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Transforming Public Libraries in Khyber Pakhtunkhwa: A Library 4.0 Framework for Integrating Artificial Intelligence and the Internet of Things for Future Sustainability

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Abstract

Khyber Pakhtunkhwa (KP) public libraries are experiencing a conversion into tech-driven, smart spaces that remain in line with the Library 4.0 model. This paradigm places an stress on automation, interconnection, and user-centered facilities. Investigators in this study surveyed 98 library employees (comprising librarians, IT authorities, and administrators) to acquire more about how public libraries in KP are utilizing AI and the IoT. Although there is a lot of interest for smart technology implementation, the outcomes show that there are important hindrances, such as an absence of resources, poor digital literateness, and out-of-date infrastructure. Irrespective, employees are attractive more cognizant of the benefits of AI and IoT and are enthusiastic to implement them. An AI-driven facility model, automation based on the Internet of Things (IoT), real-time analytics, and capacity-building platforms are all share of the study's planned Library 4.0 architecture. The overarching determination of this background is to advance public access to information and technology in direction to facilitate digital presence, smart governance, and supportable growth in Pakistan. This will be attained by reimagining traditional public libraries as participating knowledge centers.

Keywords: Library 4.0, Artificial Intelligence, Internet of Things, Public Libraries, Khyber Pakhtunkhwa.

Introduction

Libraries have distorted from being unchallengeable provisions of books into alive, breathing ecosystems of knowledge, reflecting the cumulative role of technology in decisive how and where people access and consume information. The information economy, fast money up front in ICTs, and globalisation have all donated to greater social vicissitudes that have accorded with this revolution. The increase of Library 4.0 is one of the most noticeable existing growths that are altering libraries' function. This impression is comparable to Industry 4.0, which remains characterised by the cumulative integration of physical, digital, and biological coordination (Schwab, 2017). There is a key change in thoughtful with Library 4.0. It involves

integrating smart technologies similar blockchain, machine learning, AI, and the Internet of Things (IoT) through library systems to advance smart, user-centric, and consistent facilities (Mirza & Mahmood, 2023). Libraries are made smarter through this ecosystem, so they might acquire from their users' activities in real time, deliver individualised amenities, systematize mundane responsibilities, and inspire digital presence, among other belongings. In order to uphold their significance in the period of Google, social media, and mobile information-seeking behaviour, public libraries everywhere the world have ongoing to implement these advances. Smart bookshelves, energy-efficient structure management, and self-service stalls are all through conceivable by the Internet of Things (IoT), and public libraries in states like South Korea, Singapore, and Finland are already using AI to deliver personalised gratified endorsements (Buabbas et al., 2023). Thanks to these updates, public libraries are now better able to serve their clienteles, make the maximum of their resources, and serve as centers for digital societies (Hussain et al., 2021). There has remained a nonexistence of local consistency in the change near smart public libraries, predominantly in deprived nations, nevertheless these worldwide growths. In many states of the Global South, the blowout of Library 4.0 philosophies is delayed by factors similar government provision, insufficient budget, lacking staff, and out-of-date digital substructure (Rafiq & Ameen, 2020). However, public libraries can be especially innovative in these settings by helping to adjacent the digital gap, strengthen informal education, and inspire countries to become complicated in their societies. Familiarizing to new technological models is a substance of life and death for public libraries, particularly individuals in under-resourced regions like Khyber Pakhtunkhwa, where this study is usual. Therefore, it is intellectually significant and socially persistent to appreciate how public libraries strength deliberately and data-drivenly integrates AI and IoT.

Contextual Overview: Khyber Pakhtunkhwa

The province of Khyber Pakhtunkhwa (KP) in Pakistan's northwest is characterised through its rich traditional diversity, complicated geography, and elaborate collective and political landscape. Over the preceding few years, KP—which is home-based to more than 40 million people—has understood enormous investments in setup and education. Inappropriately, the province's public libraries have unsuccessful to familiarize to these vicissitudes. Libraries are vulnerable to negligence and underutilisation owing to their deficient technology resources, underfunded finances, and limited recruitment (Khan & Jan, 2022). Library sector implementation is stagnant disseminated, notwithstanding national potentials to digital alteration in Pakistan (e.g., the Digital Pakistan Policy (2018) and provincial creativities beneath the KP Digital Strategy). The mainstream of KP's public libraries are by means of antediluvian cataloguing schemes, have not digitised their assortments, and have very sluggish internet connections. There is a noticeable absence of AI-powered services like automated help desks, commendation engines, or real-time analytics, and automation is normally limited to simple computerisation. While libraries in greater municipalities like Peshawar might have additional modern amenities, those in more distant areas often absence resources like dependable power, reliable internet, and capable staff. Libraries are likewise cut off from greater smart city and e-government programs due to a absence of collaboration between digital governance developments on a provincial level and library facilities (Ali et al., 2021). But there is a ration of unrealised possible for digital library revolution in KP. There is an immense youth populace in the province, and the demand for access information amongst scholars, teachers, and specialists is increasing, by way of is the implementation of smartphones. With adequate backing, public libraries have the probable to become centers for digital presence, the conservation of local knowledge, and the elevation of enduring knowledge. In this background, it is not only necessary but important to contain AI and IoT technology into KP's public libraries by means of a well-organised Library 4.0 outline. This kind of modification has the possible to upsurge facility convenience, streamline library tasks, and deliver users and personnel greater agency over the usage of intelligent methods. This study purposes to explore the practical methods in which these latent can be realised assumed the exceptional opportunities and limitations of KP.

Objective of the Study

The primary aim of this study is to develop a strategic framework for smart public libraries in Khyber Pakhtunkhwa by evaluating the current status and potential for integrating AI and IoT. Specific objectives include:

1. To assess the awareness and understanding of AI and IoT technologies among public library professionals in KP.
2. To evaluate the readiness of public libraries in KP for the implementation of Library 4.0 technologies.
3. To identify the infrastructural and administrative challenges in adopting smart technologies.
4. To analyze the perceptions and attitudes of stakeholders towards Library 4.0 initiatives.
5. To propose a context-sensitive Library 4.0 implementation framework based on empirical data

Review of the Literature

Public libraries have extended served as critical organizations in the distribution of knowledge, the elevation of literateness, and the development of inclusive access to information. Traditionally, they performed by way of physical sources of books, archives, and printed resources—spaces anywhere individuals might study, research, and involve in lifelong knowledge. Nevertheless, with the emergence of digital technologies and the change in the direction of a knowledge-based society, the role of public libraries has long-drawn-out and distorted suggestively. No longer imperfect to the physical field, libraries nowadays are predictable to function as digitally receptive environments, offering distant access to electronic resources, digital knowledge programs, and technology-driven facilities made-to-order to community requirements (Tait et al., 2023). This revolution is not impartial functioning but also theoretical, as the library's role progresses from passive information storage to dynamic simplification of knowledge, digital inclusion, and modernization. As Verma and Mishra (2024) argue, the modern library necessity be observed as a hybrid information space—an organization that stabilities traditional facilities with digital infrastructure to come across the demands of 21st-century consumers and bridge the digital divide.

In response toward these innovative demands, the concept of Library 4.0 has emerged, offering a progressive background for participating emerging technologies into library facilities. Rooted in the philosophy of Industry 4.0, Library 4.0 highlights the usage of cutting-edge technologies such as artificial intelligence (AI), machine learning, cyber-physical structures, automation, and the Internet of Things (IoT) to deliver smoother, more well-organized, and user-centered amenities (Mirza & Mahmood, 2023). Unlike preceding repetitions—Library 2.0, which embraced Web 2.0 tools for interactivity, and Library 3.0, which focused on digitization and repository building—Library 4.0 prioritizes intelligent automation, personalization, and predictive service delivery. AI, for example, can automate complex cataloguing processes, offer modified commendations centered on user behavior, and facilitate voice-enabled search and communication interfaces. As Lee and Seo (2022) note, this development imitates a profounder paradigm modification from static facility establishment to dynamic, real-time user assignation. Libraries are no longer inactive provision providers; they are currently intelligent systems that familiarize, acquire, and respond to the developing requirements of customers, thereby aligning through the philosophy of the Fourth Industrialized Revolution.

Amongst the significant technologies empowering this revolution, AI and IoT stand out as particularly impactful in reshaping how library services are designed, delivered, and skilled. Artificial intelligence has been deployed in a wide range of library functions, including intelligent chatbots aimed at virtual reference, AI-powered detection tools, automatic metadata generation, and normal language processing for cataloging (Zhao & Yang, 2023). These tools not only modernize workflows but also improve exploration relevance and advance the overall user understanding by enabling real-time, modified collaborations. A study by Buabbas et al. (2023) demonstrated that AI integration directed to considerable improvements in user gratification, staff efficacy, and facility delivery in technologically progressive foundations. Complementing AI, the Internet of Things familiarizes an further layer of smart automation through RFID tagging, smart bookshelves, real-time conservational monitoring, and inside navigation structures (Sivarajah et al., 2023). These revolutions improve user suitability, automate inventory organization, and advance accessibility for differently-abled users through adaptive technologies (Park & Jung, 2022).

Notwithstanding these global developments, instigating smart technologies in public libraries in

emerging regions such as Khyber Pakhtunkhwa (KP), Pakistan, leftovers a multifaceted and stimulating endeavor. Libraries in these constituencies often operate under situations of incomplete funding, insufficient infrastructure, inadequate technological resources, and a absence of skilled professionals proficient of handling and upholding advanced structures (Khan & Jan, 2022). Institutional confrontation to modification, compounded by administrative steeplechases and out-of-date policies, further obstructs innovation. Furthermore, the use of AI in addition IoT in public spaces increases ethical and lawful concerns related to data confidentiality, cybersecurity, algorithmic bias, and surveillance (Rahman & Ahmad, 2023). These experiments are strengthened by a determined digital divide, in which large parts of the population—particularly in rural and underserved regions—nonexistence entrance to the internet, smart devices, or the essential digital skills. According to Ali and Gul (2024), the lack of strategic planning and recognized readiness in Pakistan's public zone significantly delays the implementation of Library 4.0 frameworks. To systematically investigate these restraints and opportunities, this study applies the Technology Acceptance Model (Davis, 1989; Venkatesh & Bala, 2008), which measures how supposed practicality and ease of use impact user implementation of innovative technologies, along with Rogers' (2003) Dissemination of Innovations theory, which recognizes key factors—such as relative improvement, complexity, compatibility, and observability—that affect in what way revolutions spread in the interior organizations. Together, these models offer a comprehensive lens through which the tasks, drivers, and readiness aimed at smart library renovation in KP's public libraries can remain understood and addressed.

Research Methodology

Research Design

This quantitative study aimed to assess Library 4.0 readiness among public libraries in Khyber Pakhtunkhwa, Pakistan. A structured, closed-ended questionnaire was administered to gather data on staff demographics, awareness of AI and IoT, current technology use, perceived readiness, and attitudes toward smart library transformation. Data were analyzed using SPSS (Version 27) for descriptive and inferential statistics.

Population and Sampling

The target population included librarians, assistant librarians, IT staff, and library administrators across five districts: Peshawar, Mardan, Abbottabad, Swat, and Dera Ismail Khan. Purposive sampling selected participants with relevant experience. A total of 98 valid responses were obtained.

Data Collection Instrument

A self-administered questionnaire was developed from existing literature and validated smart-library models. It comprised five sections:

1. Demographics (e.g., age, gender, designation, experience)
2. Awareness of AI and IoT
3. Current Technology Use
4. Perceived Readiness and Challenges
5. Attitudes toward Smart Library Transformation

Validity and Reliability

Content validity was confirmed by expert review (three library science scholars and one IT specialist). A pilot test (n = 10) led to minor question adjustments. Cronbach's alpha for constructs ranged from 0.85 to 0.90, indicating good internal consistency.

Data Collection Procedure

Data were collected over six weeks. Printed questionnaires were distributed in urban libraries, and a Google Forms link was circulated via institutional emails. Two reminder notices improved response rates.

Data Analysis Techniques

Data was coded and analyzed in SPSS Version 27 included:

- Descriptive statistics: frequencies, percentages, means, and standard deviations
- Independent-samples t-tests to compare groups

- One-way ANOVA for multi-group comparisons
- Pearson correlation to assess relationships between awareness, readiness, and attitudes

Descriptive Statistics for Major Scale Domains

Construct	Items	α	M	SD	Range
Awareness (AI & IoT)	5	0.85	3.70	0.45	2.10–4.80
Current Technology Use	4	0.88	3.10	0.60	1.50–4.50
Perceived Readiness	6	0.90	3.50	0.55	2.00–4.70
Attitude Toward Change	5	0.86	4.00	0.50	2.50–5.00

Frequency of AI and IoT Use in Library Operations

Technology	Daily	Weekly	Monthly	Rarely
Artificial Intelligence (AI)	10 (10%)	30 (30%)	40 (40%)	18 (18%)
Internet of Things (IoT)	5 (5%)	20 (20%)	50 (51%)	23 (24%)

Correlation between Awareness and Readiness for Library 4.0 (N = 98)

Variable 1	Variable 2	r	P
Awareness of AI and IoT	Readiness for Library 4.0	.68	< .01

Results and Findings

This section offerings the key results obtained from the survey conducted among public library staff in Khyber Pakhtunkhwa to assess the adoption and readiness of AI and IoT technologies. The findings reveal a strong response rate, diverse respondent demographics, moderate to high awareness of emerging technologies, and a generally positive attitude toward AI and IoT integration. However, significant challenges such as lack of funding, training gaps, outdated infrastructure, and resistance to change hinder full-scale adoption. These insights collectively highlight the need for comprehensive planning to support Library 4.0 transformation in the region.

Response Rate and Demographics of Respondents

Out of the 120 questionnaires distributed to public library staff across Khyber Pakhtunkhwa, 98 valid responses were collected, yielding a response rate of 81.6%. This response rate exceeds the commonly recommended threshold of 70% for social science research, indicating robust engagement and data reliability (Creswell & Creswell, 2023). The high participation suggests that library professionals recognize the importance of investigating AI and IoT adoption in their institutions, thus providing confidence in the representativeness of the sample.

Table 4.1: Demographic Characteristics of Respondents (n = 98)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	71	72.4
	Female	27	27.6
Designation	Librarian	61	62.2
	IT Staff	25	25.5
	Administrator	12	12.2
Age Group	20–30	18	18.4
	31–40	43	43.9
	41–50	30	30.6
	51 and above	7	7.1
Education Level	Bachelor's	19	19.4
	Master's	56	57.1
	MPhil/PhD	23	23.5

The demographic profile shows a predominance of male respondents (72.4%), reflecting gender distribution trends in library staffing within the region. Librarians constitute the majority of respondents (62.2%), followed by IT personnel (25.5%) and administrators (12.2%). This breakdown ensures that insights are drawn from diverse professional perspectives. Age distribution is skewed toward mid-career professionals, with 74.5% aged between 31 and 50, suggesting a cohort with substantial work experience and institutional knowledge. Educational qualifications are high, with 80.6% holding postgraduate degrees, which imply a strong foundation for understanding technical concepts such as AI and IoT.

Awareness and Understanding of AI and IoT

To gauge the conceptual familiarity of library staff with emerging technologies, respondents rated their agreement with statements about AI and IoT on a 5-point Likert scale. The survey items were designed to differentiate between general technological awareness and domain-specific application knowledge.

Table 4.2: Awareness and Understanding of AI and IoT (n = 98)

Statement	Mean	SD	% Agree (≥4)
I am familiar with the basic concepts of Artificial Intelligence.	4.12	0.71	83.7%
I understand how IoT works in smart environments.	3.86	0.88	74.5%
I can distinguish between AI tools and conventional software.	3.68	0.92	67.3%
I am aware of AI applications in library settings.	3.52	0.94	61.2%

Overall, respondents demonstrated solid awareness of AI fundamentals, with an average mean score of 4.12. Understanding of IoT principles was slightly lower (M = 3.86), indicating moderate exposure to

connected device frameworks. The ability to differentiate AI tools from traditional library software (M = 3.68) shows emerging analytical skills, while awareness of AI-specific library applications (M = 3.52) highlights a need for targeted training on practical use cases.

Technological Readiness of Libraries

Technological readiness was evaluated by asking respondents to rate their libraries' current infrastructure and system capabilities. This measure reflects both hardware availability and software deployment essential for Library 4.0 transition.

Table 4.3: Technological Readiness of Libraries (n = 98)

Statement	Mean	SD	% Agree (≥4)
Our library has internet connectivity for public and staff use.	4.45	0.63	91.8%
KOHA or another ILS is implemented in our library.	4.28	0.74	87.8%
We have RFID or smart circulation tools.	3.02	1.15	48.0%
Our infrastructure supports integration of smart technologies.	3.26	0.96	54.1%

Connectivity and basic automation systems (ILS) are widely in place, with over 90% agreement on internet access and nearly 88% on KOHA implementation. Conversely, only 48% report having RFID-enabled circulation, and just 54.1% feel their infrastructure is ready for advanced smart technologies. These disparities suggest a two-tier scenario: foundational digital services versus next-generation smart capabilities.

Perceptions toward AI and IoT Integration

Respondents were requested to express their attitudes in the direction of the integration of AI and IoT within library workflows. The survey items measured optimism roughly technological assistances as well as apprehensions associated to workers impressions. Such dual-focus assessment provides perception into together the value proposition and potential communal obstacles of implementing Library 4.0 revolutions.

Table 4.4: Stakeholder Perceptions toward AI and IoT (n = 98)

Statement	Mean	SD	% Agree (≥4)
IoT can make library operations more efficient.	4.05	0.75	80.6%
Staff in my library are open to adopting AI and IoT tools.	3.64	0.91	69.4%
There is resistance to AI/IoT due to fear of job replacement.	3.48	1.08	62.2%

The high covenant scores for the benefits of AI (85.7%) and IoT (80.6%) highlight a strong constructive attitude toward technology-driven facility improvement. Nevertheless, only 69.4% consider staff are ready for such implements, and 62.2% perceive employment insecurity by way of a important concern.

These mixed insights recommend the necessity for change management policies that address both enthusiasm and anxiety concluded communication and participation.

Challenges in Adopting Smart Technologies

To pinpoint systemic obstacles, respondents nominated from a list of common tasks encountered throughout initial stages of smart technology implementation. Recognizing these hindrances is critical for communicating targeted interferences that certify maintainable implementation of AI and IoT in public libraries.

Table 4.5: Major Challenges to Smart Library technology (n = 98)

Challenge	Description	Frequency (n)	Percentage (%)
Lack of funding and budget constraints	Insufficient financial resources to procure hardware, software licenses, and maintenance services, limiting pilot and scale-up activities.	78	79.6%
Inadequate training for staff	Lack of structured professional development programs and workshops to build competencies in AI algorithms, IoT sensor deployment, and data analytics.	73	74.5%
Outdated infrastructure	Obsolete hardware, low-bandwidth networks, and lack of standardized integration platforms impede seamless implementation of smart modules.	64	65.3%
Resistance to change	Psychological and cultural barriers among staff who fear job displacement and lack trust in new technologies without clear communication.	61	62.2%
Lack of technical staff	Shortage of ICT specialists and technical personnel qualified to install, configure, and maintain AI and IoT systems in library contexts.	56	57.1%

Financial limits appeared as the leading challenge, mentioned by closely 80% of respondents, highlighting the necessity for devoted funding streams. Training insufficiencies (74.5%) and infrastructure gaps (65.3%) highlight the need of capacity-building creativities. Psychological resistance (62.2%) and technical recruitment lacks (57.1%) further opinion to the importance of holistic planning about human resource development and stakeholder engagement.

Summary of Key Findings

A strong contrast is revealed by the convergent results: while foundational digital resources are vigorous, implementation of next-generation smart technology is uneven. Funding, training, and setup are certain of the practical hindrances that stand in dissimilarity to the high levels of consciousness and positive insights. The existence of psychological confrontation highlights the necessity for change management and leadership support to enhancement technological solutions. Based on these findings, a strategy can be strained up to prioritise Library 4.0 initiatives and reserves in Khyber Pakhtunkhwa.

Comparative Insights across Demographics

Insights and preparedness wide-ranging by demographic, rendering to an intersectional examination. Respondents over the age of 50 showed more conservative opinions (AI familiarity M = 3.75; IoT readiness M = 3.60), in dissimilarity to staff under the age of 40 who showed higher mean scores on both AI knowledge (M = 4.25) and IoT readiness (M = 4.10). The record confident group in relations of smart technology implementation was IT staff (M = 4.30), although administrators were more concerned about staffing and

funding limits. Because of these changes, it's conceivable that targeted methods are essential to reach out to convinced demographics.

Implications for Smart Library Frameworks

The outcomes of the observed study should notify a multi-stage policy for the Library 4.0 framework:

- **Foundation Phase** Establishing Essential Governance Structures and Safeguarding Expanded Funding Streams is the First Stage. Set aside funds to provision the growth of training prospectuses and smart technology model programs.
- **Capacity-Building Phase** Roll out tier-one training programs cover RFID, straightforward IoT sensors, and AI-driven cataloguing systems as portion of the capacity-building stage. To encourage the transmission of assistances, organise practical workshops and pair guides with mentees.
- **Pilot Deployment Phase** First, we'll preference certain libraries to test available the integrated RFID-IoT modules, automated check-in/check-out kiosks, and artificial intelligence chatbots that employers can use to request queries. Retain an eye on KPIs like transaction speed and user contentment.
- **Scale-Up Phase** The quarter stage is the scale-up, and it involves studying the pilot's results to advance the technical setup and training resources. To assurance system interoperability and procedure standardisation, increase placements across regions.
- **Sustainability Phase** Set up evaluation sequences for the budget once a year, response loops for participants, and reviews of technology on a regular base. Plan tactically while possession influence metrics (such as system uptime and circulation rates) in concentration.

Conclusion and Recommendations

Conclusion

The purpose of this research was to inspect the level of groundwork and execution of Library 4.0 technologies, mainly AI and the IoT, in public libraries through the Pakistani province of Khyber Pakhtunkhwa (KP). Although the significance of smart technology is becoming further apparent to library experts, the examination presented that existent adoption is still in its initial phases. Advanced applications like as chatbots, AI-driven search engines, and IoT-based facilities remained up till now in the theoretical or trial phases, however essential digital infrastructure like linked library systems was usually available. The study highlighted specific important obstacles that prevent public libraries from using smart systems on a larger scale. These contain a absence of funding, lacking professional training, aversion to modification, and gaps in regulation. Respondents presented optimism in the expression of these challenges, saying they would welcome innovations with open arms if specified the right resources and direction. Furthermost highly, the study also recommended a Library 4.0 model that is specific to KP's institutional and provincial setting. An experienced and ongoing modification can be attained by combining intelligent technology through HRD and policy infrastructure, rendering to this model. Innovations indicate that public libraries in KP must the potential to renovate into advanced, community-focused information hubs power-driven by smart technology with the accurate combination of funding, education, and legislative variations. In sum, those in situations of power, as well as librarians, educators, and technologists, may acquire a great deal from this study about how to improved integrate digital developments with more conventional library services.

Recommendation

The following are certain practical recommendations for moving onward with smart library systems and effectively integrating AI and the internet of things:

Strategic Policy Development

- Frame a provincial-level Library 4.0 strategy that summaries purposes, starring role, finance models, and assessment mechanisms.
- Procedure a Smart Library Steering Committee to oversee enactment, reporting to the KP Directorate of Archives and Libraries.

Infrastructure and Technology Enhancement

- Revolutionize digital infrastructure to provide accommodations AI and IoT tools, such as lightning-fast internet, cloud storage, radio frequency identification, IOT instruments, and smart cataloging methods.
- Form compatible approaches that combine library databases with analytics of worker activity and AI.

Staff Capacity Building

- Organize continuous professional development programs focused on AI, machine learning, IoT, and data ethics.
- Collaborate with universities and ICT institutes for hands-on training, workshops, and certification.

Community and User-Centered Services

- Design AI-powered recommendation systems, smart chatbots, and adaptive learning resources tailored to user profiles.
- Introduce IoT-enabled spaces such as smart reading rooms, automated check-in/out, and environmental monitoring systems.

Research, Innovation, and Monitoring

- Allocate research grants to pilot smart library projects in select districts.
- Establish KPIs (Key Performance Indicators) for tracking technology usage, service impact, and user satisfaction.
- Encourage longitudinal studies on the societal benefits and challenges of Library 4.0 adoption.

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