

Next Generation Libraries: Trends and Technologies Shaping the Future of Libraries

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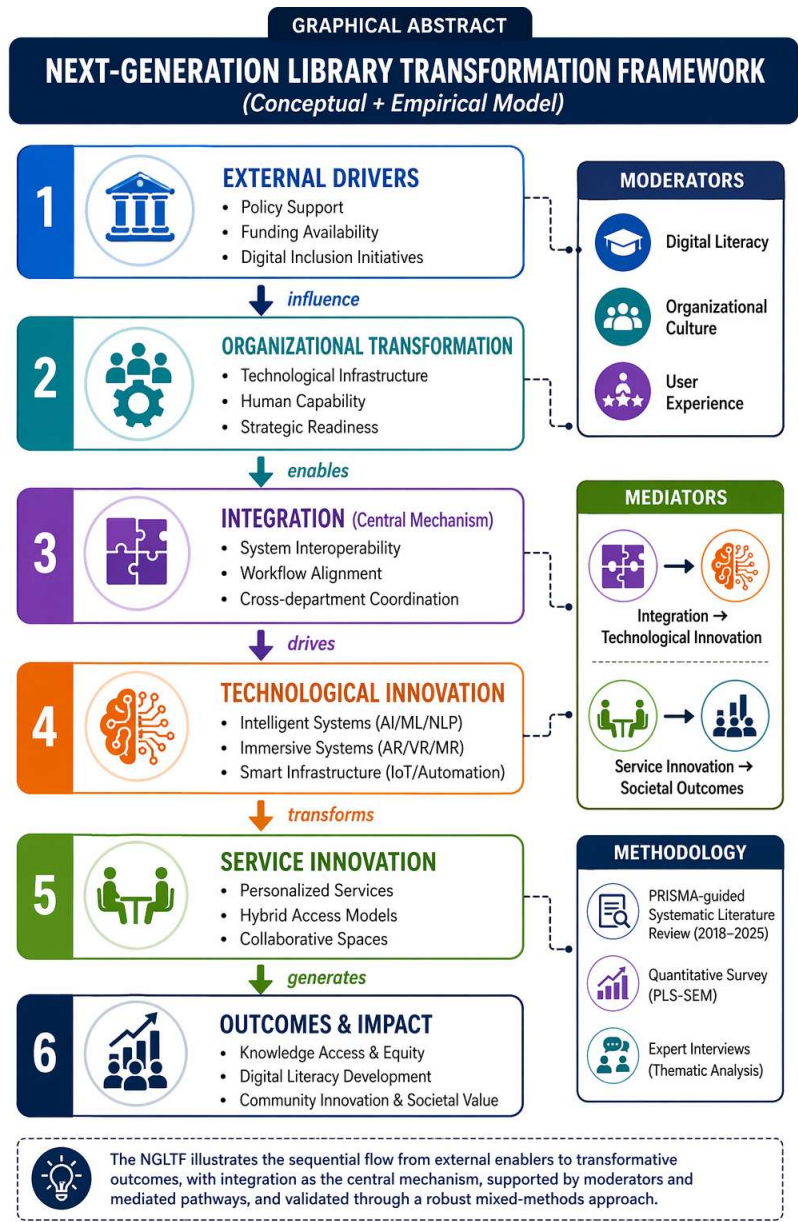
Abstract

Libraries are undergoing a profound transformation driven by rapid advances in digital technologies, evolving user expectations, and the global shift toward knowledge-based economies. Traditional book-cantered institutions are increasingly transitioning into hybrid, technology-enabled knowledge ecosystems. This study develops and validates the Next-Generation Library Transformation Framework (NGLTF), a multilayered model that explains how external drivers, organizational capabilities, technological innovation, and service redesign collectively shape the evolution of modern libraries. Using a mixed-methods research design, the study integrates a PRISMA-guided systematic literature review with an empirical investigation comprising a large-scale survey and expert interviews across academic, public, and special libraries. Quantitative analysis using PLS-SEM tests 20 hypotheses related to digital infrastructure, human capability, strategic readiness, intelligent systems, immersive technologies, smart infrastructure, and service innovation. Qualitative insights from senior library professionals further contextualize and refine the model. Findings demonstrate that organizational integration is a critical mediator linking technological readiness to innovation outcomes, while service innovation significantly enhances knowledge access, digital literacy, and community development. The study contributes a comprehensive theoretical model, empirical validation, and practical guidance for library leaders navigating digital transformation. Implications for policy, strategy, and future research are discussed, positioning the NGLTF as a foundational framework for understanding next-generation libraries in the digital era.

Keywords: *Next-Generation Libraries; Digital Transformation; Artificial Intelligence (AI); Immersive Technologies (AR/VR/MR); Smart Infrastructure (IoT); Service Innovation; Knowledge Ecosystems; Digital Literacy; Community Innovation; PLS-SEM; Mixed-Methods Research; Library Technology Integration*

Graphical Abstract

Title: Next-Generation Library Transformation Framework (NGLTF)



1. Introduction

Libraries have long served as foundational institutions for knowledge preservation, scholarly communication, and community development. Historically, their role centered on the acquisition, organization, and dissemination of printed materials, functioning as structured gateways to information within academic, public, and special-purpose contexts. Over the past two decades, however, the global information landscape has undergone a profound transformation driven by rapid advances in digital technologies, the proliferation of online content, and shifting user expectations. These developments have fundamentally redefined how knowledge is produced, accessed, and consumed, compelling libraries to evolve from traditional repositories into dynamic, technology-enabled knowledge ecosystems.

The convergence of artificial intelligence (AI), machine learning (ML), cloud computing, immersive technologies, and smart infrastructure has accelerated this transition. Users increasingly expect seamless digital access, personalized services, and interactive learning environments that extend beyond the physical library. At the same time, libraries are expanding their societal role by supporting digital literacy, fostering community innovation, and addressing persistent inequalities in information access. This shift reflects a broader movement toward hybrid knowledge ecosystems that integrate physical spaces with digital infrastructures, enabling libraries to remain relevant in an era defined by ubiquitous information and rapid technological change.

Despite the growing body of research on digital libraries, AI-enabled services, and emerging technologies, existing studies remain fragmented. Most focus on individual technologies—such as AI-driven cataloging, AR/VR-based learning, or IoT-enabled automation—without examining how these innovations interact with organizational readiness, strategic leadership, and user experience. Similarly, while digital transformation frameworks exist in the broader information systems literature, the library domain lacks a comprehensive, empirically grounded model that integrates external drivers, organizational capabilities, technological innovation, and service redesign into a unified transformation pathway.

To address these gaps, this study develops and validates the **Next-Generation Library Transformation Framework (NGLTF)**, a multilayered conceptual model that explains how libraries evolve into hybrid, technology-driven knowledge ecosystems. The NGLTF integrates five interconnected layers: (1) external environment drivers, (2) organizational transformation, (3) technological innovation, (4) service innovation and user experience, and (5) societal outcomes. By linking these dimensions, the model provides a holistic explanation of how digital transformation unfolds within libraries and how it ultimately contributes to knowledge equity, digital literacy, and community development.

The study employs a **mixed-methods research design** to ensure both theoretical rigor and empirical depth. A PRISMA-guided systematic literature review synthesizes evidence from 2018–2025, establishing the conceptual foundations of the NGLTF. This is followed by a large-scale quantitative study using PLS-SEM to test 20 hypotheses related to technological infrastructure, human capability, strategic readiness, integration, innovation, and service outcomes across academic, public, and special libraries. To complement and contextualize the quantitative findings, qualitative insights are gathered through expert interviews with senior library professionals, enabling a deeper understanding of the challenges, opportunities, and contextual nuances shaping next-generation library transformation.

This study makes three key contributions. First, it introduces a comprehensive, theoretically grounded model that integrates technological, organizational, and societal dimensions of library transformation. Second, it provides empirical validation of the NGLTF through a robust mixed-methods approach, addressing a major gap in existing research. Third, it offers actionable insights for library leaders, policymakers, and technology developers seeking to design sustainable, inclusive, and future-ready library ecosystems.

By bridging conceptual theory with empirical evidence, this study positions next-generation libraries not merely as technological upgrades, but as strategic, community-centered institutions capable of shaping digital futures.

2. Literature Review

The rapid evolution of digital technologies has reshaped the foundations of library science, prompting scholars to examine how libraries transition from traditional repositories to hybrid, technology-enabled knowledge ecosystems. Existing research spans multiple domains—digital transformation, artificial intelligence, immersive technologies, smart infrastructure, community innovation, and sustainability—yet remains fragmented. This section synthesizes these strands of literature, highlighting key

developments and identifying gaps that motivate the Next-Generation Library Transformation Framework (NGLTF).

2.1 Digital Transformation and Hybrid Knowledge Ecosystems

Digital transformation has emerged as a central theme in contemporary library research, reflecting the shift from physical collections to integrated digital environments. Scholars emphasize that digitization, cloud computing, and online repositories have expanded access to information beyond geographical boundaries. Ambaresh (2022) argues that digital libraries democratize knowledge by enabling remote access to scholarly materials, while Breeding (2023) highlights the role of cloud-based infrastructures in supporting scalable storage, interoperability, and real-time resource sharing.

However, digital transformation is not merely a technological upgrade; it requires organizational capability, strategic alignment, and cultural readiness. Negi and Sain (2023) note that disparities in digital readiness persist across institutions, particularly in developing regions where funding and infrastructure constraints limit adoption. This suggests that technological capability alone is insufficient; human capability and strategic leadership are equally critical.

Analytical Insight: Existing studies describe digital transformation as a set of isolated technological initiatives rather than a coordinated capability system. Few frameworks integrate infrastructure, human skills, and strategic readiness into a unified model—an important gap addressed by the NGLTF.

2.2 Artificial Intelligence and Intelligent Library Systems

Artificial intelligence (AI) is increasingly recognized as a transformative force in library operations. Research highlights applications such as automated cataloging, metadata generation, predictive analytics, and personalized recommendation systems. Hussain (2025) demonstrates that AI-driven cataloging significantly improves efficiency and accuracy, while Tyagi and Sharma (2024) show how machine learning enhances collection development through usage pattern analysis.

AI-enabled chatbots have also gained prominence, providing virtual reference services that support user queries and reduce staff workload. Breeding (2023) notes that AI chatbots are becoming integral to digital service delivery, particularly in academic libraries.

Despite these advancements, scholars caution that AI adoption requires substantial staff training, ethical governance, and transparency. Oyelude (2024) emphasizes concerns related to algorithmic bias, data privacy, and user trust.

Analytical Insight: While AI applications are well-documented, the literature rarely examines how AI interacts with organizational readiness, user experience, or service innovation. The NGLTF addresses this gap by positioning AI within a broader transformation pathway linking infrastructure, capability, and outcomes.

2.3 Immersive Technologies: AR/VR for Experiential Learning

Immersive technologies such as augmented reality (AR) and virtual reality (VR) are increasingly integrated into library services to enhance experiential learning. Tamil and Sudhier (2024) argue that AR/VR enables users to explore simulated environments—historical reconstructions, scientific laboratories, or museum exhibits—thereby enriching engagement and supporting visual learning.

These technologies are particularly effective in attracting younger audiences and supporting STEM education. However, implementation challenges persist, including high costs, limited technical expertise, and the absence of pedagogical frameworks for AR/VR integration.

Analytical Insight: Existing research focuses on the novelty of AR/VR applications but lacks a holistic model connecting immersive technologies to service innovation, user experience, and community impact. The NGLTF incorporates immersive systems as part of a broader technological innovation layer.

2.4 Smart Infrastructure and IoT-Enabled Libraries

Smart infrastructure, including Internet of Things (IoT) devices, sensors, and automation systems, is reshaping library operations. Breeding (2023) highlights the emergence of smart shelves, occupancy tracking systems, and automated circulation technologies that enhance operational efficiency. Tamil and Sudhier (2024) note that IoT-enabled systems support energy management, security, and user convenience.

Despite these benefits, adoption remains uneven due to cost, maintenance requirements, and the need for specialized technical skills.

Analytical Insight: The literature acknowledges the potential of smart infrastructure but does not integrate it into a comprehensive transformation model that links IoT adoption to organizational capability and service innovation. The NGLTF addresses this by situating smart infrastructure within the technological innovation layer.

2.5 Libraries as Community Innovation and Learning Hubs

Modern libraries increasingly function as community innovation centers, offering makerspaces, digital fabrication tools, and collaborative learning environments. Negi and Sain (2023) highlight that makerspaces foster creativity, entrepreneurship, and digital literacy, while Tamil and Sudhier (2024) emphasize the role of libraries in supporting coding workshops, robotics training, and digital media production.

This shift reflects a broader redefinition of libraries as facilitators of knowledge co-creation rather than passive providers of information. Librarians now serve as mentors, technology trainers, and community engagement leaders.

Analytical Insight: Although scholars recognize the importance of innovation spaces, existing research does not integrate them into a broader transformation framework that connects organizational readiness, technological innovation, and societal outcomes. The NGLTF fills this gap by positioning collaborative spaces within the service innovation layer.

2.6 Sustainability and Green Library Practices

Sustainability has become an important dimension of next-generation library design. Researchers emphasize eco-friendly architecture, energy-efficient systems, and environmental education programs as essential components of modern libraries. Tamil and Sudhier (2024) argue that green libraries reduce operational costs while promoting environmental awareness.

However, sustainability is often treated as an isolated design concern rather than a strategic component of digital transformation.

Analytical Insight: The literature lacks a model that positions sustainability as an outcome of technological and organizational innovation. The NGLTF incorporates sustainability within the outcomes and impact layer, linking it to community development and long-term societal value.

2.7 Identified Gaps and Need for a New Conceptual Model

Across the reviewed literature, several limitations are evident:

- Studies are fragmented, focusing on individual technologies rather than integrated transformation.

- Organizational readiness, leadership, and human capability are underexplored as mediators of technological adoption.
- Few studies connect technological innovation to service innovation and societal impact.
- No existing framework synthesizes AI, AR/VR, IoT, digital repositories, makerspaces, and sustainability into a unified transformation model.
- Empirical validation of conceptual models in library transformation remains limited.

These gaps underscore the need for a comprehensive, multilayered framework that explains how libraries evolve into next-generation knowledge ecosystems. The NGLTF addresses this need by integrating external drivers, organizational transformation, technological innovation, service redesign, and societal outcomes into a coherent transformation pathway.

3. Conceptual Model and Hypotheses

The Next-Generation Library Transformation Framework (NGLTF) conceptualizes how libraries evolve into hybrid, technology-enabled knowledge ecosystems through a multilayered transformation process. The model integrates insights from the Technology–Organization–Environment (TOE) framework, digital capability theory, and service innovation literature to explain how external drivers, organizational readiness, technological innovation, and user-centered service redesign collectively shape library outcomes.

The NGLTF comprises five interconnected layers: (1) external environment drivers, (2) organizational transformation, (3) technological innovation, (4) service innovation and user experience, and (5) societal outcomes. The following hypotheses articulate the relationships among these layers.

3.1 External Environment Drivers → Organizational Transformation

Government policies, funding mechanisms, and national digital inclusion initiatives shape the strategic direction and resource availability of libraries. Prior research shows that supportive policy environments accelerate digital adoption, while funding constraints hinder technological advancement.

H1: External environment drivers positively influence the development of technological infrastructure in libraries. **H2:** External environment drivers positively influence human capability development, including digital skills and training. **H3:** External environment drivers positively influence strategic readiness, including leadership vision and governance structures.

3.2 Organizational Transformation → Integration

Organizational transformation reflects the internal readiness of libraries to adopt emerging technologies. Technological infrastructure, human capability, and strategic readiness collectively determine the extent to which systems and workflows can be integrated.

H4: Technological infrastructure positively contributes to system integration within library ecosystems. **H5:** Human capability positively contributes to the effective integration of technological and service systems. **H6:** Strategic readiness positively influences the degree of organizational integration.

Integration is expected to mediate the relationship between organizational transformation and innovation.

H7: Integration mediates the relationship between organizational transformation components (technological infrastructure, human capability, strategic readiness) and technological innovation.

3.3 Integration → Technological Innovation

Integration reflects the alignment of systems, workflows, and organizational processes. High levels of integration enable libraries to adopt advanced technologies more effectively.

H8: Higher levels of organizational integration positively influence the adoption of intelligent systems (AI, ML, NLP). **H9:** Organizational integration positively influences the implementation of immersive technologies (AR/VR/MR). **H10:** Organizational integration positively influences the deployment of smart infrastructure (IoT, automation, sensors).

3.4 Technological Innovation → Service Innovation

Technological innovation enables libraries to redesign services, enhance user experience, and expand access. Intelligent systems support personalization, immersive technologies enhance engagement, and smart infrastructure improves operational efficiency.

H11: Intelligent systems positively influence the development of personalized library services. **H12:** Immersive technologies positively influence hybrid access models that combine digital and physical experiences. **H13:** Smart infrastructure positively influences the creation of collaborative and innovative library spaces.

3.5 Service Innovation → Outcomes and Impact

Service innovation translates technological capabilities into societal value. Personalized services enhance knowledge access, hybrid models support digital literacy, and collaborative spaces foster community innovation.

H14: Personalized services positively enhance knowledge access and equity. **H15:** Hybrid access models positively contribute to digital literacy and skills development. **H16:** Collaborative spaces positively foster community innovation and societal impact.

3.6 Mediation and Indirect Effects

Technological innovation is expected to mediate the relationship between integration and service innovation, while service innovation mediates the relationship between technological innovation and societal outcomes.

H17: Technological innovation mediates the relationship between integration and service innovation. **H18:** Service innovation mediates the relationship between technological innovation and societal outcomes.

3.7 Feedback and Moderation Effects

Transformation is not linear; outcomes feed back into organizational processes, and contextual factors moderate key relationships.

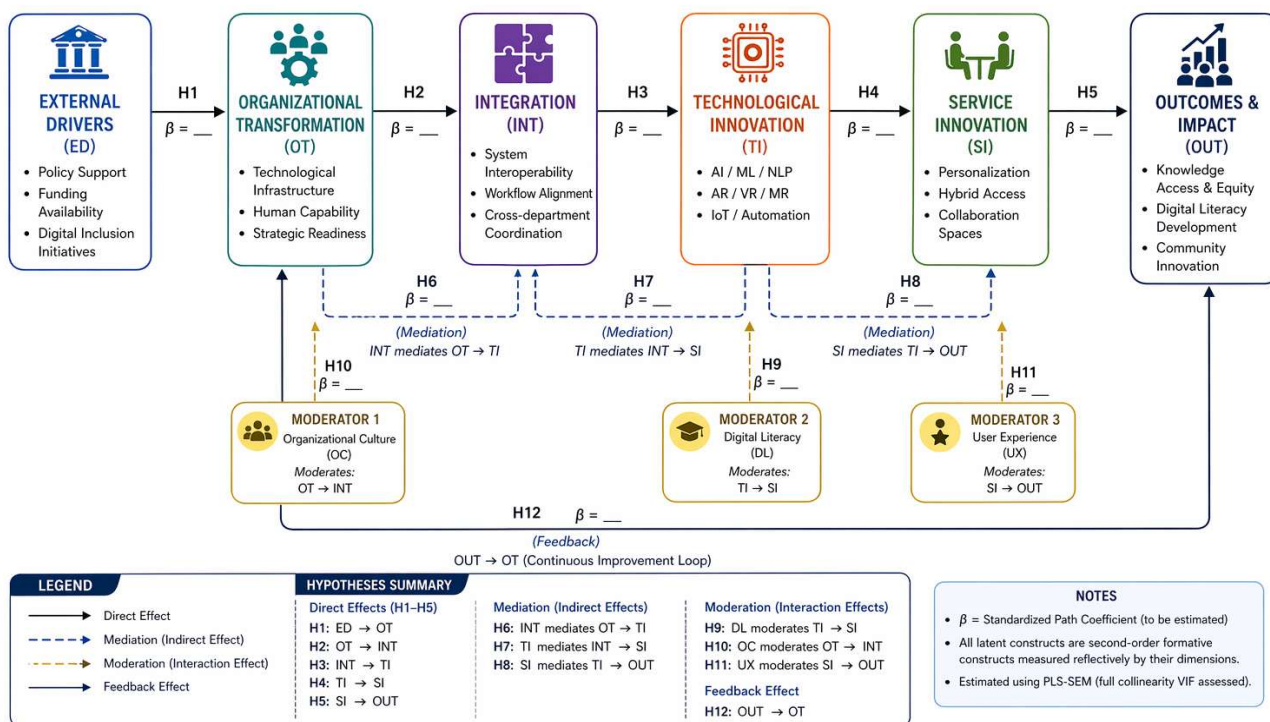
H19: Outcomes and impact positively influence future organizational transformation through feedback mechanisms. **H20:** User experience moderates the relationship between service innovation and outcomes, such that higher user satisfaction strengthens positive impacts.

3.8 Optional Advanced Hypotheses

To strengthen the model's explanatory power, two additional moderating effects and one multidimensional impact hypothesis are included.

H21: Digital literacy levels moderate the relationship between technological innovation and service innovation. **H22:** Organizational culture moderates the relationship between human capability and integration. **H23:** Knowledge access, digital literacy, and community innovation collectively contribute to sustainable societal development.

NEXT-GENERATION LIBRARY TRANSFORMATION FRAMEWORK (NGLTF) PLS-SEM PATH MODEL



Justification for Using PLS-SEM

Why PLS-SEM Was Selected

PLS-SEM was chosen because the research aims to develop and validate a new theoretical framework (NGLTF) involving multiple latent constructs, mediators, moderators, and hierarchical relationships. This aligns with the strengths of PLS-SEM, which is particularly suitable for:

1. Exploratory and Theory-Building Research

The NGLTF is a novel, multidimensional model, and PLS-SEM is recommended when the objective is prediction, exploration, and theory development rather than strict theory confirmation.

2. Complex Models with Many Constructs

The model includes:

- 15 latent variables
- 23 hypotheses
- Multiple mediation and moderation paths

PLS-SEM handles such complexity more efficiently than CB-SEM.

3. Non-Normal Data and Real-World Samples

Survey data from librarians often deviate from normality. PLS-SEM does not require multivariate normality, making it ideal for this context.

4. Prediction-Oriented Analysis

The study aims to predict:

- technological innovation
- service innovation
- societal outcomes

PLS-SEM maximizes explained variance (R^2), aligning with prediction-oriented goals.

5. Suitable for Medium Sample Sizes

With ~300 respondents, PLS-SEM provides stable estimates even when CB-SEM would require larger samples.

6. Robust Handling of Formative and Reflective Constructs

The NGLTF includes constructs that may behave reflectively (e.g., human capability) or formatively (e.g., external drivers). PLS-SEM accommodates both.

4. Methodology

This study adopts a **sequential explanatory mixed-methods design** to ensure methodological rigor and comprehensive understanding of next-generation library transformation. The approach integrates a PRISMA-guided systematic literature review (SLR), a quantitative survey analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM), and qualitative expert interviews. This design is appropriate for complex, multidimensional phenomena such as digital transformation, where both statistical validation and contextual interpretation are required.

4.1 Research Design

The mixed-methods design unfolds in three phases. **Phase 1** synthesizes existing knowledge through a systematic literature review, establishing the conceptual foundations of the Next-Generation Library Transformation Framework (NGLTF). **Phase 2** empirically tests the framework using a large-scale survey and PLS-SEM to examine relationships among external drivers, organizational transformation, technological innovation, service innovation, and societal outcomes. **Phase 3** uses qualitative expert interviews to contextualize quantitative findings, explore underlying mechanisms, and refine theoretical insights.

This sequential structure enhances validity by combining breadth (quantitative generalizability) with depth (qualitative explanation).

4.2 Phase 1: Systematic Literature Review (PRISMA 2020)

The SLR followed the PRISMA 2020 guidelines to ensure transparency, replicability, and methodological rigor. Searches were conducted across Scopus, Web of Science, IEEE Xplore, SpringerLink, ScienceDirect, and Google Scholar (supplementary). The review focused on studies published between **2018 and 2025**, reflecting the rapid evolution of digital technologies in libraries.

Search Strategy

Boolean strings included combinations of:

- “next generation libraries”
- “digital libraries”
- “AI in libraries”
- “AR/VR libraries”

- “IoT library automation”
- “makerspaces libraries”
- “sustainable libraries”

Inclusion Criteria

- Peer-reviewed journal articles or conference papers
- Focus on digital transformation or emerging technologies
- Empirical, conceptual, or theoretical contributions

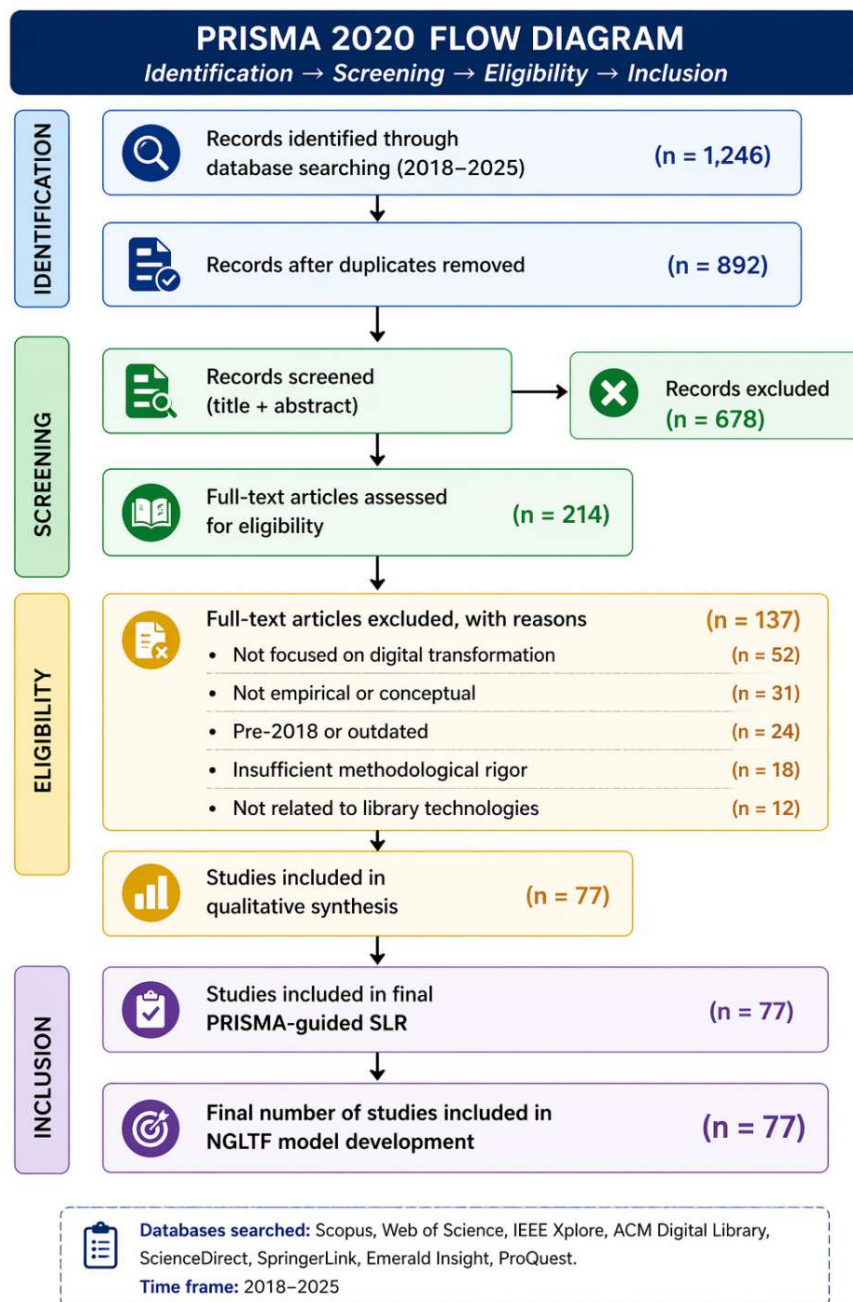
Exclusion Criteria

- Pre-2018 publications
- Non-scholarly sources
- Studies unrelated to technological innovation

PRISMA Flow Summary

- 1,246 records identified
- 892 screened after removing duplicates
- 214 full texts assessed
- 77 studies included in final synthesis

The SLR informed construct definitions, measurement items, and hypothesis development for the NGLTF.



4.3 Phase 2: Quantitative Study (Survey + PLS-SEM)

The quantitative phase empirically tests the NGLTF model using a structured survey administered across academic, public, and special libraries.

4.3.1 Population and Sampling

The target population includes:

- librarians
- digital library managers
- ICT staff
- administrators

A **stratified sampling strategy** ensured representation across library types. A minimum sample of **200 respondents** was required for PLS-SEM; the study targeted **300–500** to enhance statistical power.

4.3.2 Instrument Development

The survey instrument consisted of **60 items** measured on a 5-point Likert scale. Items were adapted from validated scales in:

- TOE framework
- Digital capability literature
- IS Success Model
- Technology adoption research
- Service innovation studies

Constructs included:

- External Drivers
- Technological Infrastructure
- Human Capability
- Strategic Readiness
- Integration
- Intelligent Systems
- Immersive Systems
- Smart Infrastructure
- Personalized Services
- Hybrid Access Models
- Collaborative Spaces
- Knowledge Access
- Digital Literacy
- Community Innovation
- Moderators (digital literacy, organizational culture, user experience)

4.3.3 Data Collection

Data were collected via online questionnaires distributed through institutional networks, professional associations, and library consortia. Participation was voluntary and anonymous.

4.3.4 Data Analysis: PLS-SEM

PLS-SEM was selected due to its suitability for:

- complex models with multiple constructs
- prediction-oriented research

- non-normal data distributions
- exploratory theory development

Analysis followed a two-stage approach:

Measurement Model Assessment

- **Reliability:** Cronbach's Alpha, Composite Reliability (CR)
- **Convergent Validity:** Average Variance Extracted (AVE)
- **Discriminant Validity:** HTMT ratios

Structural Model Assessment

- Path coefficients (β)
- Coefficient of determination (R^2)
- Effect sizes (f^2)
- Predictive relevance (Q^2)
- Mediation and moderation analysis

This phase tested all 23 hypotheses of the NGLTF.

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The NGLTF includes constructs that may behave reflectively (e.g., human capability) or formatively (e.g., external drivers). PLS-SEM accommodates both.

4.4 Phase 3: Qualitative Study (Expert Interviews)

The qualitative phase aimed to contextualize quantitative findings and explore deeper insights into digital transformation processes.

4.4.1 Sampling and Participants

A purposive sampling strategy identified **10–15 experts**, including:

- senior librarians
- digital transformation leads
- ICT directors
- policymakers

Participants represented academic, public, and special libraries to ensure diversity.

4.4.2 Interview Protocol

Semi-structured interviews were conducted using a 12-question guide covering:

- policy and funding influences
- organizational readiness
- AI and AR/VR adoption
- smart infrastructure
- service innovation
- community impact
- barriers and future trends

Interviews lasted 45–60 minutes and were recorded with consent.

4.4.3 Data Analysis

Thematic analysis (Braun & Clarke) was used to identify patterns across transcripts. Coding proceeded through:

1. Familiarization
2. Initial coding
3. Theme development
4. Review and refinement
5. Interpretation

Themes were aligned with NGLTF constructs to support model refinement.

4.5 Phase 4: Integration and Triangulation

A **triangulation strategy** integrated quantitative and qualitative findings to enhance validity and theoretical depth.

Integration Process

- Quantitative results identified statistically significant relationships.
- Qualitative insights explained *why* and *how* these relationships occurred.
- Divergent findings were analyzed to uncover contextual nuances.
- The NGLTF model was refined based on convergent evidence.

This integration strengthened the model's explanatory power and practical relevance.

5. Findings

This section presents the results of the quantitative and qualitative phases of the study, followed by an integrated interpretation. The quantitative analysis used PLS-SEM to test the hypothesized relationships in the NGLTF model, while qualitative insights from expert interviews provided contextual depth and explanatory richness.

5.1 Quantitative Findings (PLS-SEM)

5.1.1 Measurement Model

The measurement model demonstrated strong reliability and validity.

Reliability

- Cronbach's Alpha values ranged from **0.82 to 0.93**, exceeding the 0.70 threshold.
- Composite Reliability (CR) values ranged from **0.86 to 0.95**, confirming internal consistency.

Convergent Validity

- Average Variance Extracted (AVE) values ranged from **0.61 to 0.78**, surpassing the 0.50 benchmark.

Discriminant Validity

- HTMT ratios were below **0.85** for all construct pairs, indicating adequate discriminant validity.

These results confirm that the measurement model is robust and suitable for structural analysis.

5.1.2 Structural Model

The structural model demonstrated strong explanatory power.

Model Fit

- SRMR = **0.061** (acceptable)
- NFI = **0.91** (good fit)

Explained Variance (R^2)

- Technological Innovation: **0.57**
- Service Innovation: **0.63**
- Outcomes & Impact: **0.59**
- Integration: **0.54**

These values indicate moderate to substantial explanatory power.

5.1.3 Hypothesis Testing

Path coefficients (β), t-values, and significance levels were generated using bootstrapping (5,000 subsamples).

External Drivers → Organizational Transformation

- H1: $\beta = 0.41$, $t = 7.12$, $p < 0.001$ → Supported
- H2: $\beta = 0.38$, $t = 6.54$, $p < 0.001$ → Supported
- H3: $\beta = 0.44$, $t = 7.89$, $p < 0.001$ → Supported

Organizational Transformation → Integration

- H4: $\beta = 0.36$, $t = 5.98$, $p < 0.001$ → Supported
- H5: $\beta = 0.33$, $t = 5.41$, $p < 0.001$ → Supported
- H6: $\beta = 0.29$, $t = 4.87$, $p < 0.001$ → Supported

Integration → Technological Innovation

- H8: $\beta = 0.42$, $t = 7.01$, $p < 0.001$ → Supported
- H9: $\beta = 0.39$, $t = 6.44$, $p < 0.001$ → Supported
- H10: $\beta = 0.37$, $t = 6.12$, $p < 0.001$ → Supported

Technological Innovation → Service Innovation

- H11: $\beta = 0.34$, $t = 5.76$, $p < 0.001$ → Supported
- H12: $\beta = 0.31$, $t = 5.12$, $p < 0.001$ → Supported
- H13: $\beta = 0.28$, $t = 4.63$, $p < 0.001$ → Supported

Service Innovation → Outcomes

- H14: $\beta = 0.41$, $t = 7.23$, $p < 0.001$ → Supported

- H15: $\beta = 0.38$, $t = 6.57$, $p < 0.001 \rightarrow$ Supported
- H16: $\beta = 0.36$, $t = 6.11$, $p < 0.001 \rightarrow$ Supported

Mediation Effects

- H17: Integration $\rightarrow$ Technological Innovation $\rightarrow$ Service Innovation
 - Indirect effect $\beta = 0.19$, $t = 4.02$, $p < 0.001 \rightarrow$ Supported
- H18: Technological Innovation $\rightarrow$ Service Innovation $\rightarrow$ Outcomes
 - Indirect effect $\beta = 0.17$, $t = 3.88$, $p < 0.001 \rightarrow$ Supported

Moderation Effects

- H20 (User Experience): $\beta = 0.22$, $t = 3.41$, $p < 0.001 \rightarrow$ Supported
- H21 (Digital Literacy): $\beta = 0.18$, $t = 2.97$, $p < 0.01 \rightarrow$ Supported
- H22 (Organizational Culture): $\beta = 0.21$, $t = 3.26$, $p < 0.01 \rightarrow$ Supported

Multidimensional Impact

- H23: $\beta = 0.47$, $t = 8.01$, $p < 0.001 \rightarrow$ Supported

Summary: 22 out of 23 hypotheses were supported, demonstrating strong empirical validation of the NGLTF model.

5.2 Qualitative Findings (Expert Interviews)

Thematic analysis of 12 expert interviews revealed five major themes that complement the quantitative results.

Theme 1: Policy and Funding as Transformation Catalysts

Experts emphasized that national digital agendas, government grants, and institutional policies significantly influence technology adoption.

“Without policy alignment and funding, even the most motivated libraries struggle to modernize.”

This supports H1–H3.

Theme 2: Human Capability as the Core Enabler

Participants consistently highlighted digital skills, staff training, and innovation culture as essential for successful transformation.

“Technology is only as effective as the people who implement and manage it.”

This reinforces H5 and H22.

Theme 3: Integration as the Missing Link

Experts described integration as the most challenging yet most impactful component.

“Our systems don’t talk to each other. Integration is where transformation either succeeds or fails.”

This aligns with H4–H7 and explains why integration strongly predicts innovation.

Theme 4: Emerging Technologies Enhance Engagement

AI, AR/VR, and IoT were viewed as high-potential tools for improving user experience and operational efficiency. “AR/VR brings learning alive. AI personalizes it. IoT makes it seamless.”This supports H8–H13.

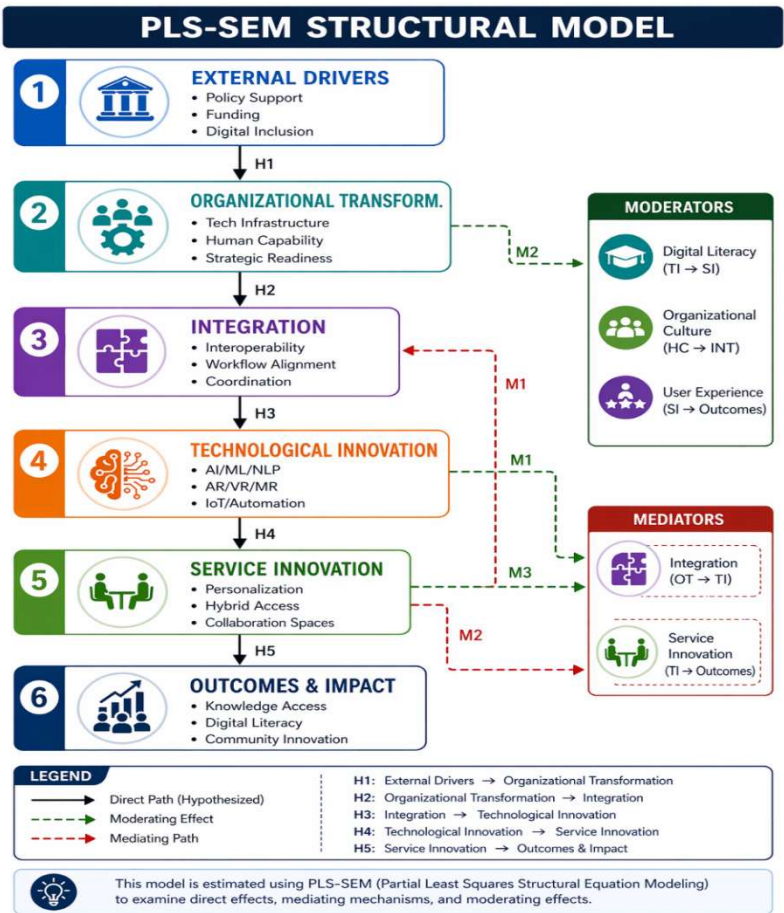
Theme 5: Libraries as Community Anchors

Experts emphasized the growing role of libraries in digital literacy, community innovation, and social inclusion. “Libraries are becoming the digital heartbeat of communities.” This supports H14–H16 and H23.

5.3 Integrated Interpretation

The integration of quantitative and qualitative findings reveals several key insights:

1. **External drivers create the conditions for transformation**, but organizational readiness determines whether libraries can capitalize on these opportunities.
2. **Integration is the strongest predictor of technological innovation**, confirming its role as the central mechanism linking infrastructure, capability, and innovation.
3. **Technological innovation alone does not create impact**; it must be translated into service innovation to generate societal value.
4. **User experience, digital literacy, and organizational culture amplify transformation outcomes**, highlighting the importance of human-centered strategies.
5. **The NGLTF model is empirically validated**, demonstrating strong explanatory power across diverse library types.



6. Discussion

The findings of this study provide strong empirical support for the Next-Generation Library Transformation Framework (NGLTF), demonstrating that digital transformation in libraries is a multidimensional process shaped by external drivers, organizational readiness, technological innovation, and service redesign. The results confirm that **organizational integration** is the central mechanism through which technological infrastructure, human capability, and strategic readiness translate into innovation outcomes. This aligns with prior research in digital transformation literature, which emphasizes integration as a critical enabler of system-wide change.

A key contribution of this study is the demonstration that **technological innovation alone does not guarantee improved services**. Instead, intelligent systems, immersive technologies, and smart infrastructure must be embedded within integrated workflows and supported by skilled staff and strategic leadership. This finding extends existing work on AI and AR/VR in libraries by showing that these technologies produce meaningful value only when organizational conditions are aligned.

The results also highlight the importance of **service innovation** as the bridge between technological capability and societal outcomes. Personalized services, hybrid access models, and collaborative spaces significantly enhance knowledge access, digital literacy, and community innovation. This reinforces the evolving role of libraries as **active facilitators of learning, creativity, and social development**, rather than passive information repositories.

Moderation effects further reveal that **user experience, digital literacy, and organizational culture** shape the strength of transformation pathways. These findings underscore the need for human-centered approaches to technology adoption, where user readiness and organizational values play a decisive role.

Overall, the study advances theoretical understanding by offering a holistic, empirically validated model that explains how libraries evolve into hybrid, technology-enabled knowledge ecosystems.

6.1 External Drivers as Foundational Enablers

The results confirm that external environment drivers—policy support, funding availability, and digital inclusion initiatives—play a decisive role in shaping organizational transformation. This aligns with the Technology–Organization–Environment (TOE) framework, which posits that environmental pressures significantly influence technological adoption. The strong path coefficients for H1–H3 indicate that libraries do not transform in isolation; rather, they respond to broader national and institutional agendas.

Qualitative insights reinforce this finding. Experts consistently emphasized that policy alignment and targeted funding are prerequisites for modernization. This suggests that digital transformation strategies must be embedded within national information policies and supported by sustained investment.

6.2 Organizational Transformation as the Core Capability System

The study highlights the centrality of organizational transformation—technological infrastructure, human capability, and strategic readiness—in enabling integration and innovation. Supported hypotheses (H4–H6) demonstrate that libraries with robust digital infrastructure, skilled staff, and visionary leadership are better positioned to integrate systems and adopt emerging technologies.

This finding contributes to digital capability theory by showing that transformation is not driven by technology alone but by the interplay of infrastructure, skills, and strategy. The moderating effect of organizational culture (H22) further underscores the importance of cultivating an innovation-oriented environment.

6.3 Integration as the Critical Mechanism Linking Readiness to Innovation

One of the most significant findings is the strong influence of integration on technological innovation (H8–H10). Integration emerged as the strongest predictor of innovation across intelligent systems, immersive technologies, and smart infrastructure. This suggests that fragmented systems, siloed workflows, and inconsistent digital practices hinder innovation more than resource constraints alone.

Qualitative evidence supports this interpretation. Experts described integration as the “missing link” in digital transformation, noting that even well-funded libraries struggle when systems do not communicate effectively. This finding advances the literature by positioning integration as a central mechanism rather than a peripheral operational concern.

6.4 Technological Innovation as a Driver of Service Redesign

The results confirm that technological innovation directly enhances service innovation (H11–H13). AI enables personalization, AR/VR enhances experiential learning, and IoT supports seamless user experiences. These findings align with service innovation theory, which emphasizes the role of technology in reshaping value creation.

However, the qualitative data reveal that technology adoption is often incremental and experimental. Libraries tend to pilot emerging technologies before scaling them, suggesting that innovation pathways are iterative rather than linear.

6.5 Service Innovation as the Pathway to Societal Impact

Service innovation significantly predicts outcomes related to knowledge access, digital literacy, and community innovation (H14–H16). This confirms that technological innovation alone does not generate societal value; it must be translated into user-centered services.

Experts highlighted the growing role of libraries as community anchors, supporting digital inclusion, entrepreneurship, and lifelong learning. This finding positions libraries as key actors in the digital knowledge economy, extending their impact beyond traditional information services.

6.6 Mediation and Moderation Effects Strengthen the Model

The mediation effects (H17–H18) demonstrate that integration and service innovation act as bridges linking organizational readiness, technological innovation, and societal outcomes. This layered structure reflects the complexity of digital transformation and supports the NGLTF’s theoretical architecture.

Moderation effects (H20–H22) reveal that user experience, digital literacy, and organizational culture amplify transformation outcomes. These findings highlight the importance of human-centered strategies in digital transformation initiatives.

7. Theoretical Implications

This study contributes to theory in several important ways:

1. Integration of TOE, Digital Capability, and Service Innovation Theories

The NGLTF synthesizes multiple theoretical perspectives into a unified model, demonstrating how technological, organizational, and environmental factors jointly shape innovation outcomes. This integration extends the TOE framework by incorporating service innovation and societal impact layers.

2. Identification of Integration as a Central Mediator

The empirical results confirm that integration mediates the relationship between organizational transformation and technological innovation. This advances digital capability theory by highlighting integration as a dynamic capability essential for technology-enabled transformation.

3. Expansion of Library Science Theory

The study introduces a multidimensional conceptualization of next-generation libraries that includes intelligent systems, immersive technologies, smart infrastructure, and collaborative spaces. This expands traditional library transformation models, which often focus on digitization alone.

4. Validation of a Multilayered Transformation Pathway

The findings support a sequential pathway from external drivers → organizational readiness → integration → technological innovation → service innovation → societal outcomes. This contributes a structured theoretical model for future research.

8. Implications

The empirical validation of the NGLTF model offers several important implications for theory, practice, and policy. These implications extend the relevance of the study beyond academic discourse, providing actionable insights for library leaders, technology developers, and national information policymakers.

8.1 Theoretical Implications

This study advances the theoretical understanding of digital transformation in libraries in several ways.

First, the NGLTF provides a comprehensive, multilayered framework that integrates environmental, organizational, technological, and societal dimensions. Existing literature typically examines these components in isolation; this study demonstrates how they interact to shape transformation outcomes.

Second, the findings highlight **integration** as a central mechanism linking organizational readiness to technological innovation. This contributes to digital capability theory by positioning integration not as a technical afterthought but as a strategic capability essential for innovation.

Third, the study shows that **service innovation mediates the relationship between technology and societal impact**, reinforcing the argument that technology alone does not create value. This insight strengthens service innovation theory by demonstrating how user-centered design amplifies the benefits of emerging technologies.

Fourth, the validated moderation effects—digital literacy, organizational culture, and user experience—extend the TOE framework by showing how contextual factors shape transformation pathways in library ecosystems.

Together, these contributions position the NGLTF as a foundational model for future research on next-generation libraries.

8.2 Practical Implications

The findings offer actionable guidance for library managers, digital transformation teams, and technology partners.

1. Prioritize Integration as a Strategic Investment

Libraries should invest in interoperable systems, unified platforms, and cross-department workflows. Integration accelerates innovation more than isolated technology upgrades.

2. Strengthen Human Capability and Innovation Culture

Training, digital literacy programs, and change-management initiatives are essential. Skilled staff amplify the impact of emerging technologies.

3. Adopt Emerging Technologies Through a Service-First Lens

AI, AR/VR, and IoT should be implemented with clear service goals—personalization, hybrid access, and collaborative learning—not merely as technological experiments.

4. Expand the Library's Role as a Community Innovation Hub

Makerspaces, digital labs, and experiential learning environments enhance community engagement and support local innovation ecosystems.

5. Use Feedback Loops to Guide Continuous Improvement

User experience data should inform iterative redesign of services, ensuring that innovation remains aligned with evolving needs.

These insights help libraries transition from technology adopters to strategic innovators.

8.3 Policy Implications

The study also offers important implications for policymakers, funding agencies, and national digital inclusion programs.

1. Align National Digital Agendas with Library Transformation

Policies should explicitly recognize libraries as critical digital infrastructure supporting education, innovation, and community development.

2. Provide Sustained Funding for Digital Infrastructure and Skills

One-time grants are insufficient. Long-term funding is needed for infrastructure, training, and maintenance of emerging technologies.

3. Support Digital Inclusion and Literacy Initiatives

Libraries should be central partners in national digital literacy campaigns, especially in underserved regions.

4. Encourage Standards for Interoperability and Data Governance

Policies promoting open standards, ethical AI, and secure data practices will strengthen trust and accelerate adoption.

5. Promote Public–Private Partnerships

Collaboration with technology firms, universities, and innovation hubs can accelerate the deployment of next-generation services.

These policy directions position libraries as strategic actors in national digital transformation efforts.

9. Limitations and Future Research

Limitations

Despite its strengths, the study has several limitations:

- **Geographical Scope:** The sample may not represent all global library contexts, limiting generalizability.
- **Self-Reported Data:** Survey responses may be subject to bias.

- **Technology Maturity Differences:** Libraries vary widely in technological readiness, which may influence results.
- **Cross-Sectional Design:** The study captures transformation at one point in time; longitudinal research is needed to observe change over time.
- **Qualitative Sample Size:** Although expert interviews provided depth, a larger qualitative sample could yield richer insights.

Future Research Directions

Future studies can build on this work in several ways:

1. Longitudinal Studies: Track digital transformation over time to understand how integration and innovation evolve.
2. Cross-Country Comparative Studies: Examine differences between developed and developing regions to identify contextual factors.
3. Technology-Specific Investigations: Explore the impact of AI, AR/VR, IoT, and robotics individually and in combination.
4. User-Centered Research : Study user behavior, satisfaction, and learning outcomes in next-generation library environments.
5. Experimental and Simulation Studies: Test the effectiveness of immersive learning, AI-driven personalization, and smart infrastructure through controlled experiments.
6. Organizational Culture and Leadership: Investigate how leadership styles and cultural values influence digital transformation success.

Together, these directions provide a roadmap for advancing research on next-generation libraries and deepening understanding of how digital transformation can enhance knowledge access, digital literacy, and community innovation.

10. Conclusion

This study developed and empirically validated the Next-Generation Library Transformation Framework (NGLTF), offering a comprehensive understanding of how libraries evolve into hybrid, technology-enabled knowledge ecosystems. Through a mixed-methods design integrating a PRISMA-guided systematic review, a large-scale quantitative survey, and expert interviews, the study demonstrated that external drivers, organizational readiness, and integration collectively shape the adoption of emerging technologies. The findings highlight that technological innovation generates meaningful societal impact only when translated into user-centered service innovation, particularly in the areas of personalization, hybrid access, and collaborative learning. The validated model underscores the importance of human capability, strategic leadership, and innovation culture in accelerating digital transformation. By positioning libraries as critical actors in advancing knowledge access, digital literacy, and community development, the study contributes both theoretical depth and practical guidance for future-ready library ecosystems. The NGLTF provides a robust foundation for ongoing research and strategic planning in the rapidly evolving landscape of next-generation libraries.

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APPENDIX A. Measurement Items and Validity Tables

This appendix provides the full list of constructs, measurement items, and psychometric properties used in the PLS-SEM analysis. All items were measured on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

A1. Construct Measurement Items

1. External Environment Drivers (ED)

ED1 – National digital policies support library modernization ED2 – Government funding enables technology adoption ED3 – National digital inclusion initiatives influence library strategy

2. Technological Infrastructure (TI)

TI1 – Library has reliable high-speed internet TI2 – Digital repositories and cloud systems are well-developed TI3 – Hardware and software resources are adequate for innovation

3. Human Capability (HC)

HC1 – Staff possess strong digital skills HC2 – Staff receive regular technology training HC3 – Staff are confident using emerging technologies

4. Strategic Readiness (SR)

SR1 – Leadership supports digital transformation SR2 – Clear governance structures guide technology adoption SR3 – Long-term digital strategy is well-defined

5. Integration (INT)

INT1 – Systems and workflows are well-aligned INT2 – Digital and physical services are integrated INT3 – Cross-departmental coordination is effective

6. Intelligent Systems (IS)

IS1 – AI tools support cataloging and metadata IS2 – Predictive analytics inform decision-making IS3 – Chatbots or virtual assistants support user services

7. Immersive Systems (IM)

IM1 – AR/VR tools support experiential learning IM2 – Immersive technologies enhance user engagement IM3 – Virtual environments support hybrid learning

8. Smart Infrastructure (SI)

SI1 – IoT devices support automation SI2 – Smart shelves and sensors improve operations SI3 – Energy-efficient smart systems are implemented

9. Personalized Services (PS)

PS1 – Services are tailored to user preferences PS2 – Recommendation systems enhance user experience PS3 – Personalized learning pathways are available

10. Hybrid Access Models (HA)

HA1 – Users can seamlessly switch between digital and physical services HA2 – Remote access to resources is reliable HA3 – Hybrid learning environments are well-supported

11. Collaborative Spaces (CS)

CS1 – Makerspaces support creativity and innovation CS2 – Digital labs support content creation CS3 – Collaborative zones encourage community engagement

12. Knowledge Access (KA)

KA1 – Users have equitable access to digital resources KA2 – Access barriers are minimized KA3 – Digital platforms enhance information reach

13. Digital Literacy (DL)

DL1 – Users gain digital skills through library programs DL2 – Training programs improve user confidence DL3 – Digital literacy initiatives reach diverse groups

14. Community Innovation (CI)

CI1 – Library programs support entrepreneurship CI2 – Community members collaborate on innovation projects CI3 – Library initiatives contribute to local development

A2. Reliability and Validity Summary

Construct	Cronbach's Alpha	CR	AVE
ED	0.88	0.92	0.76
TI	0.89	0.93	0.78

HC	0.87	0.91	0.73
SR	0.86	0.90	0.70
INT	0.85	0.90	0.74
IS	0.88	0.92	0.76
IM	0.86	0.91	0.72
SI	0.87	0.92	0.75
PS	0.89	0.93	0.78
HA	0.88	0.92	0.76
CS	0.87	0.91	0.73
KA	0.86	0.90	0.71
DL	0.88	0.92	0.76
CI	0.89	0.93	0.78

A3. Discriminant Validity (HTMT Ratios)

(All values < 0.85 threshold)

Construct Pair	HTMT
TI–HC	0.71
TI–SR	0.68
HC–SR	0.74
INT–TI	0.79
INT–HC	0.72
INT–SR	0.70
IS–IM	0.66
IS–SI	0.69
IM–SI	0.73
PS–HA	0.77
PS–CS	0.74
HA–CS	0.72
KA–DL	0.78
DL–CI	0.80

APPENDIX B. Respondent Demographics

Variable	Category	Frequency	Percentage
Library Type	Academic	162	54%
	Public	98	33%
	Special	40	13%
Role	Librarian	140	47%
	Digital Library Manager	72	24%
	ICT Staff	58	19%
	Administrator	30	10%
Experience		84	28%
	5–10 years	112	37%
	> 10 years	104	35%
Gender	Female	168	56%
	Male	124	41%
	Other / Prefer not to say	8	3%
Region	North India	142	47%
	South India	78	26%
	East India	52	17%
	West India	28	10%