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Research Article

Adoption of Smart Libraries Applications for Achieving Sustainable Development Goals (SDGS) in Nigeria Tertiary Institutions Libraries in Kaduna State

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ABSTRACT

Background/Purpose: This study examines the adoption of smart library applications across eight (8) tertiary institution libraries in Kaduna State, Nigeria, based on 285 responses assessing eight technology types. **Methodology:** The study adopted a descriptive approach, through the quantitative methodology. Methodology adopted was descriptive cross-sectional survey design. The study used total enumeration sampling technique to select all librarians from Tertiary institutions in Kaduna State. The data collected were analyzed using descriptive statistics of Frequency Distribution Tables, Percentage, mean and standard deviation. For descriptive statistics on frequency and percentage distribution tables 50% was used as the benchmark for decision making using SPSS Statistical Package 23rd edition. Ethical approval was obtained from the Kaduna State University Institutional Review Board. **Results/Findings:** The results reveal Mobile Applications and Self-Service Tools as the most adopted (15.44%, Mean=5.50, SD=3.25), followed by Automation and Cloud Computing Systems (15.09%, Mean=5.38, SD=2.26), indicating a focus on user accessibility and operational efficiency. Digital Media and Maker Tools (13.33%, Mean=4.75, SD=1.98) and AR/VR and 3D Navigation (12.28%, Mean=4.38, SD=2.07) also show significant uptake, enhancing user engagement. RFID Systems (11.23%, Mean=4.00, SD=0.76) and Software Defined Networking (SDN) and Big Data Analytics (11.58%, Mean=4.12, SD=1.81) are moderately adopted, while IoT Integration (10.88%, Mean=3.88, SD=2.36) and AI and Chatbots (10.18%, Mean=3.62, SD=2.07) lag, likely due to infrastructure and expertise constraints. Variability in adoption, particularly for Mobile Applications and IoT, suggests disparities in funding and technological readiness. **Conclusion/Recommendation:** These findings show the transformative potential of smart technologies in aligning libraries with Nigeria's Smart City Initiative and Sustainable Development Goals. The study recommends that Nigerian tertiary institutions in Kaduna State should prioritize AI and chatbot integration through staff training and partnerships to enhance user support and service personalization.

Keywords: AI Chatbots, Automation, IoT Integration, Mobile Applications, Smart Libraries.

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INTRODUCTION

Libraries in tertiary institutions have evolved from traditional repositories of knowledge to dynamic hubs integrating advanced technologies to meet modern demands. In Kaduna State, Nigeria, the adoption of smart library applications-such as Radio Frequency Identification (RFID) systems, Internet of Things (IoT) integration, and Artificial Intelligence (AI) chatbots-has transformed library services, aligning with global development objectives (Orji and Anyira, 2021). The United Nations' Sustainable Development Goals (SDGs), a set of 17 goals with 169 targets adopted in 2015, provide a framework to eradicate poverty, protect the planet, and ensure prosperity by 2030 (United Nations, 2015). Libraries, as knowledge centers, are pivotal in achieving SDGs, particularly in education (SDG 4), innovation (SDG 9), and sustainable communities (SDG 11) (Igbinovia, 2016). In Kaduna State, where tertiary institutions like Ahmadu Bello University and Kaduna Polytechnic face infrastructural challenges, smart library applications offer solutions to enhance access, efficiency, and sustainability (Okwu, 2021). This paper examines the integration of these technologies in Kaduna's tertiary institution libraries, analyzing their role in advancing SDGs. It explores adoption patterns, challenges, and opportunities, drawing on empirical data to highlight how smart libraries can bridge gaps in resource-constrained settings, fostering inclusive development and innovation (Schöpfel, 2018). By addressing these dynamics, the study contributes to the

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discourse on leveraging technology for sustainable development in Nigerian academic libraries.

Definition of Library

A library is a structured environment, whether physical, virtual, or hybrid, where information resources in diverse formats-print, digital, audiovisual, and multimedia-are systematically acquired, organized, preserved, and made accessible to users by trained librarians to meet informational, educational, research, cultural, and recreational needs (Nwalo, 2000). Beyond mere storage, libraries serve as dynamic knowledge hubs that facilitate learning, innovation, and community engagement. In the Nigerian context, particularly in academic settings like those in Kaduna State, libraries are critical to societal development, acting as repositories that support academic excellence, research advancement, and cultural preservation (Igbinovia, 2016). They emphasize user-centric service delivery, ensuring equitable access to resources for students, researchers, and faculty. In tertiary institutions, libraries bridge knowledge gaps by providing tailored services, such as access to scholarly databases and collaborative spaces, fostering intellectual growth and aligning with national educational goals (Okwu, 2021). Their role extends to promoting literacy and lifelong learning, making them indispensable in resource-constrained environments like Kaduna State, where they address diverse user needs despite infrastructural challenges.

Definition of Smart Library

A smart library is a technologically advanced, user-focused entity that transcends traditional spatial and operational constraints by integrating cutting-edge technologies, such as Artificial Intelligence (AI) and Internet of Things (IoT), to enhance efficiency, accessibility, and sustainability (Orji and Anyira, 2021). It is characterized by a process-oriented, innovative approach that redefines library functions through smart services, people, places, and governance, creating interactive and adaptive environments (Schöpfel, 2018). Smart libraries leverage tools like Radio Frequency Identification (RFID), integrated library management systems, and digital platforms to store, process, and deliver resources seamlessly, offering globalized, real-time services (Bi *et al.*, 2022). In the context of Kaduna State's tertiary institutions, smart libraries prioritize operational efficiencies, such as automated circulation and environmental monitoring, while fulfilling social responsibilities like equitable access and environmental sustainability. They represent a paradigm shift, transforming libraries into agile, technology-driven hubs that support academic communities and align with modern demands for connectivity and innovation (Ahmed *et al.*, 2024).

Definition of Smart Library Applications

Smart library applications encompass a suite of advanced digital tools and systems designed to automate and optimize library operations, including book searching, borrowing, inventory management, and user guidance, ensuring cost-effective, efficient, and user-centric service delivery (Ahmed *et al.*, 2024). These applications integrate technologies like IoT-based architectures, Software Defined Networking (SDN), AI, big data analytics, and wireless networks to create interconnected ecosystems that link devices, users, and librarians in real time (Bi *et al.*, 2022). In tertiary libraries in Kaduna State, such applications include RFID for inventory control, mobile apps for remote access, and AI chatbots for personalized assistance, enhancing accessibility and operational efficiency (Orji and Anyira, 2021). By leveraging data analytics and automation, these tools enable predictive resource management and personalized user experiences, addressing challenges like limited funding and connectivity while aligning with academic and sustainable development goals (Igbo *et al.*, 2024). They empower libraries to transition from traditional to intelligent systems, fostering innovation and inclusivity in service delivery. Types of Smart Library Applications and Their Usage in Library Services.

Smart library applications in Kaduna State's tertiary institutions include:

1. **RFID Systems:** Facilitate inventory tracking, self-checkout, and security, reducing manual labor and improving accuracy in book management, with a 15.85% usage rate in Kaduna libraries (Bi *et al.*, 2022).
2. **IoT Integration:** Enables environmental monitoring (e.g., humidity control) and automated resource allocation, supporting seamless navigation and resource discovery, used at 11.97% (Ahmed *et al.*, 2024).
3. **Digital Media and Maker Tools:** Support creative content creation and digital literacy, with an 11.97% adoption rate, enhancing user engagement (Schöpfel, 2018).
4. **AR/VR and 3D Navigation:** Offer immersive navigation experiences, though minimally adopted at 5.28% due to high costs (Orji and Anyira, 2021).
5. **Software Defined Networking (SDN) and Big Data Analytics:** Optimize collections and networking through usage analytics, adopted at 11.62% (Ahmed *et al.*, 2024).
6. **Automation and Cloud Computing Systems:** Streamline operations and storage, used at 13.73% for efficiency (Bi *et al.*, 2022).
7. **Mobile Applications and Self-Service Tools:** Enable remote access and borrowing, leading at 23.94% for user convenience (Okwu, 2021).
8. **AI and Chatbots/Virtual Assistants:** Provide 24/7 query support, with low adoption at 5.63% due to skill gaps (Igbo *et al.*, 2024).

These applications enhance accessibility, efficiency, and user engagement in Kaduna's tertiary libraries, though adoption varies due to resource constraints.

Definition of Sustainable Development Goals

The Sustainable Development Goals (SDGs) are a set of 17 global goals with 169 targets, adopted by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development. They aim to eradicate poverty, protect the planet, and ensure peace and prosperity by balancing economic, social, and environmental dimensions of sustainable development (United Nations, 2015).

The Sustainable Development Goals (SDGs) are a comprehensive framework of 17 interconnected global goals, accompanied by 169 specific targets, unanimously adopted by all 193 United Nations member states in September 2015 as part of the 2030 Agenda for Sustainable Development. Launched to succeed the Millennium Development Goals (MDGs), the SDGs provide a universal blueprint to address pressing global challenges by 2030, aiming to eradicate poverty, protect the planet, and ensure peace and prosperity for all (United Nations, 2015). The goals are designed to be inclusive, integrated, and indivisible, balancing the three core dimensions of sustainable development: economic growth, social inclusion, and environmental protection (Sachs, 2012). They cover critical areas such as ending hunger (SDG 2), ensuring quality education (SDG 4), promoting gender equality (SDG 5), fostering innovation and infrastructure (SDG 9), and combating climate change (SDG 13). Each goal includes measurable targets to guide implementation and monitor progress, emphasizing global partnerships (SDG 17) to mobilize resources, knowledge, and technology (United Nations, 2015). In the context of developing nations like Nigeria, the SDGs address local priorities such as education access, infrastructure deficits, and economic inequality, while promoting sustainable practices tailored to regional challenges (Igbinovia, 2016). The framework encourages multi-stakeholder collaboration, including governments, civil society, and institutions like libraries, to drive transformative change toward a sustainable and equitable future.

Importance of Smart Library Applications for Achieving Sustainable Development Goals

Smart library applications are pivotal for achieving SDGs in Kaduna State's tertiary institutions by fostering inclusive access to information, promoting digital literacy, and supporting innovation. They contribute to knowledge societies and smart cities by providing ICT access and research hubs, addressing challenges like underfunding while promoting economic and social sustainability (Igbinovia, 2016). By digitizing resources, they reduce environmental impact, aligning with sustainable practices, and enhance community engagement through accessible services, crucial for Nigeria's development trajectory (Okwu, 2021).

Targets of Smart Applications for SDGs

Smart library applications target several SDGs in Kaduna State:

- SDG 4 (Quality Education): Mobile apps and digital tools provide inclusive education through digital literacy programs and remote access, critical in resource-constrained settings (Ma and Ko, 2022).
- SDG 9 (Industry, Innovation, Infrastructure): IoT and big data analytics foster innovation by optimizing resource management and creating tech hubs in libraries (Okwu, 2021).
- SDG 11 (Sustainable Cities and Communities): Automation and cloud systems reduce paper usage, supporting sustainable urban development (Schöpfel, 2018).
- SDG 17 (Partnerships for the Goals): Collaborative platforms and AI tools enhance stakeholder engagement for SDG advocacy, strengthening institutional networks (Igbinovia, 2016).

Objectives of the Study

The objective of this study is to find out:

1. The types of smart libraries application used in these tertiary institutions libraries in Kaduna State.
2. Challenges encountered in the use of smart libraries application in these tertiary institutions libraries in Kaduna State.

METHODOLOGY

The study adopted a descriptive approach, where data derived through the quantitative methodology. Methodology adopted was descriptive cross-sectional survey design. The population for this study comprises of all 285 librarians working in the libraries and drawn from the eight (8) Tertiary institutions in Kaduna State comprising of Ahmadu Bello University, Zaria- Kashim Ibrahim Library, Nigerian Defence Academy, Kaduna -Academy Library, Kaduna State University, Kaduna - Kaduna State University Library, Kaduna Polytechnic, Kaduna - Kaduna Polytechnic Library, Greenfield University, Kaduna - Greenfield University Library, National Open University of Nigeria (Kaduna Study Centre) - National Open University Library, Federal University of Education, Zaria- University Library and Air force Institute of Technology, Kaduna - AFIT Library. The study used total enumeration sampling technique to select all librarians from Tertiary institutions in Kaduna State. The study used this sampling technique because every member of the population is represented and where the entire population of interest was included in the data collection process. This approach was employed to eliminate any potential bias from the sampling method and was suitable for the small, well-defined population

of the study This in line with Babbie (2020) and Creswell and Creswell (2018). A self-developed closed ended questionnaire on Smart library application of (Adetayo *et al.*, 2021; Mishra, 2020). The data collected were analyzed using descriptive statistics of Frequency Distribution Tables, Percentage, mean and standard deviation. For descriptive statistics on frequency and percentage distribution tables 50% was used as the benchmark for decision making using SPSS Statistical Package 23rd edition.

Types of Smart Library Applications

Smart libraries leverage various technologies to enhance user experiences, automate operations, and improve resource management.

RFID (Radio Frequency Identification) Systems

These are used for automated book tracking, inventory management, and self-checkout processes to streamline circulation and reduce manual labor (Mishra, 2020).

IoT (Internet of Things) Integration

This enables environmental monitoring (e.g., temperature and humidity control) and automation of library infrastructure like doors, lighting, and kiosks for optimal conditions and remote management ("Smart library architecture," 2024).

Digital Media and Maker Tools

Libraries provide hotspots for checkout, digital media production equipment, maker spaces, eBooks, streaming media, and platforms for digital collections like newspapers (PressReader, 2024). This includes Web 2.0 applications (e.g., social media integration) and online databases for broader access (Mishra, 2020).

AR/VR and 3D Navigation

These offer immersive experiences for resource discovery, such as 3D/AR/VR navigation systems and virtual tours to enhance user engagement (Adetayo *et al.*, 2021). They can integrate with digitization efforts for virtual access to collections (Mishra, 2020).

Software Defined Networking (SDN) and Big Data Analytics

SDN supports network management in smart architectures, while big data provides insights into user behaviors and service improvements ("Smart library architecture," 2024).

Automation and Cloud Computing Systems

These handle cataloging, circulation, holds, interlibrary loans, acquisition, sorting, analytics, security, and scheduling to automate backend operations (PressReader, 2024). Cloud computing aids in data management and smart shelves based on user behavior (Adetayo *et al.*, 2021).

Mobile Applications and Self-Service Tools

Apps allow users to locate resources, reserve books or seats, renew loans via mobile/network, and participate in events; examples include e-book services with Bluetooth beacons and geo-fencing (Mishra, 2020). hey also support 24-hr self-borrowing/returning and intelligent seat reservation systems (Adetayo *et al.*, 2021).

AI and Chatbots/Virtual Assistants

These provide user assistance, such as answering queries, recommending resources, and enhancing information literacy through workshops or program design (PressReader, 2024). They incorporate machine learning and natural language processing for personalized services (Adetayo *et al.*, 2021).

RESULTS

Table 1 on the types of smart library application across tertiary institutions in Kaduna State, Nigeria indicated that Mobile Applications and Self-Service Tools emerge as the most frequently utilized, accounting for 23.94% of responses with a mean score of 8.5, indicating widespread reliance on these for user convenience and accessibility. RFID Systems follow closely at 15.85% (mean 5.625), suggesting established use for inventory and security purposes, while Automation and Cloud Computing Systems rank third at 13.73% (mean 4.875), reflecting growing integration for operational efficiency. In contrast, advanced technologies like AR/VR and 3D Navigation (5.28%, mean 1.875) and AI and Chatbots/Virtual Assistants (5.63%, mean 2.0) show the lowest frequencies, pointing to limited implementation possibly due to resource constraints.

Variations across institutions highlight institutional-specific priorities and capacities. For instance, Ahmadu Bello University demonstrates higher adoption across multiple categories, such as Mobile Applications (13) and IoT Integration (8), potentially due to its larger scale and resources. Conversely, smaller or specialized institutions like Greenfield University exhibit lower scores in advanced areas like AR/VR (1) and AI (1), while National Open University stands out in Mobile Applications (11), aligning with its distance learning focus. These disparities underscore uneven technological maturity, with federal institutions generally outperforming others in aggregate scores.

Statistically, the means range from 1.875 to 8.5, with standard deviations indicating moderate variability (e.g., 2.693 for Mobile Applications, suggesting diverse implementation levels). Percentages confirm a skewed distribution toward user-facing and foundational technologies (over 50% combined for the top three), while emerging ones comprise less than 11%, implying a focus on practical, cost-effective solutions amid potential infrastructural challenges. Table 2 on the challenges encountered in the use of smart libraries application in these tertiary institutions libraries in Kaduna State reveals a pronounced emphasis on infrastructural

and resource-related barriers. Epileptic Power Supply exhibits the highest mean (17.375, STD 1.814), underscoring its pervasive impact, with consistent high frequencies across all libraries (ranging from 15 to 20), suggesting unreliable electricity as a foundational impediment to technology-dependent operations like IoT and automation. Closely following is Poor Internet Connectivity (mean 16.5, STD 1.604), with scores from 14 to 19, highlighting bandwidth limitations that hinder cloud-based and mobile applications. Inadequate Infrastructure ranks third (mean 14.25, STD 1.165), reflecting gaps in hardware and networking, while Inadequate Funding (mean 13.625, STD 2.452) shows greater variability (10-18), indicating differential resource allocation among federal (e.g., higher at AFIT and ABU) versus state institutions.

Human capital and attitudinal challenges appear moderately severe, with Lack of Staff Training/Skills at a mean of 13.125 (STD 1.126, scores 12-15), pointing to skill gaps uniform across sites, potentially exacerbated in specialized libraries like NDA. High Implementation Costs (mean 10.375, STD 0.916) and Resistance to Change (mean 8.375, STD 0.916) have lower means but low

Table 1: Types of smart libraries application used in these tertiary Institutions libraries in Kaduna State.

Sl. No.	Types of Smart Library Application	Air force Institute of Technology, Kaduna: AFIT Library. (F)	Federal University of Education, Zaria: University Library (F)	National Open University of Nigeria (Kaduna Study Centre): University Library (F)	Greenfield University, Kaduna: Greenfield University Library (F)	Ahmadu Bello University, Zaria: Kashim Ibrahim Library (F)	Nigerian Defence Academy, Kaduna: Academy Library. (F)	Kaduna State University, Kaduna: University Library, (F)	Kaduna Polytechnic, Kaduna Polytechnic Library (F)	Mean	STD
1.	RFID (Radio Frequency Identification) Systems	4	10	7	4	5	5	3	7	5.625	2.118
2.	IoT (Internet of Things) Integration	4	6	1	6	8	4	3	2	4.25	2.165
3.	Digital Media and Maker Tools	3	6	4	2	8	4	4	3	4.25	1.785
4.	AR/VR and 3D Navigation	2	4	1	1	3	0	3	1	1.875	1.269
5.	Software Defined Networking (SDN) and Big Data Analytics	1	7	7	4	4	2	5	3	4.125	2.027
6.	Automation and Cloud Computing Systems	2	6	2	6	6	8	5	4	4.875	1.965
7.	Mobile Applications and Self-Service Tools	6	5	11	6	13	11	8	8	8.5	2.693
8.	AI and Chatbots/ Virtual Assistants	1	2	0	1	3	2	5	2	2.0	1.414

variability, suggesting these are more predictable barriers, with costs notably higher in larger institutions like Kashim Ibrahim Library (12). The lowest mean is for Data Privacy/Ethical Concerns (6.375, STD 0.916), with scores clustered at 5-8, implying emerging rather than immediate issues. Overall, means above 13 dominate (five of eight challenges), comprising over 70% of the weighted distribution, with STDs below 2.5 indicating relatively consistent experiences, though federal libraries report marginally higher severities, possibly due to ambitious adoption goals clashing with realities.

DISCUSSION

The prominence of Mobile Applications and Self-Service Tools in Kaduna State's tertiary libraries aligns with broader trends in Nigerian academic libraries, where user-centric technologies are prioritized for enhanced accessibility. This is consistent with findings on high adoption of social media and mobile-related tools, which facilitate extended service delivery (Saibakumo, 2021). Similarly, the moderate use of RFID and Automation systems reflects attempts to integrate basic smart features, echoing studies on readiness for such technologies despite low overall deployment. Low adoption of AI and Chatbots in the data corroborates evidence of minimal AI integration in Nigerian libraries, where only a handful of institutions have implemented such systems due to expertise and funding barriers (Bashorun *et al.*, 2024). This agreement highlights systemic challenges like inadequate infrastructure, as seen in northern Nigerian contexts where smart services exist but at low extents (Adigun and Igboechesi, 2024). The limited use of AR/VR and IoT aligns with research showing low adoption rates for these emerging technologies in Nigerian academic settings, often below 33%, attributed to high costs and poor connectivity (Saibakumo, 2021). Comparable patterns in IoT studies reveal high awareness but constrained integration, reinforcing the need for policy interventions to bridge gaps (Abubakar and Safiyanu, 2025). Overall, these findings suggest opportunities for targeted investments to elevate advanced smart applications.

The elevated mean for Epileptic Power Supply aligns with empirical evidence from Nigerian library studies, where unstable electricity is identified as a primary deterrent to technology integration, often leading to operational disruptions and increased maintenance costs. This is particularly acute in university settings, where power outages impede continuous access to digital resources and automated systems. Similarly, the high mean for Poor Internet Connectivity corroborates findings on connectivity deficits as a core infrastructural hurdle, limiting real-time features like AI chatbots and remote self-service tools, with rural or underfunded institutions facing exacerbated bandwidth issues. Inadequate Funding and High Implementation Costs, with their substantial means, reflect systemic financial constraints in Nigerian academic libraries, where budget shortfalls restrict procurement of smart technologies like RFID and IoT devices. These barriers are compounded by economic volatility,

Table 2: Challenges encountered in the use of smart libraries application in these tertiary Institutions libraries in Kaduna State.

Sl. No.	Challenges	AFIT Library (F)	Federal University of Education, Zaria (F)	NOUN Kaduna Study Centre (F)	Greenfield University Library (F)	Kashim Ibrahim Library (F)	NDA Academy Library (F)	Kaduna State University Library (F)	Kaduna Polytechnic Library (F)	Mean	STD
1	Inadequate Funding	15	18	12	10	16	14	13	11	13.625	2.452
2	Epileptic Power Supply	18	20	16	15	19	17	18	16	17.375	1.814
3	Poor Internet Connectivity	16	17	19	14	18	16	17	15	16.5	1.604
4	Lack of Staff Training/Skills	12	14	13	12	15	13	14	12	13.125	1.126
5	High Implementation Costs	10	11	10	9	12	11	10	10	10.375	0.916
6	Resistance to Change	8	9	8	7	10	9	8	8	8.375	0.916
7	Data Privacy/ Ethical Concerns	6	7	6	5	8	7	6	6	6.375	0.916
8	Inadequate Infrastructure	14	15	14	13	16	15	14	13	14.25	1.165

resulting in stalled projects despite recognized benefits. The mean for Lack of Staff Training/Skills further echoes research on skill deficiencies, emphasizing the need for capacity-building to foster effective utilization of emerging tools, as untrained personnel often revert to manual processes. Lower means for Resistance to Change and Data Privacy/Ethical Concerns suggest these are secondary but growing issues, with resistance stemming from familiarity with traditional methods and privacy fears linked to data handling in AI applications. Studies in northern Nigerian contexts highlight how infrastructural inadequacies, including policy voids, amplify these attitudinal barriers, advocating for awareness campaigns and ethical frameworks to mitigate them. Collectively, these patterns indicate that addressing power, connectivity, and funding- the top means-could unlock broader adoption, aligning with calls for public-private partnerships in library digitization.

CONCLUSION

The analysis of smart library applications across eight tertiary institutions in Kaduna State, based on 285 aggregated responses, reveals a varied adoption of smart technologies. Mobile Applications and Self-Service Tools (15.44%, Mean=5.50, STD=3.25) and Automation and Cloud Computing Systems (15.09%, Mean=5.38, STD=2.26) are the most frequently implemented, indicating a strong emphasis on user accessibility and operational efficiency. Digital Media and Maker Tools (13.33%, Mean=4.75) and AR/VR and 3D Navigation (12.28%, Mean=4.38) also show significant adoption, reflecting efforts to enhance user engagement through innovative and immersive technologies. Conversely, AI and Chatbots (10.18%, Mean=3.62) and IoT Integration (10.88%, Mean=3.88) have lower adoption rates, potentially due to high implementation costs, technical expertise requirements, or infrastructure limitations. The standard deviations, particularly for Mobile Applications (3.25) and IoT (2.36), suggest variability in adoption across institutions, possibly linked to disparities in funding or technological readiness. Overall, while smart technologies are transforming library services in Kaduna State, their uneven adoption highlights the need for targeted interventions to ensure equitable access and maximize impact, aligning with sustainable development goals.

RECOMMENDATIONS

1. **Enhancement of AI and Chatbot Integration:** Given the lower adoption of AI and chatbots (10.18%), institutions should invest in AI-driven virtual assistants to improve user support and information literacy. Training staff and users on AI tools can address implementation challenges, as noted by Igbo *et al.*, (2024), ensuring personalized and efficient services.
2. **Expand IoT Infrastructure:** The limited use of IoT (10.88%) suggests a need for investment in IoT devices for environmental monitoring and automation. Partnerships with technology providers can help overcome infrastructure barriers, as recommended by (Ahmed *et al.*, 2024), to optimize library operations and space utilization.
3. **Standardize Mobile and Self-Service Tools:** With Mobile Applications leading at 15.44%, institutions should standardize app features across libraries, incorporating location-based services like Bluetooth beacons (Orji and Anyira, 2021). This ensures consistent user experiences and accessibility.
4. **Leverage Cloud Computing for Scalability:** Automation and Cloud Computing (15.09%) are widely adopted, but smaller institutions like ABU Zaria (score: 3) lag. Cloud-based solutions should be scaled to smaller libraries to enhance data management and reduce costs, as suggested by Schöpfel (2018).
5. **Promote AR/VR for Engagement:** AR/VR and 3D Navigation (12.28%) show promise for user engagement. Libraries should develop virtual tours and immersive learning spaces, particularly for institutions like Greenfield (score: 3), to align with modern educational trends (Bi *et al.*, 2022).
6. **Invest in Big Data Analytics:** SDN and Big Data Analytics (11.58%) are underutilized in some institutions (e.g., Kaduna Poly, score: 2). Libraries should adopt analytics for predictive resource allocation, as recommended by Okwu (2021), to enhance service delivery.
7. **Ensure Accessibility and Training:** To address variability in adoption (e.g., high STD for Mobile Apps), libraries should provide training programs and ensure accessibility features like screen readers for users with disabilities (Schöpfel, 2018).
8. **Strengthening and Development of Policy and Adequate Funding:** Tertiary Institutions must develop policies for data security and user privacy, particularly for IoT and cloud systems, as emphasized by (Ahmed *et al.*, 2024). Increased funding, potentially through public-private partnerships, can support equitable technology adoption across all institutions (Igbinovia, 2016).

By implementing these recommendations, Kaduna State tertiary institution libraries can fully harness smart technologies, aligning with Nigeria's Smart City Initiative and sustainable development goals.

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ABBREVIATIONS

ABU: Ahmadu Bello University; **AFIT:** Air force Institute of Technology; **AR/VR:** Augmented Reality/Virtual Reality; **AI:** Artificial Intelligence; **IoT:** Internet of Things; **RFID:** Radio Frequency Identification; **SDGs:** Sustainable Development Goals; **MDGs:** Millennium Development Goals; **NDA:** Nigerian Defence Academy; **NOUN:** National Open University of Nigeria; **SDN:** Software Defined Networking; **M:** Mean; **SD:** Standard Deviation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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