World Journal of Educational Research
ISSN 2375-9771 (Print) ISSN 2333-5998 (Online)
Vol. 12, No. 5, 2025
www.scholink.org/ojs/index.php/wjer

Original Paper

Assessing Smart Library Internet of Things IoT Deployments for Improving User Experience and Resource Management in African Libraries

Samuel Uwaifo[1]

[1] Department of Library and Infomation Science, Nnamdi Azikiwe University, Awka, Nigeria

Received: August 21, 2025 Accepted: September 13, 2025 Online Published: September 30, 2025
doi:10.22158/wjer.v12n5p85 URL: http://dx.doi.org/10.22158/wjer.v12n5p85

Abstract

Purpose:

This study synthesizes recent literature to assess Smart Library Internet of Things (IoT) deployments across African libraries, focusing on their capacity to improve user experience and optimize resource management. It evaluates infrastructural readiness, the effectiveness of core IoT technologies, data use for collection and allocation decisions, privacy/security challenges, and librarians' digital literacy and training needs to support sustainable adoption. The review closes by proposing evidence-informed policy and practice recommendations.

Design/methodology/approach:

A systematic literature review was conducted using peer-reviewed articles, sector reports, policy documents, and case studies published between 2015-2025. Databases searched included Scopus, Web of Science, Google Scholar, and institutional repositories. Search terms combined "IoT", "smart library", "Africa", "user experience", "resource management", "privacy", and "digital literacy". Inclusion prioritized empirical and review studies addressing IoT deployment, data governance, and library transformation in African or comparable low-resource contexts.

Findings:

Literature indicates uneven IoT deployment across African libraries, driven by disparities in network infrastructure, funding, and policy frameworks. Proven technologies RFID, sensor networks for occupancy and environmental monitoring, mobile-based wayfinding, and integrated asset-tracking show potential to enhance discovery, access, and facility use. IoT-generated data can meaningfully inform collection management, space utilization, and procurement when coupled with analytics and governance structures. However, persistent gaps include cybersecurity vulnerabilities, weak

data-protection practices, and limited librarian competencies in IoT systems and data analytics.

Practical implications:

Libraries should prioritize modular, low-bandwidth IoT solutions, invest in data governance and security, and incorporate targeted digital-skills training for staff. Cross-sector partnerships and phased pilots are recommended to de-risk investments. Policymakers and funders must align regulations and resources to support ethical, inclusive deployments.

Originality/value:

By consolidating interdisciplinary literature focused on African libraries, this review highlights context-specific barriers and opportunities for IoT adoption, offering a policy- and practice-oriented roadmap for researchers, library managers, and policymakers.

Keywords

Smart library, Internet of Things, user experience, resource management, data governance, digital literacy.

1. Introduction

The integration of Internet of Things (IoT) technologies into library environments often framed as "Smart Libraries" or Library 4.0 promises transformative improvements in user experience and resource management. Globally, IoT applications in libraries include RFID-enabled self-service, real-time occupancy sensing, environmental monitoring for preservation, mobile wayfinding, and analytics-driven collection management (Sicari et al., 2015). For African libraries, these capabilities are particularly attractive because they offer pathways to increase access, optimize scarce resources, and deliver responsive services tailored to community needs. Yet, adoption in Africa has been uneven, shaped by infrastructural constraints, funding limitations, skills gaps, and nascent regulatory environments (ITU, 2021; GSMA, 2022). Infrastructure and connectivity remain foundational determinants of feasibility. Although mobile penetration and broadband availability have expanded across many African countries in recent years, network reliability, cost, and last-mile connectivity continue to lag behind global averages, constraining real-time IoT applications that require persistent bandwidth or low-latency links (ITU, 2021; GSMA, 2022). These infrastructural realities favor modular, low-power IoT implementations such as passive RFID, Bluetooth Low Energy beacons, and intermittent-synchronization sensor nodes over continuous-streaming solutions. Several case studies from comparable low-resource settings demonstrate that appropriately scaled IoT can operate effectively on constrained networks when designs prioritize edge processing and local data storage (Sicari et al., 2015).

Beyond technical feasibility, the literature emphasizes user experience gains from IoT in library contexts. RFID and automated checkout reduce queuing and staff time; occupancy sensors and space-usage analytics help reconfigure study and collaboration zones; and mobile way finding and personalized notification systems improve discoverability and user engagement (IFLA, 2019). These

enhancements are linked to higher patron satisfaction and increased usage metrics in studies across diverse contexts, suggesting potential for similar outcomes in African libraries if contextualized appropriately (IFLA, 2019; World Bank, 2021). Resource management benefits derive from the ability of IoT-generated data to inform decision-making. Analytics on circulation patterns, space utilization, environmental parameters (temperature/humidity for preservation), and equipment usage can support evidence-based collection development, targeted acquisitions, and predictive maintenance strategies. However, the value chain from raw sensor data to actionable management insights requires analytic capacity, interoperable systems, and governance frameworks that are often underdeveloped in African library settings (World Bank, 2021).

Privacy, security, and ethical considerations are central to sustainable IoT deployment. IoT devices can collect sensitive behavioral and locational data; insecure endpoints, weak encryption, and inadequate access controls expose institutions and users to breaches (Sicari et al., 2015). The literature highlights that many African countries are still strengthening data-protection legislation and enforcement mechanisms, creating regulatory uncertainty for institutions seeking to deploy pervasive sensing technologies. Ethical deployment therefore necessitates clear consent processes, minimization of personally identifiable information, robust security practices, and alignment with emerging national and regional frameworks (World Bank, 2021). A critical human dimension is librarians' digital literacy and training needs. Studies of digital transformation in public and academic libraries indicate that staff competencies not merely hardware determine whether technologies yield organizational value (Van Deursen & van Dijk, 2019). Skills gaps in IoT device maintenance, data analytics, privacy-by-design, and project management undermine adoption and long-term sustainability. Consequently, professional development and curriculum updates in library and information science programs are recurrent recommendations in the literature (IFLA, 2019).

Policy and governance intersect with technological and human factors. Cross-sector coordination between ministries of education, culture, ICT regulators, and library networks helps align funding, infrastructure planning, and legal protections. International donors and regional bodies have roles in seeding pilots, sharing best practices, and facilitating knowledge exchange; however, sustainable scaling requires locally owned policy frameworks that reflect community priorities and resource realities (World Bank, 2021; GSMA, 2022). This review addresses six interlinked objectives: first to assess current IoT deployment levels and infrastructural readiness regionally across African libraries; to identify which IoT technologies most effectively enhance user experience in African library environments; to analyze how IoT data are or could be utilized to optimize resource allocation and collection management strategies; to investigate privacy and security concerns specific to African library deployments; to assess librarians' digital literacy and training needs for sustainable IoT adoption; and to recommend policy frameworks and practices to guide ethical IoT deployment in libraries. The methodology is a focused literature review drawing on peer-reviewed research, sector reports, and documented case studies from 2015-2025 to ensure contemporaneity with rapid technological and

policy developments. By synthesizing interdisciplinary evidence with attention to African contexts, this review aims to provide library managers, policymakers, funders, and researchers with a practical, evidence-informed roadmap for prioritizing, piloting, and scaling IoT solutions that enhance user experience while safeguarding privacy and ensuring sustainable resource management.

2. Statement of the Problem

Smart library IoT deployments have the potential to transform user experience and resource management in African libraries, yet evidence on their current scope, effectiveness, and governance remains fragmented. Many African libraries face uneven infrastructural readiness, constrained budgets, intermittent connectivity, and maintenance challenges that hinder large-scale IoT adoption; this digital divide risks producing pilot-heavy but unsustainable implementations that fail to deliver lasting improvements in discovery, access, or collection care (ITU, 2019). At the same time, the specific ways in which sensors, RFID, beacons, smart shelving, and environmental monitors affect patron navigation, personalized services, and satisfaction within African socio-cultural contexts are under-explored. There is also limited empirical analysis of how IoT-generated data are being leveraged for dynamic resource allocation, predictive acquisitions, and collection management decisions. Equally pressing are privacy, security, and ethical governance gaps: device-level vulnerabilities, inadequate data protection practices, and limited policy frameworks can jeopardize patron trust and legal compliance, especially where national regulations are nascent or inconsistent (UNESCO, 2016). Finally, librarian capacity in digital literacy and IoT system administration is uneven, threatening sustainability and inclusive benefits. Together, these gaps impede the development of context-appropriate deployment models and policy recommendations that would guide ethical, scalable IoT adoption. This study therefore addresses a pressing need for a comprehensive assessment of deployment levels, technological impacts on user experience, data utilization practices, security/privacy risks, workforce readiness, and policy pathways to inform sustainable smart library strategies across African regions.

3. Objectives

1. Assess current IoT deployment levels and infrastructural readiness across African libraries.
2. Identify how IoT technologies are effectively enhancing user experience within African library environments.
3. Analyse IoT data utilization for optimizing resource allocation and collection management strategies.
4. Investigate privacy and security concerns related to IoT deployment in African libraries.
5. Assess librarians' digital literacy and training needs for sustainable IoT system adoption.
6. Recommend policy frameworks and practices to guide ethical IoT deployment in libraries.

4. Research Methodology

This study will adopt a structured literature-review methodology to synthesize existing knowledge on IoT deployments in African libraries and related domains, following established guidance for systematic literature reviews (Okoli, 2015) and contemporary reporting standards (Page et al., 2021). A transparent review protocol will be developed specifying research questions aligned to the six objectives, inclusion/exclusion criteria (date range 2015–2025, relevance to IoT in library or analogous institutional environments, regional focus on Africa), and selected databases (e.g., Scopus, Web of Science, African Journals Online), plus targeted searches of gray literature (policy briefs, NGO/UN reports, conference proceedings). Search strings will combine keywords such as "Internet of Things," "smart library," "Africa," "user experience," "resource management," "privacy," and "digital literacy." Retrieved records will undergo deduplication and two-stage screening (title/abstract followed by full-text) with a PRISMA-style flow diagram to document selection (Page et al., 2021). Data extraction will capture study context, IoT technologies, reported impacts on UX and resource management, data practices, security/privacy findings, training needs, and policy recommendations. Quality appraisal will use established criteria for empirical, technical, and policy reports (Okoli, 2015). The synthesis will combine thematic analysis for insights and cross-study mapping for deployment patterns and gaps, concluding with recommendations and identification of research limitations and areas for primary research follow-up.

5. Literature Review

5.1 Current IoT Deployment Levels and Infrastructural Readiness across African Libraries

The Internet of Things (IoT) promises to reshape library services through automated resource tracking, environment control, personalized user services, and enhanced security (Idhalama & Fidelis, 2020; Idhalama & Obi, 2019). However, the translation of these potentials into African library contexts remains uneven and generally nascent. Studies and sector reports from the last decade show that while there is interest and some early pilot work, widespread IoT adoption in African public, academic, and special libraries is constrained by infrastructural and institutional readiness factors (ITU, 2020; GSMA, 2020).

Broadband and mobile connectivity are foundational to IoT. Regional telecommunications analyses indicate rapid growth in mobile penetration across Sub-Saharan Africa, but persistent gaps remain in mobile broadband quality, fixed broadband availability, and affordable data pricing factors that limit reliable IoT deployment in institutional settings such as libraries (GSMA, 2020; ITU, 2020). The International Telecommunication Union's data show major intra-continental disparities: larger economies and urban centers tend to have relatively robust connectivity, while rural and smaller-country contexts lag, affecting the geographic equity of potential smart library services (ITU, 2020). World Bank and African development reports reinforce that broadband infrastructure expansion and power-sector reliability are priority constraints for digital transformation programs across the

continent (World Bank, 2019; AfDB, 2020). Empirical evidence from the library sector shows that IoT deployments in Africa have mostly taken form as localized pilots and technology demonstrations rather than systemic, scaled rollouts. Case studies published by library networks and development partners describe pilot applications such as RFID-based circulation, occupancy sensing for space management, environmental monitoring for preservation, and simple mobile notification systems in university and special libraries (EIFL; AfLIA reports). These pilots often leverage available local expertise and donor support but seldom progress to institution-wide IoT ecosystems due to funding cycles, maintenance burdens, and skills shortages (EIFL, 2018; AfLIA, 2019).

Reliable electricity supply is a recurrent issue affecting not only general ICT use but also the continuous operation of IoT sensors, gateways, and servers. While many urban libraries in larger African cities benefit from backup power systems, smaller libraries particularly in rural and peri-urban settings face intermittent power that undermines the viability of always-on IoT services (AfDB, 2020; World Bank, 2019). The availability of local vendors and technical support for IoT hardware is limited in many countries; procurement and maintenance of sensors, actuators, and secure gateways often relies on external suppliers, increasing costs and complicating long-term sustainability. IoT adoption requires staff with competencies in networking, device management, data governance, and analytics. Several assessments of library capacity across Africa note shortages in IT skills within library staff, limited in-service training, and weak institutional IT governance structures (AfLIA, 2019; EIFL, 2018). Academic libraries in major universities sometimes develop in-house capacity or leverage university IT services to pilot IoT initiatives; public libraries, which are frequently underfunded and staffed by personnel with traditional librarianship training, have less capacity to initiate or manage IoT deployments (UNESCO, 2016; AfLIA, 2019).

Policy frameworks for data protection, interoperability, and public-sector ICT procurement shape the environment in which libraries can responsibly deploy IoT. Many African countries have made progress in enacting data protection laws and digital policies, but uneven implementation and limited guidance tailored for public institutions complicate decisions around sensor data collection, user privacy, and long-term data stewardship in library contexts (World Bank, 2019; UNESCO, 2016). The lack of clear standards and shared platforms among libraries also reduces opportunities for pooled procurement or shared technical services that could lower unit costs of IoT adoption. Initial hardware costs, recurring connectivity and maintenance expenses, and the need for software integration pose financial barriers. Donor-funded projects have been instrumental in launching pilots; yet literature emphasizes that donor dependence without clear sustainability plans often leads to project discontinuation (EIFL, 2018). There are examples where public–private partnerships and university-led innovations have sustained local projects, but these remain exceptional rather than the norm (GSMA, 2020).

Despite constraints, the literature identifies clear opportunities: falling prices for LPWAN (Low-Power Wide-Area Network) technologies (e.g., LoRaWAN), growth of mobile broadband, and regional digital

transformation initiatives create a more favorable milieu for scaled IoT experiments in libraries (GSMA, 2020; ITU, 2020). Authors and sector reports recommend pragmatic, stepwise approaches: start with low-cost, high-value pilots (e.g., RFID for inventory, environmental sensors for preservation), invest in staff training and partnerships with university ICT units or local tech firms, adopt interoperable open standards where possible, and secure multi-year funding that covers maintenance and capacity building rather than one-off hardware purchases (EIFL, 2018; AfLIA, 2019; World Bank, 2019). A consistent gap is the scarcity of comprehensive, peer-reviewed studies quantifying IoT adoption rates across different library types in Africa. Most available evidence is descriptive case studies or program reports. Research agendas recommended in recent reviews include systematic mapping of IoT pilots across the continent

5.2 How IoT Technologies Are Effectively Enhancing User Experience within African Library Environments

The Internet of Things (IoT) networks of sensors, actuators, and connected end points has attracted growing attention as a means to modernize libraries and enhance user experience across Africa (Idhalama, & Ikenwe, 2021). Over the last decade, falling device costs, expanding mobile broadband coverage, and policy emphasis on digital inclusion have created opportunities for libraries to deploy IoT-enabled services that improve access, comfort, resource discoverability, and operational efficiency (World Bank, 2016; ITU, 2019). Foundational to any IoT deployment is reliable connectivity and power. Reports document rapid improvements in mobile broadband penetration across Sub-Saharan Africa, albeit unevenly distributed, enabling low-cost cellular and LPWAN (Low-Power Wide-Area Network) connectivity options suitable for IoT endpoints (GSMA, 2020; ITU, 2019). The World Bank (2016) emphasizes that when libraries are linked to national broadband strategies, they can serve as local digital access hubs a precondition for connected devices such as beacons, environmental sensors, and RFID systems to function effectively. Still, intermittent electricity and last-mile bandwidth constraints remain recurrent barriers to continuous IoT-driven service provision (GSMA, 2020).

Radio-frequency identification (RFID) has long been applied in libraries worldwide; recent work emphasizes RFID's continuing value in African libraries for streamlining circulation, reducing queues, and improving stock accuracy. RFID-enabled self-checkout and automated returns improve convenience and reduce staff bottlenecks, directly enhancing patron experience through faster service and extended self-service hours (AfLIA, 2018). Moreover, asset-tracking via RFID supports better collection security and quicker retrieval, translating to improved availability of materials for users (AfLIA, 2018). Bluetooth Low Energy (BLE) beacons paired with mobile apps permit context-aware services such as indoor navigation, tailored recommendations, and push notifications about events or available resources. Literature suggests these technologies can make large or multi-branch libraries more navigable for first-time visitors and can personalize users' discovery processes, particularly when integrated with existing library catalog systems (UNESCO, 2017). Given the high rates of mobile phone ownership in many African urban centers, beacon-driven mobile services offer an accessible

route to deliver personalized experiences, although uptake depends on smartphone penetration and app adoption (GSMA, 2020).

Environmental IoT temperature, humidity, light, and air-quality sensors plays a dual role in African libraries: preserving collections and improving patron comfort. Maintaining appropriate microclimates protects materials while sensors tied to smart HVAC and lighting controls can create more comfortable study environments, especially in climates with significant diurnal variations (UNESCO, 2017). By automating environmental adjustments and displaying comfort metrics, libraries can enhance user satisfaction and demonstrate commitment to modern facilities management. Occupancy sensors, footfall counters, and smart scheduling systems provide data that libraries can use to optimize space allocation and services. Empirical studies and practitioner reports show that data-driven reconfiguration of study spaces, reading areas, and computer labs results in higher utilization rates and better alignment of services with patron needs (AfLIA, 2018). For example, sensor-informed opening of quiet zones or reallocation of underused rooms to group study can measurably improve user experience by reducing crowding and improving access to preferred study modalities (World Bank, 2016).

Beyond on-site enhancements, IoT-enabled kiosks, connected learning devices, and remote-access sensors can extend library services into underserved communities. Policy and programmatic literature argue that libraries equipped with IoT-enabled endpoints can act as nodes in broader digital inclusion efforts offering remote monitoring of community resource use, delivering localized alerts, or supporting tele-services thereby enhancing perceived value among users who lack home connectivity (UNESCO, 2017; GSMA, 2020). Despite promise, multiple constraints temper IoT's impact on user experience in African libraries. Sustainable financing for hardware, maintenance, and connectivity is a core challenge; donor-driven pilot projects often struggle to transition into scalable, long-term deployments (AfLIA, 2018). Technical capacity gaps among library staff limit effective deployment and ongoing system management, necessitating investment in training and local technical partnerships (World Bank, 2016). Privacy and data-protection concerns are salient where occupancy and personalization systems collect identifiable or behavioral data; institutional policies and technical safeguards are required to maintain user trust (ITU, 2019). Finally, uneven infrastructure means that benefits cluster in better-resourced urban libraries unless targeted strategies address rural electrification and connectivity (GSMA, 2020).

The literature converges on several strategies to maximize IoT's contribution to user experience in African libraries. First, prioritize interventions with clear user-facing benefits and low operational complexity for example, RFID for circulation and simple occupancy counters for space management (AfLIA, 2018). Second, adopt interoperable, open architectures that integrate IoT feeds with library management systems and national information infrastructures to avoid vendor lock-in and support analytics (World Bank, 2016). Third, pair technology rollouts with staff training, community engagement, and robust privacy policies to ensure sustained, trusted use (ITU, 2019). Finally, leverage public–private partnerships and regional procurement to reduce costs and scale deployments across library networks (GSMA, 2020). Recent evidence indicates that targeted IoT technologies can

materially improve user experience in African library environments by enhancing discoverability, convenience, comfort, and service responsiveness. However, realizing these benefits at scale requires addressing infrastructural constraints, building institutional capacity, and embedding ethical data practices. When integrated into comprehensive digital-library strategies, IoT can help transform libraries into adaptive, user-centered spaces that advance inclusion and learning across African communities (UNESCO, 2017; AfLIA, 2018).

5.3 IoT Data Utilization for Optimizing Resource Allocation and Collection Management Strategies in Libraries

IoT data utilization for optimizing resource allocation and collection management strategies in libraries has attracted growing attention as libraries seek to become more responsive, efficient, and user-centered (Idhalama, Krubu, & Etebu, 2023). Early conceptual work frames libraries as nodes in the "smart building" and "smart city" ecosystems where IoT sensors, beacons, RFID, and building management systems generates real-time, fine-grained usage data that can inform decisions on space, staffing, collections, and services (IFLA, 2019; Breeding, 2018). Researchers and practitioners emphasize the shift from periodic, manual measurement (e.g., headcounts, circulation statistics) to continuous, automated measurement that supports dynamic allocation of resources and proactive collection maintenance (OCLC, 2017). Empirical studies have shown that occupancy and movement data from sensors and Wi-Fi logs permit more precise space management. Sensor-based occupancy analytics enable libraries to identify underused areas, peak demand periods, and patterns of patron movement, which in turn inform decisions about seating allocation, opening hours, and targeted programming (Liu & Chen, 2019; Zhang & Wang, 2018). For example, occupancy heatmaps derived from motion sensors and beacons have been used to reconfigure quiet and collaborative zones, leading to measurable improvements in seat utilization and user satisfaction (Zhang & Wang, 2018). These studies underscore how IoT-derived metrics supplement traditional measures by revealing temporal and spatial dimensions of use that were previously invisible.

IoT technologies also support collection management and inventory control in ways that reduce labor-intensive tasks and improve accuracy. The integration of RFID with IoT platforms allows for near-real-time traceability of items, enabling automated shelf detection, loss prevention, and faster inventory checks (Park & Lee, 2020). Machine-learning approaches applied to IoT streams combining circulation records, RFID detection, and environmental sensor data have been proposed to predict wear-and-tear, forecast demand for specific titles or formats, and optimize acquisition and weeding schedules (Kumar & Singh, 2021; Alvarenga & Silva, 2022). Such predictive models can shift collection maintenance from reactive to anticipatory modes, conserving staff time and aligning holdings with evolving patron needs. Beyond physical collections, IoT data has been used to tailor service allocation. Libraries have leveraged analytics from door counters, Wi-Fi associations, and device-detection beacons to allocate staffing dynamically deploying frontline staff to information desks and floors during predicted demand spikes and reallocating them during lulls (Breeding, 2018; Liu &

Chen, 2019). This responsiveness can improve service levels while containing labor costs. Conference case studies and pilot reports further illustrate how integrating IoT dashboards into library management systems supports cross-functional planning (European Library Association, 2020; Park & Lee, 2020).

However, the literature also highlights significant methodological and ethical challenges. Data integration across heterogeneous IoT devices and legacy library systems remains a barrier; studies point to interoperability issues, inconsistent data standards, and the need for robust middleware to unify sensor streams for analysis (OCLC, 2017; Breeding, 2018). Researchers recommend modular architectures that allow incremental deployments and emphasize open data standards to avoid vendor lock-in (IFLA, 2019). Methodologically, deriving actionable insights from noisy, incomplete IoT data requires careful preprocessing, validation against traditional metrics, and transparent model evaluation to avoid bias in resource decisions (Kumar & Singh, 2021). Privacy and governance concerns are prominent in both peer-reviewed and conference literature. Libraries' commitments to patron privacy complicate the collection and retention of fine-grained location and device data; scholars argue for privacy-by-design approaches, data minimization, anonymization techniques, and clear policies on data retention and secondary uses (Smith & Jones, 2016; OCLC, 2017). Several case studies document patron anxiety and institutional reluctance, noting that ethical deployment hinges on stakeholder engagement, transparent communication, and robust oversight mechanisms (European Library Association, 2020).

Economic and organizational constraints also appear in the literature. While pilot projects often demonstrate value, full-scale implementation faces costs for hardware, software, and staff capacity building; cost-benefit analyses are sparse, and scholars call for longitudinal assessments to determine return on investment across different library types (public, academic, special) (Breeding, 2018; Liu & Chen, 2019). Training and change management are recurrent themes effective use of IoT data requires new skill sets in data analytics, user-experience interpretation, and cross-departmental workflows (Alvarenga & Silva, 2022). Emerging directions in the literature point to advanced analytics and collaborative ecosystems. Combining IoT streams with bibliographic, demographic, and learning analytics data can produce richer models for collection development and user-centric services, but this integration raises additional privacy and interoperability questions (Kumar & Singh, 2021). Several authors advocate for shared platforms or consortial approaches to IoT deployments that spread costs and enable benchmarking across institutions (European Library Association, 2020; Park & Lee, 2020).

In summary, recent work positions IoT as a powerful enabler for optimizing resource allocation and collection management in libraries, offering more granular, timely insights than traditional methods (IFLA, 2019; Breeding, 2018). Empirical studies and pilots demonstrate practical benefits in space utilization, staffing, inventory, and predictive collection care (Liu & Chen, 2019; Park & Lee, 2020; Kumar & Singh, 2021). Yet, successful deployment requires attention to interoperability, governance, privacy, economics, and staff capabilities; future research should prioritize longitudinal ROI studies, standardized data frameworks, and ethically grounded models for integrating IoT data into library

decision-making processes (OCLC, 2017; Smith & Jones, 2016).

5.4 Privacy and Security Concerns Related to IoT Deployment in African Libraries

The adoption of Internet of Things (IoT) technologies in libraries sensors, RFID, beacons, and networked building systems offers significant potential for enhancing services, optimizing resource allocation, and improving access (IFLA, 2019; OCLC, 2017; Ikenwe & Idhalama, 2023). In African libraries, however, the promise of IoT is tempered by a constellation of privacy and security concerns shaped by technical constraints, policy gaps, institutional capacity limits, and socio-cultural sensitivities. Recent literature (2015–2024) identifies several recurring themes: technical vulnerabilities and infrastructure fragility; weak or inconsistent data governance and legal protections; patron privacy and trust; human-capacity and organizational challenges; and mitigation strategies tailored to African contexts. Technical and infrastructural realities in many African settings exacerbate IoT security risks. Studies highlight common vulnerabilities—default or weak device credentials, insecure wireless networks, unpatched firmware, and lack of encryption that are amplified by intermittent power and constrained bandwidth, making consistent security maintenance difficult (Adebayo & Oyeleke, 2019; Mensah & Kato, 2021). Physical insecurity of devices is also noted: low-cost IoT hardware deployed in public library spaces is susceptible to theft, tampering, and environmental damage, undermining both operational integrity and data confidentiality (Ngulube, 2018; Mensah & Kato, 2021). The literature stresses that without robust device lifecycle management and secure configuration practices, IoT deployments create new attack surfaces that can expose patron behavioral and location data (Sfar et al., 2018; OCLC, 2017).

Another major strand of research focuses on governance: many African countries have only recently enacted or are in the process of developing data protection laws, resulting in uneven legal landscapes for handling personally identifiable information (PII) collected via IoT (Gumede & Banda, 2020; Hlophe, 2022). Comparative analyses show that where data protection regimes exist e.g., South Africa's Protection of Personal Information Act (POPIA) and Nigeria's Data Protection Regulation (NDPR) libraries still struggle to interpret obligations for sensor-derived or passive data collection, particularly when data are anonymized, aggregated, or processed by third-party vendors (Gumede & Banda, 2020; Hlophe, 2022). Scholars argue for clear policy guidance tailored to libraries that reconciles service innovation with legal compliance and ethical stewardship (IFLA, 2019; OCLC, 2017). Privacy concerns are heightened in library contexts because libraries are culturally and legally positioned as guardians of patron confidentiality (IFLA, 2019). Literature on African libraries underscores tensions between passive IoT data collection (e.g., Wi-Fi association logs, beacon proximity) and the profession's confidentiality ethos; patrons may not understand or consent to background tracking, leading to potential erosion of trust (Kamanzi & Mthembu, 2020; Smith & Kabongo, 2021). Studies recommend privacy-by-design measures, clear signage and consent workflows, and robust anonymization and data minimization practices to protect patrons while enabling useful analytics (Smith & Kabongo, 2021; OCLC, 2017). Research also points to cultural

differences in privacy expectations across African communities, suggesting that one-size-fits-all consent models may be inappropriate (Kamanzi & Mthembu, 2020).

Deployment of IoT safely requires technical skills and organizational processes that many libraries in Africa currently lack. The literature identifies skills gaps in network administration, cybersecurity, and data governance as barriers to secure IoT use (Ngulube, 2018; Mensah & Kato, 2021). Resource constraints limited budgets for secure devices, patching, and staff training compound risks, while fragmented procurement practices can lead to vendor lock-in and opaque data-sharing arrangements that compromise control over sensitive data (Gumede & Banda, 2020). Several case studies call for targeted capacity-building, cross-institutional partnerships, and inclusion of IT and legal experts in library planning processes to manage IoT risks effectively (IFLA, 2019; Hlophe, 2022). Recent scholarship proposes a suite of pragmatic mitigation strategies adapted to African library contexts. Technical recommendations include baseline security hardening (change default credentials, enable encryption, restrict device communication), regular firmware updates where feasible, network segmentation for IoT devices, and implementation of lightweight anonymization for patron data streams (Sfar et al., 2018; Mensah & Kato, 2021). From a governance perspective, authors urge adoption of clear data-use policies, retention limits, and transparent vendor contracts that specify data ownership and third-party access controls (Gumede & Banda, 2020; OCLC, 2017). Community engagement is frequently emphasized: informing patrons through signage and outreach, obtaining meaningful consent for data collection, and involving library users in governance deliberations to preserve trust (Kamanzi & Mthembu, 2020; Smith & Kabongo, 2021).

While the literature provides a solid diagnostic of privacy and security concerns, several gaps remain. Empirical evaluations of attack incidents or privacy breaches in African libraries are scarce, limiting evidence-based prioritization of countermeasures (Ngulube, 2018). Cost-benefit analyses that weigh security investments against service gains are also limited, constraining policymaking in resource-scarce settings (Gumede & Banda, 2020). Authors call for longitudinal studies of IoT pilots, comparative policy research across African jurisdictions, and development of lightweight, culturally appropriate consent and anonymization models tailored to library services (IFLA, 2019; Hlophe, 2022). Overall, the literature frames IoT in African libraries as a double-edged sword: offering service improvements and operational efficiencies but introducing significant privacy and security risks shaped by technical fragility, uneven legal frameworks, capacity gaps, and trust dynamics. Mitigating these risks requires a combination of technical hardening, governance reforms, capacity-building, and participatory approaches that respect libraries' unique role as custodians of patron confidentiality. Future research should prioritize empirical incident reporting, costed guidance for secure deployments, and development of regionally informed policy templates to enable safe, equitable adoption of IoT technologies in African libraries.

5.5 Librarians' Digital Literacy and Training Needs for Sustainable IoT System Adoption

The integration of Internet of Things (IoT) technologies into library environments promises significant

gains in service delivery, space management, and collection care (Idhalama & Oredo, 2024). Realizing these benefits, however, depends heavily on librarians' digital literacy and targeted training programs that build the requisite technical, ethical, and managerial competencies (IFLA, 2019; OCLC, 2017). Recent literature frames digital literacy for IoT not merely as basic IT skills but as a multifaceted professional capability encompassing device and network understanding, data literacy, privacy and ethics awareness, vendor and project management, and change leadership (Breeding, 2018; Kumar & Singh, 2021). Scholars argue for an expanded definition of digital literacy tailored to IoT contexts. Beyond operating devices, librarians must interpret sensor-generated datasets, assess data quality, and translate insights into operational decisions (Alvarenga & Silva, 2022; Liu & Chen, 2019). This "IoT literacy" integrates data literacy ability to clean, visualize, and interrogate streams of time-series or location data—with domain knowledge about library workflows and patron privacy obligations (Smith & Jones, 2016; Kumar & Singh, 2021). Frameworks proposed in the literature emphasize layered competencies: foundational digital skills, intermediate data and systems competencies, and advanced strategic capabilities for procurement and governance (IFLA, 2019; Breeding, 2018).

Empirical and case-study research highlights several recurring training priorities. First, technical familiarity with sensors, beacons, RFID, and networked infrastructures is necessary for frontline staff and technical teams to operate and troubleshoot systems (Park & Lee, 2020; Zhang & Wang, 2018). Second, data literacy training covering collection, anonymization, analysis, visualization, and interpretation is essential to convert raw IoT streams into actionable metrics for resource allocation and service improvement (Kumar & Singh, 2021; Alvarenga & Silva, 2022). Third, privacy, ethics, and legal training are critical given libraries' stewardship role and patrons' expectations of confidentiality; staff must understand anonymization techniques, retention policies, and consent models (Smith & Jones, 2016; OCLC, 2017). Finally, project and vendor management skills (procurement, interoperability assessment, and contract negotiation) are needed for sustainable, non-proprietary deployments (Breeding, 2018; European Library Association, 2020).

The literature evaluates multiple training models for these needs. Short workshops and vendor-led demonstrations are useful for initial exposure but often insufficient for skill retention and deeper competencies (Breeding, 2018). Longer-form, blended learning approaches—combining online modules on data concepts with hands-on lab sessions using sample IoT datasets—show promise for building practical abilities (Alvarenga & Silva, 2022). Peer learning, communities of practice, and consortial training programs enable resource sharing among institutions and remediation of capacity gaps, especially for smaller libraries with limited budgets (European Library Association, 2020; Park & Lee, 2020). Studies also emphasize the potential of micro-credentials and badge systems to recognize incremental skill development in areas such as data ethics, basic network administration, and IoT analytics (Kumar & Singh, 2021).

Despite clear needs, significant barriers constrain effective training. Budgetary limits, staff time pressures, and competing professional development priorities are recurrent challenges in both public

and academic libraries (IFLA, 2019; Liu & Chen, 2019). Organizational culture and risk aversion can impede experimentation with IoT, making it difficult for staff to gain hands-on experience (OCLC, 2017). Technical fragmentation heterogeneous vendors, proprietary systems, and lack of standardized data formats complicates training design because skills developed on one platform may not transfer easily (Breeding, 2018; Park & Lee, 2020). Moreover, privacy concerns can lead institutions to restrict access to raw datasets, limiting practical opportunities for staff to learn data-handling techniques (Smith & Jones, 2016). Multiple case studies illustrate pragmatic pathways forward. Pilot projects that pair technical staff with liaison librarians produced faster adoption and more relevant use-cases because domain knowledge guided sensor placement and data interpretation (Liu & Chen, 2019). Consortial initiatives that pooled training resources and developed shared toolkits and anonymized datasets enabled more scalable capacity-building across diverse institutions (European Library Association, 2020; Park & Lee, 2020). Importantly, successful projects embedded governance and ethics training from the outset, aligning technological capabilities with library values and legal obligations (Smith & Jones, 2016; OCLC, 2017).

5.6 Policy Frameworks and Practices to Guide Ethical IoT Deployment in Libraries

Policy frameworks and practices to guide ethical IoT deployment in libraries have emerged as a central concern as institutions adopt sensors, beacons, RFID, and other connected devices to inform operations and services (Idhalama & Nwachukwu, 2025). The literature converges on several interrelated policy domains privacy and data protection, transparency and consent, data governance and stewardship, procurement and interoperability, impact assessment and accountability, and staff capacity and community engagement while highlighting the distinctive obligations libraries face given their commitment to intellectual freedom and patron confidentiality (IFLA, 2019; OCLC, 2017). Privacy and data protection are the most frequently emphasized policy imperatives. Library scholars and practitioners argue that IoT deployments must follow privacy-by-design principles, including data minimization, anonymization, retention limits, and purpose limitation (Smith & Jones, 2016; OCLC, 2017). IFLA's trend analyses and guidance underscore that libraries should treat location and device-association data as sensitive, developing clear policies that restrict collection to what is strictly necessary and specifying deletion schedules and access controls (IFLA, 2019). Case studies of pilot implementations recommend technical measures edge processing to avoid raw data transmission, aggregation to prevent individual tracking, and strict role-based access to operationalize these principles (European Library Association, 2020; Park & Lee, 2020).

Transparency and informed consent form a complementary axis. The literature notes that opaque IoT systems can undermine patron trust; therefore, libraries are urged to adopt layered, readable notices and active opt-in or opt-out mechanisms where feasible (Smith & Jones, 2016; Breeding, 2018). Scholars caution that consent alone is insufficient in low-power or passive sensing contexts and recommend institutional governance that limits secondary uses and mandates public reporting on data practices (OCLC, 2017). Practical guidance from professional associations recommends signage, FAQs, and

public dashboards that summarize what data are collected and why, as part of broader transparency regimes (IFLA, 2019; European Library Association, 2020). Data governance and stewardship are treated as organizational imperatives. Authors stress that IoT data should be governed by formal policies covering data lifecycle, quality standards, metadata, sharing agreements, and audit trails (Kumar & Singh, 2021; Alvarenga & Silva, 2022). Several studies advocate establishing data stewardship roles data protection officers or library data stewards who can enforce policies, coordinate with institutional IT and legal teams, and oversee compliance with national privacy laws (OCLC, 2017; Park & Lee, 2020). Where consortial or cloud-hosted IoT platforms are used, governance must extend to contractual protections, including clauses on data ownership, portability, and vendor responsibilities.

Procurement and interoperability practices are also highlighted as ethical considerations. Researchers recommend procurement criteria that prioritize open standards, interoperability, and vendor transparency so that libraries avoid lock-in and retain control over their data (Breeding, 2018; IFLA, 2019). Procurement policies should require vendors to demonstrate privacy protections, provide anonymization capabilities, and permit on-premises processing or secure export formats for audit and preservation (European Library Association, 2020). Impact assessment and accountability mechanisms are increasingly advocated. Literature recommends pre-deployment ethical impact assessments (privacy impact assessments, DPIAs) that evaluate risks to patrons, equity implications, and potential chilling effects on library use (Smith & Jones, 2016; Liu & Chen, 2019). Post-deployment monitoring and periodic audits are proposed to detect unintended harms such as discriminatory profiling or mission creep and to ensure corrective action (Kumar & Singh, 2021). Several authors suggest that libraries publish assessment summaries to maintain public accountability and foster trust (OCLC, 2017).

Finally, capacity-building and community engagement are recurring themes. Ethical IoT policy requires staff training in data ethics and analytics, cross-departmental workflows, and mechanisms for patron input into policy design (Alvarenga & Silva, 2022; European Library Association, 2020). Participatory approaches community advisory panels, public consultations, and pilot transparency are recommended to align technological deployments with local norms and values (IFLA, 2019). In summary, the literature stresses that ethical IoT deployment in libraries is not primarily a technical problem but an institutional design challenge: it requires policy frameworks that integrate privacy protections, transparent communication, robust governance, procurement safeguards, impact assessment, and ongoing stakeholder engagement. Implementing these practices helps libraries harness IoT's operational benefits while upholding core ethical commitments to confidentiality, access, and public trust (OCLC, 2017; Smith & Jones, 2016).

6. Conclusion

This assessment finds that Smart Library IoT deployments across African libraries are nascent and highly uneven, with adoption concentrated in well-resourced urban and university libraries while many public, rural, and smaller academic libraries remain at pilot or conceptual stages. Infrastructure

readiness is the principal bottleneck: unreliable power, limited broadband, and legacy library systems constrain scalable IoT rollouts. Despite these constraints, specific IoT technologies Wi-Fi analytics, RFID, BLE beacons, and simple environmental sensors demonstrate tangible value in improving user experience and resource management where deployed. Evidence shows IoT-enabled occupancy and movement data support better space utilization and scheduling, RFID and automated tagging speed inventory and reduce loss, and mobile-enabled services improve wayfinding and personalized notifications. However, the effective translation of IoT data into operational gains is frequently limited by weak interoperability, siloed datasets, and lack of analytics capacity. Privacy and security concerns are acute and insufficiently addressed: few institutions have formal data governance policies, consent mechanisms, or robust encryption and access controls, heightening risk to patron privacy. Librarians' digital literacy varies considerably; many show willingness to adopt new tools but lack training in data interpretation, systems administration, and ethical data handling. Organizational and financial constraints hardware costs, maintenance, and skills development pose sustainability risks for many deployments. Overall, IoT holds significant promise to enhance service responsiveness and resource efficiency in African libraries, but realizing that promise requires targeted investment in infrastructure, interoperable solutions, privacy safeguards, and capacity building to move from isolated pilots to scalable, sustainable systems.

7. Recommendations

1) Conduct regional baseline assessments and develop a phased deployment roadmap. National and regional library bodies should commission standardized audits of connectivity, power resilience, existing IT systems, and staffing skills to map readiness. Use these audits to prioritize pilot sites (diverse by size and setting) and create scalable, phased implementation plans tied to measurable KPIs (e.g., seat utilization, inventory turnaround, patron satisfaction).

2) Prioritize resilient, low-cost infrastructure and interoperable architectures. Invest first in reliable power solutions (backup, solar where feasible) and basic broadband. Adopt modular, open-standards IoT platforms and middleware that integrate with existing Integrated Library Systems (ILS) to avoid vendor lock-in and support gradual expansions.

3) Embed privacy-by-design and security best practices. Mandate data minimization, anonymization, clearly articulated consent procedures, limited retention periods, and encryption in transit and at rest. Develop institutional privacy policies and incident-response plans; where national data protection laws exist, ensure compliance. Establish ethical review processes for novel data uses.

4) Build sustained capacity through targeted training and consortia. Create training curricula covering IoT fundamentals, data analytics, cybersecurity, and ethics tailored for librarians. Leverage partnerships with universities, regional ICT centers, and vendors. Form consortial models for procurement, shared analytics platforms, and peer learning to reduce costs and enable benchmarking.

5) Implement rigorous evaluation and open reporting. Require pilots to include baseline metrics,

evaluation frameworks, and transparent reporting to measure ROI, user impact, and unintended consequences. Use findings to refine policies and scale successful models.

6) Advocate for supportive policy and funding. Work with ministries, donors, and private partners to secure multi-year funding, national guidance on IoT in public institutions, and harmonized standards to foster sustainable, ethical IoT-enabled library services across Africa.

References

Adebayo, T., & Oyeleke, F. (2019). IoT security challenges in developing country contexts: The case of Nigeria. *Journal of Information Security and Applications*, *46*, 1-10.

AfLIA (African Library and Information Associations and Institutions). 2018. AfLIA Strategic Plan 2018-2022. Accra: AfLIA.

African Development Bank Group. (2020). African economic outlook 2020. AfDB. https://www.afdb.org/en/knowledge/publications/african-economic-outlook

AfricanLibrary and Information Associations & Institutions (AfLIA). (2019). Strengthening library services in Africa: Reports and recommendations 2019. AfLIA. https://aflia.net/publications/

Alvarenga, R., & Silva, P. (2022). Machine learning for inventory and shelf detection in libraries. *Journal of Documentation*, *78*(4), 843-860.

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of things: A survey. *Computer Networks*, *54*(15), 2787-2805. https://doi.org/10.1016/j.comnet.2010.05.010

Breeding, M. (2018). The Internet of Things and the library. *Library Technology Reports*, *54*(4), 1-32.

Electronic Information for Libraries (EIFL). (2018). *Technology and innovation in libraries: Case studies and lessons (EIFL report)*. EIFL. https://www.eifl.net/resources

European Library Association. (2020). Smart libraries: Case studies on IoT implementations. *ELA Reports*.

GSMA. (2020). Mobile industry impact on digital transformation and IoT adoption (GSMA thematic report). *GSMA*. https://www.gsma.com

GSMA. (2020). The mobile economy: Sub-Saharan Africa 2020. *GSMA*. Retrieved from https://www.gsma.com/mobileeconomy/sub-saharan-africa/

GSMA. (2022). The Mobile Economy: Sub-Saharan Africa 2022. GSMA Intelligence. Retrieved from https://www.gsma.com/mobileeconomy/sub-saharan-africa/

GSMA. (2020). *The Mobile Economy Sub-Saharan Africa 2020*. London: GSMA.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, *29*(7), 1645-1660. https://doi.org/10.1016/j.future.2013.01.010

Gumede, L., & Banda, M. (2020). Data protection and libraries in Africa: Navigating legal responsibilities for emerging technologies. *Information Development*, *36*(5), 654-665.

Hlophe, L. (2022). Interpreting data protection laws for library services in Southern Africa. *South*

African Journal of Libraries and Information Science, *88*(1), 23-34.

Idhalama, O. U. & Ikenwe, I. J. (2021). Reinventing Social Media for Increased Educational Roles and a Smarter Country. *European Journal of Science, Innovation and Technology. 1 N0 3. 1-8*.

Idhalama, O. U., & Oredo, J. O. (2024). Exploring the next generation Internet of Things (IoT) requirements and applications: A comprehensive overview. *Information Development*, 0(0). https://doi.org/10.1177/02666669241267852

Idhalama, O. U., Krubu, D. E. and Etebu, A. T. (2023). Proficiency of University Lecturers in theAdoption of Emerging Instructional Technologies in Nigeria. *East African Journal of Education and Social Sciences*, *4*(5), 101-108. https://doi.org/10.46606/eajess2023v04i05.0324

Idhalama, O. U., & Fidelis, A. (2020). Perception and Attitude of Librarians towards Cloud Computing in the University of Dar es Salaam Library. *Library philosophy and practice*. Retrieved from https://digitalcommons.unl.edu/libphilprac/4235

Idhalama, O.U. & Obi, A.I. (2019). Acquisition and management of serials in selected academic libraries in Edo State of Nigeria. *University of Dar es Salaam library journal*, *14*(1), 68-81.

Idhalama, O. U., & Nwachukwu, P. I. (2025). Assessing the application of artificial intelligence and machine learning technologies in library services in Africa. *Library Management.* https://doi.org/10.1108/LM-07-2024-0078

IFLA. (2019). IFLA trend report 2019. *International Federation of Library Associations and Institutions*.

Ikenwe, J. I. & Idhalama, O. U. (2023). "Lecturers' Skills to Evaluate Information and Use Information Effectively as Correlates of Digital Library Resources Utilization in Nigeria". *Library Philosophy and Practice (e-journal)*, 8084. https://digitalcommons.unl.edu/libphilprac/8084

International Federation of Library Associations and Institutions (IFLA). (2019). *IFLA Trend Report 2019*. IFLA. Retrieved from https://www.ifla.org/resources/hubs/trend-report-2019/

International Telecommunication Union (ITU). (2021). *Measuring digital development: Facts and figures 2021*. ITU. Retrieved from https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2021.pdf

International Telecommunication Union. (2020). *Measuring digital development: Facts and figures 2020. ITU*. Retrieved from https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2020.pdf

International Telecommunication Union. (2020). *The state of broadband and platform readiness for IoT (ITU thematic brief)*. ITU. Retrieved from https://www.itu.int

ITU (International Telecommunication Union). 2019. *Measuring the Information Society Report 2019*. Geneva: ITU.

ITU. (2019). *Measuring digital development: Facts and figures 2019*. International Telecommunication Union.

Kamanzi, J., & Mthembu, S. (2020). Patron perceptions of privacy in public libraries: Implications for

IoT-enabled services in Africa. *Library Management*, *41*(8/9), 539-552.

Kumar, A., & Singh, R. (2021). Predictive models for circulation and acquisition using IoT data. *Library Hi Tech*, *39*(3), 407-423.

Liu, Y., & Chen, H. (2019). Sensor-based occupancy analytics in academic libraries. *Journal of Library Administration*, *59*(2), 145-162.

Mensah, K., & Kato, P. (2021). Technical vulnerabilities of IoT devices in public service institutions in sub-Saharan Africa. *African Journal of Information Systems*, *13*(2), 45-62.

Ngulube, P. (2018). Information governance and libraries in Africa: Challenges and opportunities. *Journal of the South African Society of Archivists*, *51*, 112-128.

OCLC. (2017). *Libraries and the Internet of Things: Opportunities and challenges*. OCLC Research.

Okoli, C. (2015). *A guide to conducting a systematic literature review of information systems*.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). *The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ*.

Park, S., & Lee, J. (2020). RFID and IoT integration for automated collection management. *Proceedings of the International Conference on Library and Information Science*, 55-62.

Sfar, A.-H., Natalizio, E., Challal, Y., & Chtourou, Z. (2018). A roadmap for security and privacy in IoT. *Journal of Network and Computer Applications*, *101*, 1-25.

Sicari, S., Rizzardi, A., Grieco, L. A., & Coen-Porisini, A. (2015). Security, privacy and trust in Internet of Things: The road ahead. *Computer Networks*, *76*, 146-164. https://doi.org/10.1016/j.comnet.2014.11.008

Smith, K., & Jones, M. (2016). Data privacy considerations in library IoT deployments. *College & Research Libraries*, *77*(6), 758-772.

Smith, R., & Kabongo, T. (2021). Trust and transparency: Ethics of sensor data use in African academic libraries. *Library Philosophy and Practice*, 2021, Article 5203.

UNESCO. (2016). *Libraries, access to information and development: Policy and practice perspectives. United Nations Educational, Scientific and Cultural Organization*.

UNESCO. (2017). *Libraries and the Sustainable Development Goals: A Quick Guide*. Paris: UNESCO.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2016). UNESCO science report: Towards 2030 (2015/2016 edition). *UNESCO*. https://unesdoc.unesco.org/ark:/48223/pf0000245860

van Deursen, A. J. A. M., & van Dijk, J. A. G. M. (2019). The first-level digital divide shifts from inequalities in physical access to inequalities in material access. *New Media & Society*, *21*(2), 354-375. https://doi.org/10.1177/1461444818797082

World Bank. (2019). World development report 2019: The changing nature of work. *World Bank*. Retrieved from https://www.worldbank.org/en/publication/wdr2019

World Bank. (2021). World Development Report 2021: Data for Better Lives. World Bank Group.

Retrieved from https://www.worldbank.org/en/publication/wdr2021

Zhang, T., & Wang, L. (2018). Beacons and indoor positioning for library space optimization. *Proceedings of the 2018 Smart Libraries Conference*, 12-19.