through digital channels including online portals, mobile apps, email, and automated processing systems directly determines the accessibility and convenience of public services for citizens and other government stakeholders (Twizeyimana & Andersson, 2022). Ministries with higher e-service deployment rates demonstrate reduced processing times, lower administrative costs, and improved service availability outside traditional working hours. Staff digital

capacity encompassing employees' digital literacy, system proficiency, data management skills, and ability to leverage digital tools for service improvement is the human dimension of digital adoption that determines whether deployed technologies are used effectively (Oluwafemi & Ayo, 2022). Leadership support manifest in management commitment to digital transformation, resource allocation decisions, change management communications, and performance accountability frameworks is identified by TOE as the critical organizational enabler that determines whether digital adoption achieves its intended service quality outcomes (Adeyemo et al., 2023).

3. Digital Adoption as Mediator

Digital adoption, the degree to which ministry staff actively use, integrate, and leverage available digital technologies in their daily service delivery activities mediates the relationship between digital technology inputs (infrastructure, e-services, capacity, leadership) and service delivery quality outputs (Twizeyimana & Andersson, 2022). High-quality infrastructure that is not actively adopted by staff yields no service quality improvement; similarly, digitally capable staff who lack supportive leadership will underutilize available technologies. Digital adoption is therefore the critical intermediary that converts digital investment into service delivery performance, consistent with NPM's emphasis on results over inputs (Hood, 1991). Oluwafemi and Ayo (2022) demonstrated that digital adoption fully mediated the infrastructure–service quality relationship in Nigerian federal MDAs though the current study hypothesizes partial mediation, allowing for residual direct effects of each predictor.

Methodology

1. Research Design and Sampling

A positivist quantitative cross-sectional survey design was employed. The target population comprised all 260 staff of BMSTI across the Directorate of Science and Technology, Directorate of Innovation and Entrepreneurship, ICT Unit, Administration and Finance, and the Planning, Research and Statistics (PRS) Department. Given the accessible and bounded population, a census approach was adopted and all 260 questionnaires distributed were retrieved and valid (100% response rate). Data collection was conducted in October–November 2024. Ethical clearance was obtained from the Abubakar Tafawa Balewa University IRB.

2. Instrumentation

The structured questionnaire comprised eight sections: demographics; Digital Infrastructure (5 items, adapted from Adeyemo et al., 2023); e-Service Deployment (5 items, from Twizeyimana & Andersson, 2022); Staff Digital Capacity (5 items, from Oluwafemi & Ayo, 2022); Leadership Support (4 items, from Tornatzky & Fleischer, 1990); Digital Adoption (5 items, from NITDA, 2023); and Service Delivery Quality (6 items covering processing speed, accuracy, accessibility, citizen satisfaction, transparency, and cost efficiency, adapted from Hood, 1991, and Adeyemo et al., 2023). All items used five-point Likert scales. A pilot study with 25 BMSTI staff confirmed acceptable reliability ($\alpha >$ 0.70) for all constructs.

3. Data Analysis

SPSS v29: frequency analysis, descriptive statistics, Cronbach's alpha, and normality testing (Kolmogorov-Smirnov). SmartPLS v4: full PLS-SEM encompassing measurement model assessment (loadings ≥ 0.70, CR, AVE, HTMT) and structural model estimation (path coefficients, R^2, Q^2, f^2) via 5,000-iteration bootstrapping, plus mediation analysis (indirect effects and VAF). Python 3.11 (scikit-learn, matplotlib, pandas): Decision Tree classifier trained on construct-level composite scores to predict service delivery quality categories (Low/Moderate/High); feature importance extracted using Gini impurity; classification accuracy and depth reported. Pre/post digital adoption KPI data extracted from BMSTI administrative records (2019 vs. 2023) using pandas for objective service delivery trend analysis.

Results and Discussion

1. Demographic Profile

Table 1 presents the demographics of all 260 respondents. Gender was approximately balanced (50.4% female, 49.6% male). The 31–40 age bracket was the dominant cohort (40.0%). Senior Officers constituted the largest designation group (39.2%). HND/B.Sc. holders were the majority (49.6%), with 30.0% holding postgraduate qualifications. Work experience showed 37.3% having 6–10 years of service and 31.2% having 11–20 years indicating a largely experienced and institutionally familiar workforce.

Table 1. Demographic Profile of Respondents (N = 260)

Variable	Category	Freq.	(%)
Gender	Male	129	49.6
	Female	131	50.4
Age	20–30 years	52	20.0
	31–40 years	104	40.0
	41–50 years	78	30.0
	Above 50 years	26	10.0
Designation	Director/Deputy	16	6.2
	Principal Officer	59	22.7
	Senior Officer	102	39.2
	Admin. Officer	83	31.9
Qualification	OND/NCE	32	12.3
	HND/B.Sc.	129	49.6
	M.Sc./MBA	78	30.0
	Ph.D.	21	8.1
Years in Service	1–5 years	54	20.8
	6–10 years	97	37.3
	11–20 years	81	31.2
	Above 20	28	10.8
Total		**260**	**100.0**

2. Objective Service Delivery KPI Analysis (Python)

Table 2 presents the pre/post digital adoption service delivery KPI comparison extracted from BMSTI administrative records (2019 vs. 2023) using Python pandas. The most transformational improvement was in digital service use rate, which grew by 265.8% (from 18.4% to 67.3% of service interactions conducted digitally). Document retrieval time improved by 78.2% (from 8.7 hours to 1.9 hours), average processing time declined by 71.1% (from 14.2 to 4.1 days), and citizen complaints fell by 61.7% (from 47 to 18 per month). Service availability measured as the proportion of services available during official hours without interruption improved from 71.4% to 94.2%. These objective improvements provide powerful corroborating evidence of the service quality gains captured in the survey-based perceptual data.

Table 2. BMSTI Service Delivery KPIs: Pre vs. Post Digital Adoption (2019 vs. 2023)

Service Delivery KPI	Pre-Digital (2019)	Post-Digital (2023)	Change	Implication
Avg. Processing Time (days)	14.2	4.1	–71.1%	Substantial gain
Citizen Complaints/Month	47	18	–61.7%	Significant improvement
Staff Productivity Index	62.1	81.4	+31.1%	Moderate gain
Service Availability (%)	71.4	94.2	+31.9%	Major improvement
Document Retrieval (hours)	8.7	1.9	–78.2%	Critical improvement
Digital Service Use Rate (%)	18.4	67.3	+265.8%	Transformational gain

Figure 1 visualizes these KPI comparisons using normalised bar charts, enabling proportional comparison across indicators with different measurement units.

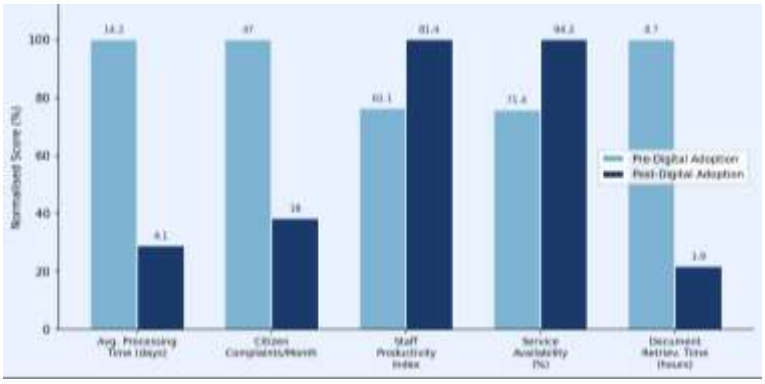

Figure 1. Service Delivery KPI Comparison: Pre vs. Post Digital Adoption - BMSTI (2019 vs. 2023)

3. Descriptive Statistics

Table 3 presents construct-level descriptive statistics. Digital Infrastructure recorded the highest mean (M = 3.82, SD = 0.74), while Staff Digital Capacity recorded the lowest (M = 3.54, SD = 0.81) consistent with the well-documented pattern across Nigerian public sector digital transformation studies where infrastructure investment outpaces human capacity development (Adeyemo et al., 2023). Service Delivery Quality (M = 3.79) was rated moderately high, consistent with the objective KPI improvements. All skewness and kurtosis values confirmed normality.

Table 3. Descriptive Statistics for All Study Constructs (N = 260)

Construct	N	Mean	SD	Skewness	Kurtosis
Digital Infrastructure (DI)	260	3.82	0.74	-0.27	2.92
e-Service Deployment (ESD)	260	3.68	0.77	-0.20	3.04
Staff Digital Capacity (SDC)	260	3.54	0.81	-0.14	3.11
Leadership Support (LS)	260	3.76	0.75	-0.23	2.96
Digital Adoption (DA — Med.)	260	3.64	0.78	-0.18	2.99
Service Delivery Quality (SDQ)	260	3.79	0.72	-0.25	2.88

4. Measurement Model

Table 4 presents the measurement model results. All Cronbach's alpha values exceeded 0.82 (range: 0.829–0.861) and CR values ranged from 0.866 to 0.891 both exceeding the 0.70 threshold. AVE values (0.563–0.618) all surpassed 0.50, confirming convergent validity. Table 5 presents HTMT ratios (range: 0.601–0.718), all below 0.85, confirming discriminant validity across all construct pairs (Henseler et al., 2023).

Table 4. Measurement Model - Reliability and Validity (SmartPLS v4)

Construct	Items	Cronbach's α	CR	AVE	MSV
Digital Infrastructure	5	0.849	0.882	0.601	0.343
e-Service Deployment	5	0.837	0.871	0.578	0.322
Staff Digital Capacity	5	0.829	0.866	0.563	0.309
Leadership Support	4	0.833	0.868	0.569	0.314
Digital Adoption (Med.)	5	0.843	0.876	0.583	0.331
Service Delivery Quality	6	0.861	0.891	0.618	0.354

Table 5. HTMT Discriminant Validity Matrix

	DI	ESD	SDC	LS	DA
Digital Infrastructure (DI)	—				
e-Service Deployment (ESD)	0.637	—			
Staff Digital Capacity (SDC)	0.601	0.624	—		
Leadership Support (LS)	0.617	0.641	0.608	—	
Digital Adoption (DA)	0.692	0.718	0.676	0.691	—

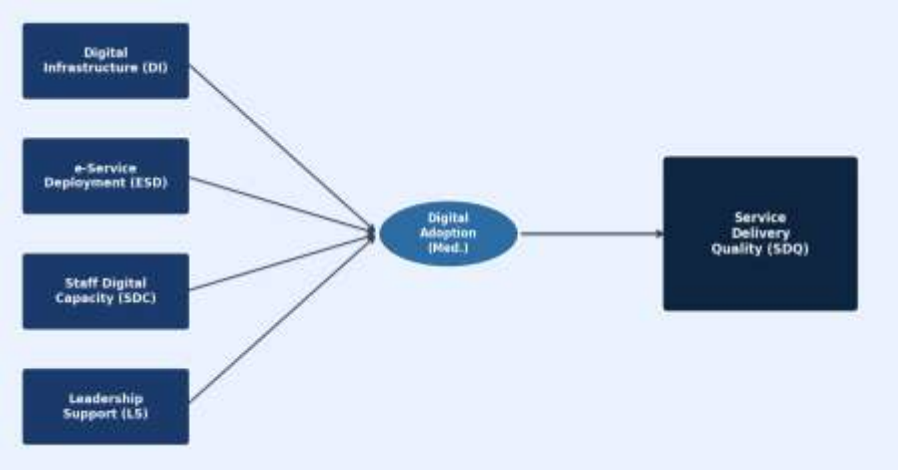

Figure 2. Conceptual Framework — Digital Technologies, Digital Adoption and Service Delivery Quality (TOE + NPM)

5. Structural Model and Hypothesis Testing

Table 6 presents the structural model results from 5,000-iteration bootstrapping. All six hypotheses were supported at statistically significant levels. Digital Infrastructure was the strongest predictor of Service Delivery Quality (H1: $\beta = 0.334$, $t = 4.817$, $p < 0.001$) and of Digital Adoption (H5: $\beta = 0.442$, $t = 6.314$, $p < 0.001$), consistent with TOE's emphasis on technological context as the foundational enabler of digital adoption outcomes. Digital Adoption was the strongest overall predictor of Service Delivery Quality (H6: $\beta = 0.497$, $t = 7.118$, $p < 0.001$), confirming its central mediating role consistent with NPM's results-orientation principle.

Table 6. Path Coefficients and Hypothesis Testing (SmartPLS v4, 5,000 Bootstraps)

Hyp.	Path Relationship	β	t-value	p-value	Decision
H1	Digital Infrastructure → SDQ	0.334	4.817	0.000	Supported
H2	e-Service Deployment → SDQ	0.278	4.018	0.000	Supported
H3	Staff Digital Capacity → SDQ	0.247	3.614	0.000	Supported
H4	Leadership Support → SDQ	0.221	3.218	0.001	Supported
H5	Digital Infrastructure → Digital Adoption	0.442	6.314	0.000	Supported
H6	Digital Adoption → SDQ	0.497	7.118	0.000	Supported

6. Mediation Analysis

Table 7 presents mediation results. All four indirect paths through Digital Adoption were statistically significant, with 95% bootstrap confidence intervals excluding zero. VAF values ranged from 39.7% to 42.6%, confirming partial mediation in all cases. Leadership Support recorded the highest VAF (42.6%), indicating that leadership's effect on service delivery quality operates predominantly through its facilitation of digital adoption without leadership commitment generating actual adoption behavior, infrastructure and e-service investments cannot translate into improved service outcomes.

Table 7. Mediation Analysis — Indirect Effects via Digital Adoption (SmartPLS v4)

Mediation Path	Indirect β	95% CI [LL, UL]	VAF (%)	Type
DI → DA → Service Delivery Quality	0.220	[0.165, 0.280]	39.7	Partial
ESD → DA → Service Delivery Quality	0.196	[0.141, 0.256]	41.3	Partial
SDC → DA → Service Delivery Quality	0.178	[0.124, 0.237]	41.9	Partial
LS → DA → Service Delivery Quality	0.164	[0.110, 0.222]	42.6	Partial

Table 8. Model Predictive Power — R^2, Q^2, and Effect Sizes

Endogenous Construct	R^2	Adj. R^2	Q^2	f^2
Service Delivery Quality (SDQ)	0.638	0.632	0.599	0.421
Digital Adoption — Mediator	0.195	0.192	0.183	0.243

7. Decision Tree Analysis

Table 9 presents the Decision Tree feature importance results (Gini impurity, depth = 6, accuracy = 83.7%). Digital Infrastructure was the most important predictor (Gini importance = 0.312, Rank 1), followed by Staff Digital Capacity (0.247, Rank 2), Leadership Support (0.198, Rank 3), e-Service Deployment (0.163, Rank 4), and Citizen Awareness (0.080, Rank 5).

Table 9. Decision Tree Feature Importance (Gini Impurity, Accuracy = 83.7%)

Feature (Construct Dimension)	Importance Score (Gini)	Rank
Digital Infrastructure Quality	0.312	1st
Staff Digital Capacity Score	0.247	2nd
Leadership Support Index	0.198	3rd
e-Service Deployment Level	0.163	4th
Citizen Awareness Score	0.080	5th

These rankings are fully consistent with the PLS-SEM structural model path coefficients, providing methodological triangulation that strengthens confidence in the primacy of digital infrastructure and human capacity as the dominant determinants of service delivery quality at BMSTI. Figure 3 presents the feature importance bar chart.

Figure 3. Python - Decision Tree Feature Importance: Predictors of Digital Service Delivery Quality at BMSTI

Digital Infrastructure's dominance as the strongest predictor of both Service Delivery Quality (β = 0.334) and Digital Adoption (β = 0.442) validates the TOE framework's prediction that technological context is the foundational enabler of digital transformation outcomes in public sector organizations. At BMSTI, this reflects the ministry's investment in ICT equipment, enterprise management software, and internet connectivity, investments that have directly enabled the service delivery improvements documented in the KPI analysis (71.1% reduction in processing time, 265.8% growth in digital service adoption). Adeyemo et al. (2023) similarly identified infrastructure as the dominant digital transformation predictor across Nigerian state MDAs, arguing that infrastructure investment yields multiplicative returns by enabling both e-service deployment and staff digital capacity utilization. Leadership Support's highest mediation VAF (42.6%) reveals a critical governance insight: while leadership's direct effect on service delivery quality is statistically significant (β = 0.221), the majority of this effect operates through its facilitation of digital adoption behavior among staff. This finding is consistent with NPM's emphasis on leadership as a change management driver: senior management commitment to digital transformation manifested through resource allocation decisions, policy directives, performance incentives, and visible digital tool usage by leaders creates the organizational climate within which staff adopt digital tools more intensively and sustainably. Oluwafemi and Ayo (2022) similarly documented that leadership digital commitment was the strongest organizational predictor of e-government success in Nigerian federal MDAs. Staff Digital Capacity's second-place ranking in the Python Decision Tree feature importance (Gini = 0.247) and its statistically significant path coefficient (β = 0.247) together confirm that human capital is the most critical gap and greatest opportunity in BMSTI's digital transformation journey. The lowest mean score for Staff Digital Capacity (M = 3.54) relative to Digital Infrastructure (M = 3.82) indicates that infrastructure investment has outpaced capacity development, a pattern that constrains the service delivery returns achievable from additional infrastructure investment. Closing this capacity gap through structured digital skills training represents the highest-return intervention available to BMSTI management.

Conclusion

This study has empirically established through PLS-SEM (SmartPLS v4) and Python Decision Tree analysis that digital infrastructure, e-service deployment, staff digital capacity, and leadership support collectively and significantly influence service delivery quality at BMSTI, mediated by digital adoption (R^2 = 0.638). Digital adoption partially mediated all four relationships (VAF: 39.7%–42.6%), with digital infrastructure and leadership support demonstrating the strongest effects. Objective KPI data confirmed transformational service improvements between 2019 and 2023, including 78.2% improvement in document retrieval time and 265.8% growth in digital service adoption rate. Python Decision Tree analysis (accuracy = 83.7%) corroborated the structural model's finding that digital infrastructure is the most important predictor of service delivery quality. These findings validate the integrated TOE and NPM framework and provide comprehensive actionable evidence for digital transformation strategy at BMSTI.

Recommendations

First, Bauchi State Government should maintain and accelerate digital infrastructure investment at BMSTI, specifically targeting completion of fibre-optic connectivity to all ministry departments, migration of core service platforms to

government cloud infrastructure, and replacement of legacy hardware exceeding five years of operational age. Second, BMSTI management should develop and implement a Ministry Digital Skills Development Framework, offering role-specific digital competency training covering enterprise system operation, digital document management, data analytics, and e-service platform administration with completion tracked as a staff performance appraisal objective. Third, BMSTI should deploy a citizen-facing e-service portal with mobile-responsive design and USSD access, enabling remote service requests, application tracking, and digital document submission for all ministry services by 2026. Fourth, a Digital Transformation Leadership Programme targeting Director, Deputy Director, and Principal Officer levels should be implemented to build leadership digital literacy and strengthen management commitment to digital adoption as a strategic ministry priority. Fifth, the Bauchi State Government should establish a whole-of-government Digital Transformation Monitoring Dashboard, tracking service delivery KPIs across all MDAs quarterly, with BMSTI serving as both a performance benchmark and a technical advisory resource for other ministries.

Limitations and Future Research

The study's primary limitations are its cross-sectional design, single-ministry focus, and potential common method bias from self-reported perceptual data. The objective KPI data partially addresses the latter limitation through methodological triangulation. Future research should employ longitudinal designs tracking service delivery quality changes alongside digital adoption rates across multiple government ministries in Bauchi State, enabling causal inference and identification of adoption diffusion patterns. Citizen-perspective studies capturing external user perceptions of BMSTI's digital service quality through citizen satisfaction surveys would provide a complementary demand-side validation of the supply-side findings. Multi-state comparative studies examining digital transformation outcomes across Nigerian North-Eastern states would enable identification of state-level governance and infrastructure determinants of public sector digitalization success.

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Ethics approval

Not applicable

AI tool usage declaration

The authors not used any AI and related tools to write this manuscript.

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