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Viksit Bharat@2047

From Vision to Transformation



Editors

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PREFACE

Viksit Bharat@2047: From Vision to Transformation explores the opportunities, challenges, and pathways for India's journey towards becoming a developed nation by 2047. The vision of Viksit Bharat encompasses inclusive growth, technological advancement, economic prosperity, social progress, environmental sustainability, and strengthened human capabilities. Achieving this vision requires coordinated efforts across diverse sectors and active participation from all sections of society.

This volume brings together multidisciplinary perspectives on the transformative processes shaping India's future. The chapters address education, science and technology, agriculture, healthcare, entrepreneurship, digital transformation, sustainability, governance, industry, social development, and innovation. These contributions illustrate how knowledge, research, creativity, and collaboration can support national development and address emerging societal needs.

Technology and innovation are important enablers of transformation, through artificial intelligence, digital infrastructure, advanced computing, biotechnology, sustainable technologies, and data-driven decision-making. At the same time, development must remain inclusive and responsible, ensuring that economic and technological progress contributes to improved quality of life, employment opportunities, social equity, environmental protection, and resilient communities.

The book also emphasizes the importance of education and skill development in preparing citizens for a changing world. Strengthening research ecosystems, encouraging entrepreneurship, supporting local innovation, and building collaborations among academia, industry, government, and communities can create a strong foundation for sustained progress.

The contributions presented in this volume offer insights into India's developmental priorities and future possibilities. It is hoped that this book will serve as a valuable academic and reference resource for students, researchers, educators, policymakers, professionals, and readers interested in India's development journey. By bringing together diverse ideas and perspectives, this volume seeks to encourage informed discussion, interdisciplinary collaboration, innovative thinking, and constructive action towards a prosperous, inclusive, sustainable, and knowledge-driven Viksit Bharat by 2047.

- Editors

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DIGITAL TRANSFORMATION OF EDUCATION IN INDIA: THE ROLE OF NEP 2020 AND EDTECH IN BUILDING VIKSIT BHARAT 2047

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Abstract

Teaching, learning, assessment, teacher development and access to educational materials are all being impacted by digital transformation, which is changing the educational landscape in India. This chapter looks at how the National Education Policy (NEP) 2020 and Educational Technology (EdTech) advance digital transformation and support Viksit Bharat 2047. The development of digital public infrastructure, online learning platforms, blended learning, artificial intelligence, learning analytics and technology-enabled assessment are all critically examined. The chapter also looks at how EdTech may support lifelong learning, digital literacy, employability, teacher professional development, inclusive education and personalized learning. The digital divide, insufficient infrastructure, teacher readiness, accessibility obstacles, data privacy, cybersecurity, academic integrity and ethical issues with AI are all examined concurrently. In order to promote the long-term educational foundations of Viksit Bharat 2047, the chapter makes the case that the strategic and inclusive integration of EdTech under NEP 2020 can enhance India's people capital, innovation potential and knowledge economy.

Keywords: Digital Education, NEP 2020, EdTech, Digital Transformation, Viksit Bharat 2047.

1. Introduction

In the twenty-first century, digital transformation has grown in importance as a component of educational reform. It encompasses changes in pedagogy, assessment, teacher development, educational administration, learning environments and institutional behaviors thru digital technologies, going beyond the introduction of computers and internet connectivity. The ways that students acquire and interact with knowledge are being progressively impacted by digital platforms, artificial intelligence (AI), learning analytics, mobile applications, virtual learning environments and adaptive learning systems. Research shows that digital technologies can enable innovative pedagogical methods and increase learning opportunities although their educational impact depends on suitable infrastructure, teacher competency, institutional capacity and pedagogical design [8].

The National Education Policy (NEP) 2020 in India, which recognizes technology as a key tool for enhancing access, quality, teacher development, evaluation and educational management, has given this shift significant policy momentum [3]. The National Educational Technology Forum, digital material, online and blended learning and technology-enabled learning are all encouraged under the policy. According to recent research, NEP 2020 offers a crucial framework for combining technology with more comprehensive educational reform, such as flexible and hybrid learning strategies [4].

This change has been reinforced by the growth of Educational Technology (EdTech). Personalized learning, flexible access, interactive learning, digital evaluation and ongoing professional development can all be supported by digital platforms and online learning systems. According to research done in Uttar Pradesh, Students' attitudes, technological preparedness, motivation and perceived difficulties all have a big impact on how engaged they are with e-learning [2]. Research on digital learning also shows that teachers continue to play a crucial role in the successful integration of technology because technological instruments by themselves cannot guaranty meaningful learning outcomes [12].

India's shift to digital education was expedited by the COVID-19 epidemic, which also highlighted the advantages and disadvantages of technology-assisted education. International studies revealed swift transitions toward online and emergency remote teaching in addition to highlighting issues with teacher readiness, student involvement, technology access and institutional support [1;7]. Further research shows that institutional support, perceived utility, technological proficiency and contextual factors all influence teachers' adoption and efficient use of digital tools [13]. Institutional opposition and ongoing digital inequality have also been linked to the deployment of computers in Indian schools [5].

The development of AI has given the revolution of education a new facet. Personalized learning, intelligent tutoring, automatic feedback, content creation and learning analytics can all be supported by AI-based solutions. Recent study on the Indian educational system also raises issues with ethics, accessibility and responsible implementation while there are many opportunities for AI-supported individualized learning and teacher support [6].

Therefore, the goal of Viksit Bharat 2047 and digital transformation are strongly related, especially when it comes to human capital development, digital competence, innovation, employability and lifelong learning. However, digital inequality, teacher readiness, accessibility, data privacy, academic integrity and AI ethics must all be addressed in technology-led educational progress. Therefore, this chapter looks at how EdTech and NEP 2020 might help reform Indian education and assist the creation of a human capital base for Viksit Bharat 2047 that is inclusive, inventive, digitally capable and prepared for the future.

2. Concept of Digital Transformation in Education

The process by which digital technologies transform teaching, learning, assessment, institutional management, teacher development and educational delivery is known as “Digital Transformation” in education. It goes beyond just having computers, internet access or digital educational resources. Digital education is defined by UNESCO as the use of digital resources and technologies, such as virtual classrooms, online courses and educational software, to support teaching and learning. Digital transformation, however, calls for more significant adjustments to organizational structures and educational practices, where technology is incorporated into pedagogy, institutional procedures, and decision-making.

Meaning of Digital Transformation

Digital Transformation in Education means integrating digital tools, cloud software and data analytics into teaching, learning and campus management. It moves schools beyond simple computer use, reshaping how students learn, how teachers instruct and how institutions run operations.

The concepts of digitization, digitalization and digital transformation should be distinguished. In general, digitization is the process of transforming data from analog to digital representations, like turning printed textbooks into electronic books. Digitalization is the practice of utilizing digital tools to enhance current procedures, such as administering tests online or utilizing a learning management system. The term ‘digital transformation’ refers to a more comprehensive and fundamental shift in the way educational establishments function as well as the design and experience of teaching and learning. Digital technologies have an impact on leadership, professional development, infrastructure, organizational procedures, educational methods and institutional capability [8].

In order to enhance the quality, accessibility, flexibility, efficiency and relevance of education, digital transformation can be defined as the deliberate and ongoing integration of digital technology into educational systems. It also requires technical infrastructure in addition to changes in pedagogy, institutional culture, teacher competences, learner behavior, assessment procedures and educational governance.

Core Pillars of Transformation

- **Personalized Learning:** Adaptive software customized lessons to fit each student’s pace and skill level.
- **Administration Automation:** Cloud platforms handle tasks like admission, grading and attendance.
- **Flexible Access:** Hybrid models and learning management systems (LMS) let students study from any location.

- **Data Driven Insights:** Analytics track student engagement and performance to spot issues early.

Major Dimensions of Digital Transformation

Digital transformation can be understood through several interconnected dimensions:

- **Technological infrastructure:** Reliable internet connectivity, computers, tablets, smartphones, smart classrooms, cloud services, digital platforms and other infrastructure form the basic foundation of digital education.
- **Digital content and resources:** Open educational resources, e-books, multimedia materials, digital repositories, simulations, virtual laboratories and multilingual learning resources expand the availability of educational content.
- **Digital pedagogy:** Technology can support collaborative learning, flipped classrooms, blended learning, personalized instruction, project-based learning, simulations and interactive learning environments. The educational value, however, depends on how teachers integrate technology with sound pedagogical practices.
- **Digital assessment:** Online examinations, computer-adaptive assessment, automated feedback, e-portfolios, learning analytics and formative assessment tools can provide new approaches to monitoring student progress.
- **Teacher digital competence:** Teachers require competencies to select, evaluate, design and use digital resources effectively. Digital transformation therefore requires continuous professional development rather than one-time ICT training.
- **Learner digital competence:** Students need digital literacy, information literacy, media literacy, data literacy, critical thinking, online safety and responsible technology-use skills.
- **Institutional transformation:** Educational institutions increasingly use digital technologies for admissions, attendance, communication, academic records, student support, professional development and administrative decision-making.
- **Digital governance and ethics:** Data privacy, cybersecurity, accessibility, algorithmic fairness, intellectual property, academic integrity and responsible AI use have become essential components of digital education.

3. Evolution of Digital Education in India

The evolution of digital education in India reflects a gradual shift from computer-assisted instruction and ICT-based initiatives towards integrated digital learning ecosystems. This development can be broadly understood through the following stages:

- **Early ICT Initiatives:** The initial phase focused on introducing computers and information and communication technologies (ICT) into educational institutions. Government programmes such as the Computer Literacy and Studies in Schools (CLASS) programme and later ICT initiatives sought to improve students' computer awareness and introduce technology into school education. During this period, technology was primarily viewed as a supplementary instructional resource.
- **Expansion of Digital Learning Platforms:** With improvements in internet connectivity, digital education expanded beyond computer laboratories. Initiatives such as e-Pathshala, SWAYAM, SWAYAM Prabha, and the National Digital Library of India increased access to digital educational content for school, higher education and lifelong learners. These initiatives gradually shifted the focus from technology access towards online learning and open educational resources.
- **Digital Transformation under NEP 2020:** The National Education Policy 2020 marked an important policy transition by recognizing technology as an integral component of educational reform. NEP 2020 emphasizes technology for improving teaching-learning processes, teacher development, assessment, educational planning and access to quality education. The proposed National Educational Technology Forum (NETF) further reflects the policy's emphasis on systematic and evidence-based technology adoption [3].
- **COVID-19 and Rapid Digital Adoption:** The COVID-19 pandemic accelerated digital education across India. School and higher education institutions rapidly adopted online classes, digital content, video conferencing, learning management systems and mobile-based learning. The PM eVIDYA initiative brought together multiple modes of digital and remote learning, while DIKSHA became an important national platform for school education. However, the pandemic also exposed inequalities related to internet connectivity, device availability, digital literacy and teachers' preparedness (UNESCO, 2023).
- **Emergence of AI and EdTech:** The post-pandemic period has witnessed rapid growth of EdTech, artificial intelligence, learning analytics, adaptive learning, virtual laboratories and immersive technologies. AI-supported systems can provide personalized learning, automated feedback, content creation and learning support. At the same time, issues related to privacy, academic integrity, algorithmic bias, accessibility and responsible AI use require careful attention.
- **Towards an Integrated Digital Education Ecosystem:** India is now moving towards an integrated digital education ecosystem in which digital public infrastructure, EdTech, AI,

multilingual resources, blended learning, teacher development and digital credentials increasingly interact. Platforms such as DIKSHA and SWAYAM illustrate the movement towards large-scale digital learning infrastructure. This transformation aligns with NEP 2020's emphasis on flexible, inclusive, technology-supported education.

This evolution provides an important foundation for developing future-ready human capital and supporting the educational objectives of Viksit Bharat 2047.

4. Role of EdTech in Transforming Teaching and Learning

In India, educational technology has grown to be a significant part of the country's current educational revolution. In order to enhance teaching, learning, assessment and educational management, EdTech refers to the deliberate use of digital tools, platforms, applications, artificial intelligence, learning management systems, multimedia materials and other technology. With the passage of NEP 2020's technology-focused measures and the COVID-19 pandemic's rapid digital adoption, its function has grown significantly. EdTech can improve learning's flexibility, interactivity, personalization and accessibility when properly incorporated with curriculum and pedagogy. However, learner preparedness, infrastructure, instructor skill, content quality and suitable pedagogical design all affect its efficacy [8].

- **Personalized Learning:** One of the major contributions of EdTech is its capacity to support personalized learning. Digital platforms can provide learners with different levels of content, activities, practice exercises, and feedback according to their learning pace and performance. Adaptive learning systems can analyze learner responses and recommend appropriate learning materials. Such approaches can be particularly useful in large classrooms where teachers may find it difficult to provide individualized support to every learner. However, personalization should complement rather than replace teacher guidance and human interaction.
- **Interactive and Experiential Learning:** EdTech can make learning more interactive through videos, simulations, animations, virtual laboratories, digital storytelling, quizzes, educational games and interactive presentations. These resources can help learners understand abstract concepts by providing visual and practical representations. Virtual laboratories, for example, can allow students to conduct simulated experiments when physical laboratory facilities are limited. Technology-supported experiential learning can therefore supplement conventional classroom activities and provide additional opportunities or practice.
- **Blended and Flexible Learning:** EdTech has expanded learning beyond fixed classroom schedules. Blended learning combines face-to-face teaching with online resources and activities, while hybrid approaches allow learners to participate through both physical and

virtual environments. Online platforms also support asynchronous learning, enabling students to access lectures, readings, assignments and recorded lessons at convenient times. Research following the COVID-19 pandemic indicates that appropriately designed online and blended approaches can provide flexibility, although student engagement and learning quality depend strongly on instructional design and teacher support [1].

- **Digital Content and Open Educational Resources:** Digital platforms have increased access to educational resources. E-books, open educational resources, recorded lectures, multimedia content, question banks and digital repositories can supplement textbooks and classroom instruction. In India, platforms such as DIKSHA, SWAYAM, e-Pathshala and SWAYAM Prabha have contributed to the wider availability of digital educational resources. Multilingual digital content is particularly important in the Indian context because learners study through multiple regional and national languages.
- **Technology-Enabled Assessment:** EdTech has changed the way student learning can be assessed. Online quizzes, computer-based tests, digital portfolios, automated feedback, formative assessment applications and learning analytics allow teachers to monitor learner performance more frequently. Digital assessment can provide immediate feedback and help teachers identify areas where students require additional support. However, institutions need appropriate safeguards to address academic integrity, accessibility, privacy and technical reliability.
- **Learning Analytics and Data-Informed Teaching:** Digital platforms generate data concerning learner participation, completion, assessment performance and learning behaviour. Learning analytics can help teachers identify students who may require additional academic support. At the institutional level, aggregated data can support curriculum planning and monitoring. Nevertheless, educational decisions should not rely solely on automated indicators because learner performance is influenced by social, psychological, technological, and contextual factors.
- **Gamification and Motivation:** Gamification introduces selected elements of game design, such as points, badges, challenges, progress indicators and rewards, into learning environments. These features can increase learner participation and provide immediate feedback. Digital games and interactive activities can also support problem-solving and collaborative learning. Their educational value depends on whether game elements are connected with clearly defined learning outcomes rather than being used simply for entertainment.

- **AI-Supported Teaching and Learning:** Artificial intelligence is introducing new possibilities in EdTech. AI systems can support personalized explanations, automated feedback, content generation, language translation, tutoring, question generation and learning recommendations. Generative AI can also assist teachers with lesson planning and educational material development. However, concerns regarding inaccurate information, bias, data privacy, plagiarism, overdependence and academic integrity require responsible implementation. AI should therefore function as a support mechanism within a teacher-led educational process.
- **Supporting Teachers' Professional Development:** EdTech has expanded opportunities for continuous teacher professional development. Online courses, webinars, digital communities, micro-credentials, and self-learning modules allow teachers to update their knowledge without always requiring physical attendance at training institutions. This is particularly relevant to NEP 2020, which emphasizes continuous professional development and the development of teachers' capabilities for changing educational requirements.
- **Promoting Inclusive Education:** EdTech can support learners with diverse educational needs through assistive technologies, captions, screen readers, text-to-speech tools, adjustable fonts, audio resources, recorded lectures and accessible digital content. It can also support learners who face geographical or mobility-related barriers. However, digital inclusion requires affordable devices, reliable connectivity, accessible platforms, appropriate language resources and digital competence. Without these conditions, EdTech can reinforce existing inequalities rather than reduce them.
- **Developing Future-Ready Skills:** EdTech can contribute to the development of digital literacy, information literacy, communication, collaboration, creativity, critical thinking, problem-solving and technological competence. These skills are increasingly important in a labour market shaped by automation, AI, digital platforms and emerging technologies. Integrating technology with experiential and project-based learning can therefore help learners develop competencies relevant to higher education, employment, entrepreneurship and lifelong learning.
- **EdTech and the Vision of Viksit Bharat 2047:** The contribution of EdTech to Viksit Bharat 2047 can be understood through its potential to expand access to quality education, strengthen digital competence, support teacher development, promote innovation and develop future-ready human capital. However, technology adoption alone cannot achieve these objectives. India requires a balanced approach that combines digital

infrastructure, quality content, teacher competence, inclusive access, sound pedagogy, responsible AI, data protection and evidence-based implementation.

5. Challenges and Risks of Digital Transformation

Significant prospects for enhancing access, flexibility, customization and efficiency in education have been made possible by digital revolution. However, there are risks associated with technology-led change in the areas of education, society, ethics, institutions and the economy. UNESCO (2023) warns that better learning outcomes are not ensured by the sheer availability of technology. Equitable access, suitable pedagogy, teacher readiness, evidence-based implementation and efficient regulation are all necessary for its advantages. Due to significant disparities in socioeconomic circumstances, connectivity, language, infrastructure and digital competency, these issues are especially crucial in the Indian context. The following are major obstacles:

- **Digital Divide and Unequal Access:** The digital divide remains one of the most significant barriers to educational digitalization in India. Differences in access to smartphones, computers, reliable internet, electricity and suitable learning environments can produce unequal educational opportunities. Rural communities, economically disadvantaged households and learners in poorly connected regions may face greater barriers to participating in online education. Shankar *et al.* (2024) demonstrate that the introduction of computers into Indian schools has been accompanied by institutional and structural inequalities, showing that providing technology alone does not eliminate the digital divide [5].
- **Infrastructure and Connectivity Constraints:** Effective digital education requires reliable electricity, broadband or mobile connectivity, suitable devices, technical support and maintenance. Infrastructure limitations can interrupt online classes, restrict access to multimedia content and reduce learner participation. Educational institutions in remote and rural areas may face additional challenges related to network quality and equipment maintenance. Consequently, digital transformation requires sustained investment rather than one-time infrastructure provision.
- **Digital Literacy and Teacher Preparedness:** Teachers and students need appropriate digital competencies to use educational technologies effectively. Teachers may possess basic ICT skills but still lack the pedagogical knowledge required to integrate technology meaningfully into curriculum and classroom practices. Research indicates that teachers' acceptance and use of digital tools are influenced by perceived usefulness, technological competence, institutional support, and contextual conditions [13]. Continuous

professional development is therefore essential for successful implementation of NEP 2020's technology-related provisions.

- **Quality and Effectiveness of Digital Learning:** Digital content is not automatically equivalent to quality education. Poorly designed videos, excessive text, inaccurate information, passive learning activities and technology-centred instruction can limit learning effectiveness. UNESCO (2023) reports that evidence concerning the educational effectiveness of many technologies remains uneven. Educational institutions therefore need mechanisms for evaluating digital content and platforms according to learning outcomes, accessibility, pedagogical quality and evidence of effectiveness.
- **Privacy and Data Protection:** Digital learning platforms collect substantial amounts of learner and teacher data, including attendance, assessment performance, interaction patterns and personal information. Unauthorized access, inappropriate data sharing, weak cyber-security or unclear data ownership can threaten privacy. Educational institutions must therefore establish clear policies concerning data collection, storage, access, consent, retention and responsible use.
- **Artificial Intelligence and Algorithmic Risks:** AI-based educational systems introduce additional concerns. Algorithms may reproduce biases present in training data, generate inaccurate information or make recommendations that lack adequate transparency. Generative AI also creates challenges related to plagiarism, academic integrity, fabricated references and inappropriate dependence on automated outputs. UNESCO (2023) and UNESCO (2021) emphasize the importance of ethical and human-centered approaches to the use of AI and digital technologies [10;11].
- **Academic Integrity:** The increasing availability of generative AI and online information has complicated conventional approaches to academic assessment. Students can use AI systems to generate assignments, essays, answers and other academic work. This makes it increasingly difficult to determine whether submitted work reflects the student's own knowledge and skills. Institutions therefore need assessment approaches that emphasize application, reasoning, problem-solving, oral interaction, projects and authentic learning rather than relying exclusively on conventional written assignments.
- **Screen Exposure and Learner Well-Being:** Excessive dependence on digital devices can contribute to prolonged screen exposure, reduced physical activity, distraction and difficulties in maintaining attention. Digital learning can also reduce opportunities for face-to-face interaction when poorly designed. Technology should therefore complement meaningful human interaction rather than replace it. Balanced learning environments

should include physical activities, collaborative interaction, practical experiences and offline learning.

- **Language and Cultural Barriers:** India's linguistic diversity presents a major challenge for digital education. A large proportion of high-quality digital educational resources remain concentrated in English and a limited number of Indian languages. Learners who are more comfortable in regional languages may therefore experience difficulties accessing or understanding digital resources. Expanding high-quality multilingual and culturally relevant digital content is essential for equitable implementation of technology-supported education.
- **Accessibility for Learners with Disabilities:** Digital transformation can support inclusive education through screen readers, captions, speech-to-text, text-to-speech and other assistive technologies. However, poorly designed websites, applications, documents and videos can create additional barriers for learners with disabilities. Accessibility must therefore be incorporated into the design and procurement of educational technologies rather than being treated as an optional feature.
- **Commercialization and Dependence on EdTech Platforms:** Rapid growth in the EdTech sector has increased access to educational products and services but has also raised concerns about commercialization. Excessive dependence on private platforms may create problems related to cost, data ownership, interoperability, platform continuity and institutional autonomy. Public digital infrastructure and open educational resources can help reduce excessive dependence on proprietary systems.
- **Institutional Resistance and Change Management:** Digital transformation often requires changes in institutional culture, leadership, teaching practices, administrative systems and professional roles. Resistance may emerge when teachers or administrators perceive technology as increasing workload, reducing autonomy, or creating uncertainty about existing practices. Digital transformation therefore requires institutional leadership, consultation, technical support, adequate training, and realistic implementation timelines.
- **Unequal Quality of Digital Learning Environments:** Learners' digital experiences vary considerably according to household conditions. A student with a personal laptop, high-speed internet, a quiet study environment and parental or institutional support may have a substantially different learning experience from a student relying on a shared smartphone and intermittent mobile data. Consequently, equal access to a platform does not necessarily mean equal access to meaningful learning.

- **Risk of Technology-Centred Education:** One of the fundamental risks is treating technology as an objective rather than a means of achieving educational goals. Educational institutions may adopt AI, smart classrooms or digital platforms because these technologies appear innovative without sufficient evidence regarding their educational value. Effective digital transformation requires alignment among technology, pedagogy, curriculum, teachers, learners and learning outcomes [8].

The challenges demonstrate that India's digital education strategy must move towards equitable, inclusive, ethical, evidence-based and human-centered digital transformation. This requires investment in infrastructure and teacher capacity alongside strong data governance, accessible design, multilingual content, responsible AI, cyber security and continuous evaluation. NEP 2020 provides an important policy foundation, but successful implementation will depend on the capacity of educational institutions to translate policy objectives into sustainable practices.

6. Strategic Recommendations

The successful digital transformation of Indian education requires a coordinated strategy that connects NEP 2020, EdTech, digital infrastructure, teacher development, inclusion, artificial intelligence, quality assurance and future-ready skills. Technology should be adopted according to clearly defined educational objectives and learner needs. The following recommendations can support the development of an inclusive, effective, ethical and sustainable digital education system aligned with Viksit Bharat 2047.

- **Strengthening Digital Infrastructure and Connectivity:** India should continue expanding reliable and affordable internet connectivity, electricity, digital devices, smart classrooms, digital laboratories and institutional networks. Priority should be given to rural, remote, tribal, economically disadvantaged and educationally underserved areas. Schools and higher education institutions also require technical support, maintenance systems, cybersecurity infrastructure and regular hardware and software upgrades. Digital infrastructure should be treated as a continuing educational investment rather than a one-time expenditure.
- **Promoting Equitable Digital Access:** Digital transformation should ensure that technological progress does not increase existing educational inequalities. Governments and educational institutions should develop mechanisms for affordable devices, subsidized connectivity, community digital learning centres and shared technology facilities. Special attention should be given to learners from low-income households, rural communities and other disadvantaged groups. Digital inclusion should be assessed through meaningful access to learning rather than merely counting the number of devices or internet connections.

- **Strengthening Teachers' Digital Competence:** Teachers are central to the successful integration of EdTech. Continuous professional development should move beyond basic computer training towards digital pedagogical competence. Teacher education and professional development programmes should include digital content development, blended learning, online assessment, learning analytics, AI literacy, cybersecurity, digital ethics and inclusive technology use. Teachers should also receive practical opportunities to apply these competencies in authentic classroom situations.
- **Developing High-Quality Digital Content:** India needs curriculum-aligned, evidence-based, interactive, accessible and multilingual digital learning resources. Digital content should be developed according to learners' age, language, cognitive level and educational context. Resources should include videos, simulations, virtual laboratories, interactive activities, assessments, open educational resources and accessible materials for learners with disabilities. Regular academic review should be used to maintain content accuracy and relevance.
- **Promoting Multilingual Digital Education:** India's linguistic diversity requires greater investment in multilingual digital education. Digital resources should increasingly be available in Indian languages, with appropriate translation and localization rather than simple machine translation. AI-based language technologies can support translation, speech recognition, text-to-speech and language learning, but their accuracy should be evaluated carefully. Multilingual EdTech can improve participation among learners who are less comfortable with English-based digital content.
- **Expanding Inclusive and Accessible EdTech:** Digital platforms should follow accessibility principles from the design stage. Features such as captions, audio descriptions, screen-reader compatibility, adjustable text, keyboard navigation, text-to-speech and speech-to-text can improve access for learners with disabilities. Inclusive design should also consider learners with different learning needs, socioeconomic circumstances, languages and levels of digital competence. This approach would strengthen the equity objectives of NEP 2020.
- **Integrating EdTech with Pedagogy:** Educational institutions should avoid technology-centred adoption in which new technologies are introduced without clear learning objectives. Teachers should select technology according to the curriculum, learner characteristics, learning outcomes and pedagogical requirements. Blended learning, project-based learning, experiential learning, collaborative learning, simulations and personalized learning can be strengthened through appropriate technology.

- **Promoting Responsible Use of Artificial Intelligence:** AI should be integrated into education through clear ethical and academic guidelines. Educational institutions should develop policies covering:
 - Responsible use of generative AI
 - Data privacy and security
 - Academic integrity
 - AI-generated content
 - Algorithmic bias
 - Transparency
 - Accuracy and verification
 - Intellectual property
 - Appropriate human decision-making

Teachers and students should be trained to critically evaluate AI-generated information rather than accepting automated outputs without verification. AI should strengthen educational processes while preserving the central role of teachers.

- **Strengthening Digital Assessment:** Digital transformation should include assessment reform. Institutions can use online formative assessment, e-portfolios, digital rubrics, adaptive testing, competency-based assessment and automated feedback where appropriate. At the same time, assessment systems should minimize opportunities for cheating and inappropriate use of AI. Greater emphasis on projects, presentations, problem-solving, application-based tasks and authentic assessment can provide a more comprehensive understanding of student learning.
- **Strengthening Data Governance and Cybersecurity:** Educational institutions increasingly collect personal, academic, behavioural and performance-related data. Strong safeguards are therefore required for data collection, storage, sharing, access and retention. Institutions should establish clear data governance policies, cybersecurity protocols, access controls, regular security audits, and awareness programmes for teachers and students. Educational data should be collected only for legitimate and clearly defined purposes.
- **Supporting Research and Evidence-Based EdTech Adoption:** India should strengthen research examining the actual educational impact of digital technologies. Institutions should evaluate EdTech according to learning outcomes, student engagement, teacher effectiveness, accessibility, equity, scalability and cost-effectiveness. Researchers should also examine differences across educational levels, regions, socioeconomic groups and learner populations. This evidence can help policymakers and institutions distinguish

technologies that genuinely improve learning from those that primarily offer technological novelty.

- **Strengthening Digital Public Infrastructure:** Public digital education platforms should be strengthened through interoperability, scalability, accessibility, multilingual support and secure data systems. Platforms such as DIKSHA, SWAYAM, PM eVIDYA and NDEAR can provide important foundations for large-scale digital education. Greater interoperability can allow learners and institutions to access resources across platforms while reducing duplication and fragmentation.
- **Building Public-Private Partnerships:** Responsible collaboration between government, universities, schools, researchers, technology organisations, and EdTech companies can accelerate innovation and improve access to digital resources. However, such partnerships should operate within clear standards relating to educational quality, data protection, accessibility, transparency, affordability and institutional autonomy. Commercial interests should not determine educational priorities.
- **Strengthening Vocational Education and Employability:** EdTech can connect formal education with vocational training and labour-market requirements. Online skill courses, virtual laboratories, simulations, industry certifications, digital portfolios and micro-credentials can support employability. Universities and vocational institutions should work with industry to identify emerging skill requirements and update digital learning programmes accordingly.
- **Strengthening Institutional Leadership and Digital Governance:** Educational institutions should develop institutional digital transformation plans with measurable objectives, budgets, timelines, responsibilities, and evaluation mechanisms. Leadership teams should assess technological readiness, teacher capacity, infrastructure, cybersecurity, accessibility, and learner needs before implementing major digital initiatives. Digital transformation should become part of institutional planning rather than remaining the responsibility of individual technology departments.
- **Developing a Long-Term Roadmap towards 2047:** India should establish a long-term digital education roadmap aligned with the broader objectives of Viksit Bharat 2047. The roadmap should connect infrastructure, inclusion, teacher competence, digital pedagogy, AI, skills, research, innovation and lifelong learning. It should include short-term, medium-term and long-term targets and should be reviewed periodically according to technological developments and educational evidence.

Conclusion

With the National Education Policy (NEP) 2020, digital transformation has become even more crucial to India's educational growth. New opportunities for enhancing access, flexibility, personalization and educational quality are being created by the growth of EdTech, digital public infrastructure, online learning platforms, artificial intelligence, learning analytics and digital assessment. India is moving toward a more integrated digital education system, as evidenced by initiatives like DIKSHA, SWAYAM, PM eVIDYA and NDEAR but technology by itself cannot ensure better education. Significant obstacles still include digital inequality, poor infrastructure, insufficient teacher preparation, accessibility issues, data privacy concerns, academic integrity and responsible AI use. Therefore, alignment between technology, pedagogy, teacher competency, learner needs, institutional capacity and ethical governance is necessary for effective change.

By enhancing digital literacy, future-ready skills, innovation, employability, and lifelong learning, digital education may significantly contribute to the development of human capital for Viksit Bharat 2047. India's ultimate goal should be to create a digital education system that is human-centered, inclusive, moral and prepared for the future. By 2047, EdTech may play a significant role in creating a skilled, creative, knowledge-based and developed India if it is guided by NEP 2020 and supported by suitable infrastructure, qualified teachers, high-quality material, research-based practices and efficient governance.

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LIBRARIES IN TRANSITION: FROM INFORMATION REPOSITORIES TO KNOWLEDGE ECOSYSTEMS

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Abstract

Libraries have historically been understood as repositories of books and other recorded information. Their principal functions have included collection development, organization, preservation, retrieval, and dissemination of knowledge. The rapid development of information and communication technologies, however, has transformed this traditional model. Contemporary libraries increasingly operate as digital platforms, research infrastructures, learning environments, community spaces, data hubs, and centres for knowledge creation. The emergence of artificial intelligence, big data, cloud computing, digital humanities, open science, institutional repositories, and generative AI is accelerating this transformation.

This chapter examines the evolution of libraries from information repositories to interconnected knowledge ecosystems. It explores the changing nature of library collections, digital transformation, data-driven services, research support, open knowledge, artificial intelligence, information and AI literacy, digital inclusion, and the changing competencies of library professionals. It also considers ethical issues involving privacy, intellectual property, algorithmic bias, misinformation, accessibility, and technological inequality. The chapter argues that the future library should not be defined by the technologies it adopts but by its capacity to connect people, information, technology, and communities in an ethical, inclusive, and sustainable manner. The future library is therefore best understood as a human-centred knowledge ecosystem in which technology serves learning, research, inclusion, preservation, and responsible knowledge creation.

Keywords: Artificial Intelligence, Digital libraries, Future libraries, Information repositories, Knowledge ecosystem, Open knowledge.

Introduction

For centuries, libraries have been among society's most important institutions for preserving, organizing, and transmitting knowledge (Battles, 2003; Casson, 2001). From ancient manuscript repositories to contemporary academic and public libraries, their fundamental purpose has been to provide organized access to recorded knowledge (Casson, 2001; Rubin and Rubin, 2020).

Books, journals, newspapers, manuscripts, maps, photographs, audiovisual materials, and other documentary resources consequently became the principal components of library collections (Rubin and Rubin, 2020).

The traditional image of a library is therefore closely associated with shelves, books, catalogues, reading rooms, librarians, and reference desks. This image, although still relevant, is increasingly incomplete as technological change has transformed both library collections and professional practices (Rubin and Rubin, 2020). A contemporary library may provide access to millions of electronic articles, e-books, bibliographic databases, digital archives, institutional repositories, research datasets, open educational resources, multimedia collections, and digital scholarship platforms (ACRL Research Planning and Review Committee, 2024; Rubin and Rubin, 2020). Librarians may assist researchers with research data management, scholarly communication, digital preservation, bibliometrics, information evaluation, and the responsible use of artificial intelligence (AI) (ACRL Research Planning and Review Committee, 2024; Yoon and Schultz, 2017).

The transformation is not simply a movement from print to electronic resources. It represents a deeper change in the position of the library within the wider knowledge system. The library is increasingly connected to universities, researchers, publishers, archives, museums, technology providers, governments, communities, and international information networks. IFLA's work on libraries and AI similarly positions libraries within broader information and knowledge environments and emphasizes the profession's continuing values of equitable access, privacy, openness, accountability, and responsible innovation (IFLA, 2025).

The concept of the knowledge ecosystem provides a useful way of understanding this transformation. Rather than functioning primarily as places where information is stored, libraries increasingly connect people, collections, data, technologies, institutions, and communities in processes of discovery, interpretation, learning, research, preservation, and knowledge creation.

The central argument of this chapter is that the contemporary library should be understood not simply as a repository of information but as a human-centred knowledge ecosystem in which people, information, institutions, technologies, and practices interact (Altman and Cohen, 2022). Its future relevance will depend less on whether it possesses the largest collection or the newest technology and more on whether it can create trustworthy, inclusive, ethical, and sustainable connections among people and knowledge (International Federation of Library Associations and Institutions [IFLA] and UNESCO, 2022).

Scope and Conceptual Approach

This chapter adopts a conceptual and literature-based approach to examine the evolution of libraries from information repositories into knowledge ecosystems. It draws on literature and professional frameworks relating to digital libraries, information literacy, institutional repositories, research data management, scholarly communication, open science, digital humanities, artificial intelligence, and community engagement (ACRL Research Planning and Review Committee, 2024).

The discussion focuses particularly on academic and research libraries, while also considering implications for public and community libraries. The purpose is not to propose a single technological model for the future library. Instead, the chapter develops a conceptual understanding of the library as a socio-technical institution in which human expertise, information resources, data, technologies, and communities interact (Borgman, 2015).

The concept of a knowledge ecosystem can therefore be defined as an interconnected environment in which people, information resources, data, technologies, institutions, professional expertise, and communities interact to support the creation, organization, evaluation, preservation, dissemination, and reuse of knowledge (Altman and Cohen, 2022).

This definition is important because it shifts attention from technologies themselves to relationships among the components of the knowledge environment (Altman and Cohen, 2022).

From Repository to Knowledge Ecosystem: A Conceptual Model

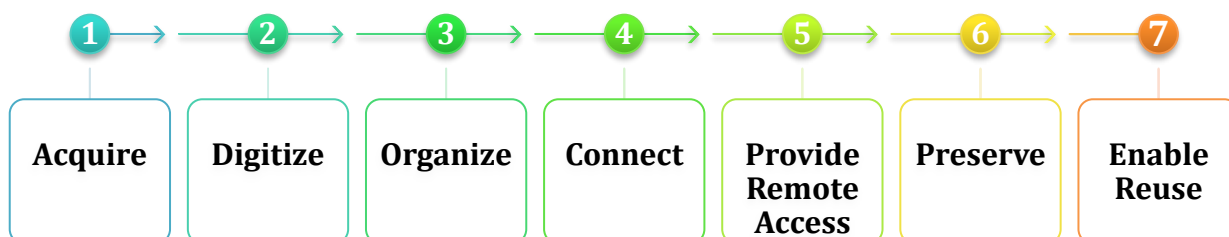
The transformation discussed in this chapter can be represented through a four-stage model.

Stage 1: Information Repository: Its basic model was:



The library acquired information resources, organized them using classification and cataloguing systems, preserved them for future generations, and provided users with access.

Stage 2: Digital Library: The digital transformation has expanded this model:



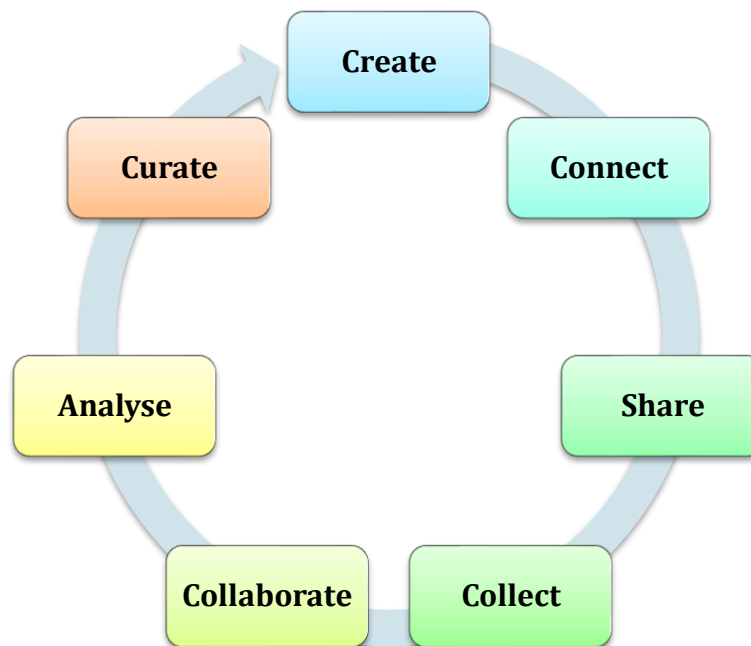
The library expands beyond its physical boundaries and provides networked access to information.

Stage 3: Research and Knowledge Infrastructure



The library becomes increasingly embedded within research and scholarly communication processes.

Stage 4: Knowledge Ecosystem: The emerging knowledge ecosystem goes further



This final model changes the institutional identity of the library. The library is no longer merely the endpoint of an information supply chain. It becomes an active participant in processes of knowledge production and dissemination.

For example, a university library may support a researcher by providing scholarly literature, advising on research data management, helping create metadata, supporting an institutional repository, facilitating open-access publishing, providing bibliometric information, assisting with digital scholarship, and developing AI literacy. The researcher therefore interacts with the library through a network of services rather than through a single reference transaction.

This transformation can also be understood through the broader movement from collection-centred to user-, research-, community-, and knowledge-centred librarianship. Lankes (2021), for example, emphasizes the social and participatory dimensions of librarianship and the role of librarians in facilitating knowledge creation within communities. The knowledge ecosystem

perspective therefore does not imply that collections have become unimportant. Instead, collections become one component of a larger system.

The Evolution of Library Collections: One of the most visible transformations has occurred in library collections.

- **Print Collections:** Books and journals remain valuable for cultural, educational, historical, and scholarly purposes, but now form only one part of the information environment.
- **Electronic Resources:** E-journals, e-books, databases, and digital media have expanded library access beyond physical and geographical boundaries, enabling users to access information anytime and from anywhere.
- **Institutional Repositories:** Institutional repositories enable libraries to collect, preserve, and disseminate scholarly outputs such as thesis, articles, datasets, reports, and digitized collections, strengthening institutional memory and scholarly communication.
- **Research Data:** Libraries increasingly support research data management through planning, metadata creation, preservation, citation, repository selection, and researcher training, making data services an important part of modern academic librarianship (Cox and Pinfield, 2014; Cox *et al.*, 2019).

The FAIR Principles—Findable, Accessible, Interoperable, and Reusable provide an important framework for research data management (Wilkinson *et al.*, 2016). Thus, research data has become an important library resource that supports research, analysis, collaboration, and knowledge creation.

Libraries as Digital Knowledge Infrastructures

Traditional libraries primarily provided access to existing knowledge, while contemporary libraries increasingly support knowledge creation and digital scholarship. Researchers use digitised collections for text and data mining, corpus analysis, mapping, data visualization, and other computational research.

Libraries support these activities through datasets, technical infrastructure, metadata expertise, training, consultation, and preservation services. As a result, librarians increasingly function as research partners rather than simply information providers. Digital humanities further strengthen this role through collaborations involving digital editions, text corpora, digital exhibitions, geospatial projects, and linked data (Hartsell-Gundy *et al.*, 2024).

Open Knowledge and Scholarly Communication

Digital technologies and the open-access movement have expanded the role of libraries in scholarly communication. Libraries now support open-access publishing, institutional

repositories, open educational resources, research data, copyright guidance, persistent identifiers, research visibility, and digital preservation.

The growth of open science has further strengthened this transformation. UNESCO's Recommendation on Open Science emphasizes broader and more equitable access to scientific knowledge, infrastructures, data, and research processes (UNESCO, 2021). Libraries are well-positioned to contribute through their expertise in information organization, metadata management, digital preservation, and access to scholarly resources. Scholarly communication librarianship has consequently expanded to include repository management, library publishing, copyright education, open-access advocacy, research visibility, and emerging scholarly technologies (Bonn *et al.*, 2023).

The scholarly record now includes datasets, software, preprints, multimedia, and other digital outputs alongside traditional publications. Libraries are therefore becoming active partners throughout the research lifecycle, supporting the creation, organization, dissemination, discovery, and preservation of diverse scholarly outputs. Library publishing and open scholarship further strengthen this role, positioning libraries as important facilitators of sustainable and accessible scholarly communication.

Data-Driven Libraries

Data is becoming an important part of library transformation. Libraries can use data analytics to support collection development, service planning, user experience, research support, preservation, and decision-making.

However, being data-driven should not mean collecting unnecessary user information. Libraries must protect privacy and confidentiality through transparent, secure, and responsible data practices. This is especially important as libraries increasingly use third-party platforms and AI-enabled services. The key challenge is to use data effectively while protecting users' rights and privacy.

Artificial Intelligence and the Intelligent Library

Artificial intelligence (AI) is transforming libraries through automated metadata, classification, semantic search, recommendations, reference services, translation, digitization, accessibility, and research support. These applications contribute to the development of the “intelligent library” by improving service efficiency and accessibility (Cox *et al.*, 2019).

AI can also support information discovery, data analysis, and routine tasks, allowing librarians to focus on professional and user-centred services. However, its adoption raises concerns about privacy, bias, accuracy, equity, accountability, and sustainability. IFLA (2025) and ALA (2026) emphasize responsible AI implementation and the importance of human judgment.

Therefore, AI should augment rather than replace librarians. Its effective use requires ethical oversight, professional development, and a balanced relationship between technology and human expertise.

Generative AI and the New Information Environment

Generative AI has introduced a new form of interaction with information. Traditional information searching generally requires users to identify keywords, search databases, evaluate results, and consult documents. Generative AI enables users to pose questions conversationally and receive synthesized responses. This creates both opportunities and risks.

Opportunities: Generative AI can help users:

- **Explore unfamiliar subjects:** Helps users understand new topics and identify areas for further study.
- **Identify keywords:** Suggests relevant terms and phrases to improve information searches.
- **Summarize complex material:** Provides concise summaries of lengthy or difficult texts.
- **Generate research questions:** Helps users develop and refine possible research questions.
- **Translate text:** Supports quick translation and understanding of materials in other languages.
- **Organize ideas:** Helps arrange concepts, create outlines, and structure research work.
- **Identify potential sources:** Suggests relevant authors, topics, databases, and types of sources, which should be verified.
- **Support preliminary research:** Assists with initial exploration, search planning, and understanding of a research topic.

Research on librarians' use of generative AI suggests that such tools can support research and teaching activities when used critically and with appropriate verification (Chiang and James, 2025).

Risks: Generative AI can also:

- **Generate inaccurate information:** May provide incorrect or misleading answers.
- **Produce fabricated citations:** Can create references or sources that do not actually exist.
- **Reproduce bias:** May reflect biases present in its training data.
- **Oversimplify complex issues:** Can present complicated subjects without sufficient context or nuance.

- **Obscure information origins:** May make it difficult to identify the original source of information.
- **Create intellectual-property concerns:** May raise questions about copyright, ownership, and the use of protected content.
- **Encourage uncritical acceptance:** Users may accept AI-generated answers without checking their accuracy or reliability. Therefore, AI does not eliminate the need for information literacy. It makes information literacy even more important.

These risks are especially important in academic environments, where evidence, source authority, attribution, and research integrity are fundamental. UNESCO's guidance on generative AI in education and research adopts a human-centred approach and highlights issues including data privacy, institutional preparedness, and responsible governance (UNESCO, 2021). Generative AI therefore does not eliminate the need for information literacy. It makes information literacy more important.

Information and AI Literacy in the Knowledge Ecosystem

Information literacy enables users to identify information needs, locate and evaluate sources, and use information ethically. The ACRL *Framework for Information Literacy for Higher Education* highlights concepts such as authority, information creation, information value, research as inquiry, and strategic searching (ACRL, 2016). In the AI era, these skills need to be extended to include AI literacy. AI literacy involves understanding how AI systems generate and present information, recognizing their limitations and biases, verifying AI-generated claims, and understanding issues related to privacy, copyright, and ethical use. Users should also recognize when human expertise and original evidence are essential.

The ACRL *AI Competencies for Academic Library Workers* emphasizes ethical considerations, AI knowledge, analysis and evaluation, and responsible application. AI literacy is therefore an extension of traditional information literacy, not a replacement for it.

Libraries are well positioned to develop these skills through instruction, workshops, and research support. Their role is not simply to teach users how to use AI tools, but to help them understand when, why, and how AI should be used responsibly. This strengthens users' ability to evaluate evidence, recognize bias, protect their information, and make informed decisions in AI-mediated environments.

The Library as a Community Knowledge Hub

The knowledge ecosystem extends beyond academic research, with public libraries increasingly functioning as community knowledge hubs that support digital literacy, lifelong learning,

employment information, government information, digital access, community history, cultural programming, media literacy, and digital citizenship (International Federation of Library Associations and Institutions [IFLA] and UNESCO, 2022; Public Library Association [PLA], 2024). This role is particularly important for communities where people may lack reliable internet access, digital devices, digital skills, or professional information resources, enabling libraries to contribute to reducing the digital divide (IFLA and UNESCO, 2022; PLA, 2024). However, digital inclusion should not be understood simply as providing internet access. Meaningful inclusion requires a combination of access, skills, confidence, accessibility, and access to trustworthy information, allowing individuals to participate effectively in an increasingly digital society (Helsper, 2021; IFLA and UNESCO, 2022).

The Changing Role of the Librarian

The transformation of libraries has expanded the role of librarians beyond traditional collection development, cataloguing, reference, and preservation. Today, librarians may also work as data specialists, digital scholarship experts, research-data consultants, scholarly communication professionals, AI literacy educators, and digital curators (Federer, 2018; Rubin and Rubin, 2020). The growing involvement of academic librarians in research data management and scholarly communication demonstrates this broader research-support role (Cox and Pinfield, 2014; Federer, 2018).

Traditional skills such as metadata, information evaluation, preservation, and reference services remain essential but are increasingly applied in digital environments (Rubin and Rubin, 2020). Future librarians therefore need a combination of library expertise, technological awareness, data skills, critical thinking, communication, and ethical judgment to support users and manage the evolving knowledge ecosystem (Association of College and Research Libraries [ACRL], 2025; Federer, 2018)

Ethical and Social Challenges

The knowledge ecosystem creates important ethical challenges.

- **Privacy:** Libraries must protect users from unnecessary data collection and surveillance and ensure that personal information is handled responsibly.
- **Algorithmic Bias:** AI systems may reproduce biases and affect discovery and recommendations.
- **Copyright:** Digital resources, text mining, and AI raise complex intellectual-property issues (IFLA, 2025).

- **Misinformation:** The speed with which digital and AI-generated information can circulate makes critical evaluation increasingly important.
- **Digital Inequality:** Technological transformation can benefit users who have good connectivity and digital skills while excluding those who do not.
- **Vendor Dependence:** Reliance on commercial platforms may limit institutional control and independence.

Consequently, technological adoption must be accompanied by institutional independence, transparency, sustainability, and ethical governance.

Building a Human-Centred Knowledge Ecosystem

Future libraries should be human-centred rather than technology-centred. Technology should improve access, learning, research, inclusion, privacy, and sustainability while reducing barriers for users. Libraries should adopt technologies only when they strengthen services, protect privacy, promote inclusion, preserve human judgment, and support long-term sustainability (American Library Association, 2026).

Technology should therefore support, not replace, professional expertise and human values. A successful knowledge ecosystem will use technology as a means of serving people and enhancing access to trustworthy knowledge.

Future Directions

The library of the future is likely to become increasingly interconnected. Several developments deserve particular attention:

- **Intelligent Discovery:** Natural-language interfaces, semantic search, knowledge graphs, and AI-assisted discovery may make information retrieval more intuitive.
- **Research Data Services:** Libraries will expand support for data management, preservation, sharing, and reuse, guided by FAIR principles (Wilkinson *et al.*, 2016).
- **Digital Humanities:** Libraries will increasingly collaborate with researchers using computational methods to investigate cultural and historical collections.
- **Open Science:** Libraries will promote open access, open data, and transparent research practices (UNESCO, 2021).
- **AI Literacy:** Libraries will help users understand, evaluate, and responsibly use AI.
- **Digital Preservation:** As more cultural and scholarly content becomes digital, libraries will remain essential for long-term preservation and access.
- **Collaborative Knowledge Networks:** Libraries will strengthen partnerships with researchers, institutions, communities, archives, museums, and technology organizations.

IFLA's recent work on AI and broader library trends reflects this movement toward libraries as active participants in wider technological and knowledge environments. Overall, future libraries will function as interconnected knowledge hubs, combining technology, professional expertise, collaboration, and human-centred services.

Conclusion

The evolution of libraries from information repositories to knowledge ecosystems reflects a major transformation in librarianship. Modern libraries now connect people, collections, data, technologies, institutions, and communities to support research, learning, knowledge creation, open science, and digital scholarship (Altman and Cohen, 2022; UNESCO, 2021).

This transformation also brings challenges involving privacy, AI bias, misinformation, copyright, digital inequality, sustainability, and technological dependence. Therefore, future libraries must balance technological innovation with ethics, inclusion, professional judgment, and public trust.

The future library should be technology-enabled but human-centred. Its relevance will depend not on the size of its collections or the sophistication of its technology, but on its ability to provide trusted pathways for discovering, evaluating, creating, sharing, and preserving knowledge (Altman and Cohen, 2022; IFLA, 2020). Thus, the library of the future is best understood as a living knowledge ecosystem serving people, communities, and society.

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BEYOND THE STACKS: LEVERAGING AI AND LINKED DATA FOR NEXT-GENERATION KNOWLEDGE DISCOVERY

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Abstract

Academic and public libraries are undergoing a fundamental transformation from physical book repositories to dynamic, data-drive digital knowledge hubs. This chapter explores how emerging technologies – specifically Artificial Intelligence (AI), Machine Learning (ML) and Linked Open Data (LOD) – are redefining resource discoverability, metadata organization and user engagement. By shifting from traditional MARC-based structures to graph-based knowledge frameworks like BIBFRAME, libraries can break down data silos and integrate seamlessly into the broader ecosystem. Furthermore, the incorporation of AI-driven semantic search, conversational discovery interfaces and automated indexing enhances information retrieval while presenting new ethical considerations around algorithmic bias and digital privacy. This chapter presents actionable strategies and operational models for information professionals navigating this digital transition.

Keywords: Digital Libraries, Linked Open Data, Artificial Intelligence, Knowledge Discovery, BIBFRAME, Academic Publishing.

1. Introduction

For centuries, libraries operated under a physical-first paradigm, relying on classified shelving systems—such as the Dewey Decimal Classification (DDC) or Library of Congress Classification (LCC)—to organize human knowledge. However, the exponential growth of digital-native scholarship, institutional repositories, open access (OA) datasets, and non-textual digital media has exposed the limits of traditional organization. Modern information seekers expect immediate, contextual, and interconnected access to information, mirroring the fluidity of modern search engines. To remain relevant in this evolving ecosystem, libraries must expand their footprint 'beyond books.' This shift requires leveraging advanced data architectures and artificial intelligence to transform static metadata into actionable, interconnected digital knowledge. This chapter investigates the tools, standards, and strategic frameworks driving this transformation, offering information professionals a roadmap for implementation.

2. The Evolution of Metadata: From Cataloging to Linked Open Data

Traditional library cataloging has long relied on Machine-Readable Cataloging (MARC) standards. While MARC revolutionized automated library catalogs in the mid-20th century, its rigid, record-based structure isolates library data from the broader semantic web.

2.1 Transitioning from MARC to BIBFRAME

To bridge the gap between library systems and the open web, the Library of Congress developed the Bibliographic Framework (BIBFRAME). BIBFRAME replaces record-based cataloging with a graph-based entity-relationship model using Resource Description Framework (RDF) triples (Subject–Predicate–Object).



By decoupling conceptual works from physical or digital manifestations, BIBFRAME allows libraries to:

- Expose catalog data directly to web search engines using schema.org markup.
- Connect disparate resources—such as manuscripts, datasets, audio recordings, and author profiles—into a unified knowledge graph.
- Reduce redundancy across multi-institutional catalogs through disambiguated entity references.

2.2 The Role of Linked Open Data (LOD) in Knowledge Systems

Linked Open Data enables information networks to cross organizational boundaries. When libraries link their authority control identifiers (e.g., ORCID for researchers, LCNAF, and Wiki data) to global datasets, the library catalog transforms into a dynamic network of interlinked knowledge nodes.

Table 1: Key Linked Data Standards and Tools in Digital Knowledge Infrastructure

Standard / Tool	Core Function in Digital Libraries
Resource Description Framework (RDF)	Formats data as triples (Subject-Predicate-Object) to build flexible knowledge graphs
SPARQL	A graph query language used to retrieve and manipulate data stored in native RDF formats
ORCID / Wiki data	Provides persistent, global identifiers for creators, institutions and research outputs.
Int. Image Interoperability Framework (IIIF)	Delivers standardized high performance access to digital image repositories across institution.

3. Artificial Intelligence and Machine Learning in Resource Discovery

As digital collections expand to millions of scholarly items, traditional manual indexing and basic keyword-based searching are increasingly inadequate for addressing complex research inquiries. Artificial Intelligence (AI) and Machine Learning (ML) offer transformative approaches to managing, organizing, and discovering information within vast digital repositories. These technologies can automate knowledge extraction, identify meaningful patterns, classify and categorize documents, generate intelligent metadata, and improve search accuracy. AI-driven systems can also understand contextual relationships and user intent, enabling more relevant and personalized retrieval of scholarly resources. Consequently, integrating AI and ML into digital libraries can significantly enhance information discovery, accessibility, efficiency, and overall research productivity.

3.1 Semantic Search vs. Keyword Search

Traditional Boolean search matches literal text strings, often missing relevant materials that use synonyms or alternate phrasing. In contrast, natural language processing (NLP) models utilize vector embeddings to capture the contextual meaning of a search query. This enables semantic search engines to retrieve resources based on conceptual relevance, drastically improving discovery in multi-disciplinary research.

3.2 Automated Metadata Generation and Optical Character Recognition (OCR)

ML pipelines can process uncataloged digital archives at scale, unlocking previously hidden special collections:

- **Advanced OCR & HTR:** Optical Character Recognition and Handwritten Text Recognition algorithms transcribe historical manuscripts, newspapers, and archival correspondence into fully searchable text.
- **Named Entity Recognition (NER):** Extracting key entities—such as historical figures, geographic locations, dates, and organizations—automatically generates rich metadata tags for uncataloged collections.
- **Computer Vision for Visual Archives:** Automated image classification labels visual materials (photographs, maps, artifacts) without requiring manual cataloger intervention for every item.

4. Challenges, Ethics, and Governance in Digital Libraries

The implementation of advanced technologies across library workflows introduces significant operational, social, and ethical challenges that require careful planning and continuous management. While technologies such as Artificial Intelligence, Machine Learning, automation, and data analytics can improve efficiency and service quality, their adoption also raises concerns

related to data privacy, security, transparency, bias, accessibility, and workforce adaptation. Libraries must therefore establish appropriate policies, ethical guidelines, and monitoring mechanisms to ensure responsible technology use. Addressing these challenges requires collaboration among librarians, technology professionals, researchers, and policymakers to balance innovation with professional values, user rights, inclusivity, accountability, and the long-term mission of libraries.

- **Algorithmic Bias and Representational Fairness:** Machine learning models trained on historical text corpora risk perpetuating historical biases, harmful subject headings, or exclusionary classifications. Libraries must audit AI tools to preserve critical equity and inclusion standards.
- **Data Privacy vs. Personalization:** Recommender systems and personalized search tools analyze user search histories, raising privacy concerns. Libraries must adhere to strict data-minimization policies to safeguard intellectual freedom.
- **Technical and Financial Sustainability:** Moving from legacy integrated library systems (ILS) to linked-data platforms requires specialized skills (e.g., Python, RDF modeling, SPARQL) and sustainable funding that small or regional institutions may lack.

5. Strategic Implementation Roadmap for Information Professionals

To build a sustainable digital knowledge ecosystem, library leadership should adopt a phased approach to implementation:

- **Phase 1: Readiness and Literacy (Months 1–6):** Upskill library staff in metadata serialization (JSON-LD, RDF), AI ethics, data management practices, and Python scripting.
- **Phase 2: Pilot Linked Data Projects (Months 7–12):** Convert a targeted digital collection (e.g., local history archives or institutional repositories) into BIBFRAME/RDF triples and evaluate web visibility via search engines.
- **Phase 3: AI Integration (Months 13–18):** Implement open-source semantic search interfaces or NLP extraction tools on digitized text archives.
- **Phase 4: Continuous Evaluation (Ongoing):** Conduct regular usability testing to assess discovery workflows, audit algorithm performance for bias, and maintain privacy compliance.

Conclusion

The digital age does not lessen the importance of libraries; rather, it expands their mandate. By evolving beyond physical books and adopting modern data architectures—such as Linked Open

Data, knowledge graphs, and AI-driven semantic tools—libraries transform into interconnected digital knowledge systems. Through careful planning, ethical oversight, and a commitment to open access, libraries will continue to serve as essential hubs for learning, exploration, and discovery.

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ANTI-INFLAMMATORY FOODS IN NEURODEGENERATIVE DISEASE: NEUROIMMUNE REGULATION AND COGNITIVE PROTECTION

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Abstract

Neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease and related dementias, are characterised by progressive neuronal dysfunction accompanied by oxidative stress, mitochondrial impairment and persistent neuroinflammation. Dietary strategies that attenuate these processes may help preserve cognitive function and complement conventional disease management. Anti-inflammatory foods—including berries, leafy vegetables, whole grains, legumes, nuts, fatty fish and extra-virgin olive oil—provide polyphenols, carotenoids, fermentable fibre and unsaturated fatty acids capable of influencing neuroimmune signalling. This chapter examines the mechanisms through which these foods may regulate microglial activation, protect blood–brain-barrier integrity and support synaptic function. Polyphenols can modulate nuclear factor- κ B, NLRP3 inflammasome and nuclear factor erythroid 2-related factor 2 pathways while limiting protein aggregation and oxidative injury. Omega-3 fatty acids support neuronal-membrane structure and generate specialised pro-resolving mediators, whereas fermentable fibre and microbial metabolites influence the gut–brain–immune axis. Mediterranean and MIND dietary patterns combine these bioactives and are associated with slower cognitive decline and lower risks of dementia and Alzheimer's disease. Nevertheless, causality remains uncertain because much of the evidence is observational, and intervention trials vary in duration, cognitive endpoints and participant characteristics. Anti-inflammatory foods should therefore be considered long-term contributors to cognitive resilience rather than treatments capable of reversing established neurodegeneration. A varied, minimally processed, plant-forward dietary pattern containing appropriate sources of fish and unsaturated fat offers a practical strategy for reducing neuroinflammatory exposure and supporting healthy brain ageing.

Keywords: Anti-Inflammatory Foods, Neurodegeneration, Neuroinflammation, Cognitive Protection, Gut–Brain Axis, Polyphenols.

1. Introduction

Neurodegenerative diseases arise through interconnected pathological processes involving protein misfolding, mitochondrial dysfunction, oxidative stress, synaptic failure and dysregulated neuroimmune responses. Although inflammation initially protects neural tissue, sustained activation of microglia and astrocytes can amplify neuronal injury and accelerate cognitive deterioration. Nutrition may influence this trajectory by modifying systemic inflammation, vascular health, intestinal integrity and brain-directed metabolic signalling.

Anti-inflammatory foods provide polyphenols, carotenoids, omega-3 fatty acids, fermentable fibre, vitamins and minerals. Berries, leafy vegetables, legumes, whole grains, nuts, fatty fish and extra-virgin olive oil are therefore prominent components of brain-supportive dietary patterns. Their actions may include suppression of inflammatory signalling, enhancement of antioxidant defences and modulation of the microbiota–gut–brain axis. However, clinical effects depend on long-term adherence, bioavailability, disease stage and broader lifestyle factors. This chapter evaluates the mechanisms and recent evidence connecting anti-inflammatory foods with neuroimmune regulation, cognitive preservation and reduced neurodegenerative-disease risk.

2. Neuroinflammation and Neurodegenerative Progression

Microglia are the principal immune cells of the central nervous system. Under physiological conditions, they remove cellular debris and support synaptic maintenance. Persistent exposure to amyloid- β , α -synuclein, damaged mitochondria or inflammatory mediators can shift microglia towards chronically activated phenotypes that release interleukin-1 β , interleukin-6, tumour necrosis factor- α and reactive oxygen species.

The NLRP3 inflammasome is particularly relevant because its activation promotes inflammatory cytokine maturation and pyroptotic cellular damage. Sustained nuclear factor- κ B signalling further intensifies inflammatory gene expression, while oxidative stress impairs neuronal membranes and mitochondrial function (van der Heiden & te Velde, 2026). Systemic inflammation associated with obesity, insulin resistance and cardiovascular disease may reinforce these brain-directed processes by disrupting the blood–brain barrier.

Dietary inflammatory potential has consequently emerged as a modifiable risk indicator. Meta-analyses associate higher Dietary Inflammatory Index values with increased risks of mild cognitive impairment, Alzheimer's disease and global cognitive decline (Ding *et al.*, 2023; Jia *et al.*, 2023). Among older adults with cardiometabolic disorders, diets with lower inflammatory potential have also been associated with reduced dementia risk and more favourable brain imaging markers (Dove *et al.*, 2024). These findings support neuroinflammation as a plausible bridge between long-term dietary exposure and cognitive deterioration.

3. Polyphenols and Neuronal Defence

Berries, grapes, tea, cocoa, coffee, olives and colourful vegetables supply flavonoids, anthocyanins, phenolic acids and related phytochemicals. These compounds influence neuroprotection through signalling mechanisms rather than functioning solely as direct antioxidants. Polyphenols can suppress nuclear factor- κ B and NLRP3 activity while activating nuclear factor erythroid 2-related factor 2, which regulates endogenous antioxidant enzymes.

Anthocyanins and flavonols may protect neuronal membranes, support cerebral blood flow and enhance synaptic plasticity. Certain polyphenols can also interfere with amyloid- β aggregation, tau hyperphosphorylation and α -synuclein fibrillation in experimental models. However, their ability to cross the blood–brain barrier differs substantially according to chemical structure and microbial transformation (Sbai *et al.*, 2026).

Ferulic acid, quercetin and related metabolites may strengthen tight-junction proteins in intestinal and cerebral barriers. They can additionally regulate brain-derived neurotrophic factor, which supports neuronal survival, learning and memory. Recent evidence emphasises that polyphenol metabolites produced by intestinal microorganisms may provide stronger systemic and neurological activity than their original dietary compounds (Chelliah *et al.*, 2025).

Although supplementation trials are promising, whole foods provide mixtures of polyphenols, fibre, vitamins and minerals. Berries combined with nuts or unsweetened yoghurt, for example, may offer a more physiologically balanced intervention than concentrated extracts with uncertain long-term safety.

4. Omega - 3 Fatty Acids and Inflammatory Resolution

Fatty fish supplies eicosapentaenoic acid and docosahexaenoic acid, which are incorporated into neuronal and glial membranes. Docosahexaenoic acid is especially important for membrane fluidity, synaptic signalling and photoreceptor and neuronal function. These fatty acids can also generate resolvins, protectins and maresins that actively promote inflammatory resolution.

Omega-3 fatty acids may limit microglial overactivation, reduce pro-inflammatory eicosanoids and support mitochondrial function. Neuroprotectin D1, derived from docosahexaenoic acid, has been associated with neuronal-survival signalling and reduced amyloidogenic processing. Altered fatty-acid metabolism is increasingly recognised as a contributor to neurodegenerative progression (Yang *et al.*, 2025).

Nevertheless, food-based intake and supplementation should not be treated as equivalent. Clinical effects depend on baseline omega-3 status, dose, disease stage, apolipoprotein E genotype and treatment duration. Fish also provides protein, selenium and vitamin D and may replace processed meat, producing benefits not captured by isolated capsules. Nuts, flaxseed and

chia provide α -linolenic acid, although conversion to longer-chain fatty acids remain limited. Regular consumption of appropriate food sources is therefore preferable to indiscriminate high-dose supplementation.

5. Gut - Brain Axis and Neuroimmune Regulation

The intestinal microbiota communicates with the brain through neural, endocrine, metabolic and immune pathways. Dysbiosis and impaired intestinal-barrier integrity may permit microbial products, including lipopolysaccharide, to enter circulation and promote systemic and cerebral inflammation. This mechanism may contribute to microglial activation and blood–brain-barrier dysfunction.

Whole grains, legumes, vegetables, fruits, nuts and seeds provide fermentable fibres that support microbial production of acetate, propionate and butyrate. Butyrate strengthens epithelial integrity and may influence microglial maturation, histone acetylation and brain-derived neurotrophic-factor expression. Polyphenols also shape microbial activity while being converted into smaller neuroactive metabolites (Zafari *et al.*, 2025).

Microbiota-derived metabolites may influence amyloid deposition, neurotransmitter synthesis and immune-cell trafficking. Conversely, microbial imbalance can promote the production of inflammatory or neurotoxic compounds. Recent reviews therefore identify the microbiota–gut–brain axis as a promising target for nutritional prevention of neurodegenerative disorders (Paul *et al.*, 2025; Castillo-Moral *et al.*, 2026).

However, large taxonomic changes are not always necessary for benefit. Functional alterations in short-chain fatty acids, bile acids and tryptophan metabolites may be more informative than the abundance of individual bacterial groups. Future interventions should consequently measure microbial function alongside composition.

6. Mediterranean and Mind Dietary Pattern

The Mediterranean diet combines vegetables, fruits, legumes, whole grains, nuts, fish and olive oil while limiting processed meat and refined foods. The MIND diet adapts Mediterranean and DASH principles by emphasising leafy greens, berries, nuts, whole grains and fish. Both patterns deliver complementary anti-inflammatory and vascular benefits.

Recent meta-analytic evidence associates greater Mediterranean-diet adherence with reduced risks of dementia and Alzheimer's disease (Fekete *et al.*, 2025). Long-term adherence may also protect against cognitive decline by improving vascular health, insulin sensitivity and oxidative balance. Evidence for the MIND diet indicates favourable associations with global cognition, memory and reduced dementia risk, although randomised evidence remains limited (Kim *et al.*, 2025).

A Mediterranean or MIND diet may influence multiple pathological pathways simultaneously: vascular injury, metabolic dysfunction, neuroinflammation, oxidative stress and microbial dysbiosis. This systems-level action may explain why complete dietary patterns demonstrate more consistent associations than individual supplements.

However, these patterns should not be interpreted rigidly. Regional adaptation can incorporate locally available leafy vegetables, berries or other coloured fruits, pulses, millets, whole grains, seeds, fish and unsaturated oils. The underlying biological profile is more important than geographical authenticity.

7. Cognitive Protection and Clinical Relevance

Observational findings consistently support an inverse association between anti-inflammatory dietary patterns and cognitive deterioration. Higher dietary inflammatory potential has been independently associated with cognitive impairment, while Mediterranean and MIND adherence is generally related to better cognitive outcomes (Fang *et al.*, 2025; Fei *et al.*, 2025).

Nevertheless, cognitive intervention trials face substantial challenges. Neurodegeneration develops over decades, whereas most dietary trials last months or a few years. Cognitive testing can be influenced by education, mood, sleep and practice effects. Participants with established dementia may also have irreversible neuronal loss, limiting the observable impact of dietary change.

Anti-inflammatory foods should therefore be positioned primarily as components of risk reduction and cognitive-resilience strategies. They may be most effective when adopted during midlife or before significant neuropathology develops. Diet should complement—not replace—blood-pressure management, diabetes care, physical activity, cognitive engagement, sleep optimisation and indicated pharmacotherapy.

8. Challenges and Future Perspectives

The field must progress from broad associations towards precision neuroprotective nutrition. Most evidence relies on food-frequency questionnaires, observational cohorts and variable cognitive tests. Residual confounding and reverse causality remain important concerns, particularly when early cognitive changes alter food selection (Christimann *et al.*, 2026).

Future trials should begin earlier, continue longer and integrate cognitive testing with blood–brain-barrier markers, inflammatory mediators, neurofilament light, amyloid and tau biomarkers, brain imaging and microbiome metabolites. Polyphenol exposure should be defined by food source, dose, metabolism and bioavailability rather than total intake.

Personalised approaches could incorporate apolipoprotein E genotype, vascular risk, inflammatory phenotype and microbial functionality. Digital dietary monitoring and

metabolomics may identify responders before irreversible neuronal loss occurs. Culturally adapted MIND-style patterns could improve long-term adherence without relying on expensive supplements. Future functional foods should preserve fibre and phytochemicals while limiting sugar, sodium and saturated fat. The brightest opportunity is to transform neuroprotective nutrition from late-stage supportive advice into an early, measurable and personalised component of lifelong brain-health preservation.

Conclusion

Anti-inflammatory foods offer a biologically plausible strategy for protecting the ageing brain and reducing exposure to processes that contribute to neurodegeneration. Berries, leafy vegetables, legumes, whole grains, nuts, fatty fish and extra-virgin olive oil provide polyphenols, fermentable fibres, omega-3 fatty acids, vitamins and minerals within complex food matrices. These constituents may suppress excessive neuroimmune activation, enhance antioxidant defences, preserve neuronal membranes and strengthen intestinal and blood–brain barriers.

The potential benefits arise through several interacting pathways. Polyphenols regulate inflammatory and cytoprotective signalling; omega-3 fatty acids support synaptic structure and inflammatory resolution; and microbial fermentation generates metabolites capable of influencing immune activity and neuronal function. Improved vascular and metabolic health may provide additional cognitive protection by maintaining cerebral perfusion and reducing insulin resistance. Current evidence most strongly supports Mediterranean and MIND dietary patterns. However, many associations remain observational, and dietary intervention trials have not established that anti-inflammatory foods can reverse Alzheimer's disease, Parkinson's disease or advanced dementia. These foods should therefore be presented as contributors to cognitive resilience and risk reduction rather than curative treatments.

Timing may be decisive. Dietary patterns adopted during midlife or before substantial neuropathology develops are more likely to preserve cognitive reserve than interventions introduced after extensive neuronal loss. Anti-inflammatory nutrition should accompany physical activity, vascular-risk control, adequate sleep, cognitive engagement and appropriate medical therapy. The brain is not protected by one antioxidant-rich food; cognitive resilience is cultivated over decades through a dietary pattern that continually lowers inflammatory pressure while nourishing neurons, vessels and the gut–brain axis.

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VIKSIT BHARAT:
ROLE OF LIVESTOCK IN THIS VISION AND TRANSFORMATION

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Introduction

India's development journey has entered a phase in which economic growth, social inclusion, technological advancement, environmental sustainability and livelihood security need to progress together. The vision of Viksit Bharat@2047 represents the long-term national aspiration of transforming India into a developed country by the centenary of independence. The vision has been described in terms of a prosperous India living in harmony with nature, supported by modern infrastructure and providing opportunities for citizens and regions to achieve their potential.

The transformation of India cannot be achieved through urban and industrial growth alone. Agriculture and allied sectors remain fundamental to rural livelihoods, food and nutritional security and balanced regional development. In this context, livestock assumes particular importance because it links agriculture with household income, nutrition, employment, women's participation, entrepreneurship and rural industrialisation. The recent Economic Survey identifies livestock as an important engine of agricultural growth, with its contribution to agricultural and allied-sector GVA increasing from 24.38% in FY2015 to 30.23% in FY2023.

Thus, livestock development should not be viewed merely as an increase in milk, meat or egg production. It represents an opportunity to transform smallholder agriculture into a more diversified, resilient and remunerative livelihood system. The transition from the earlier concept of livestock as a subsidiary agricultural activity towards a technology-driven, market-oriented and sustainable livestock enterprise can make a significant contribution to the broader objectives of Viksit Bharat@2047.

Livestock and the Rural Livelihood System

Livestock have historically formed an integral component of Indian agriculture. Cattle, buffaloes, sheep, goats, pigs and poultry provide products for consumption and sale while also functioning as productive assets for rural households. For small and marginal farmers, livestock can provide a more regular stream of income than seasonal crop production. Milk, eggs and other livestock products can generate frequent cash returns, while the sale of animals can provide relatively larger payments during periods of financial requirement.

The importance of livestock becomes particularly evident in smallholder production systems where landholdings are limited. Livestock enable farmers to diversify their sources of income and reduce dependence on a single crop. Crop residues can be converted into animal products, while manure can return nutrients and organic matter to agricultural land. This crop–livestock interaction creates an integrated production system in which resources generated by one enterprise can support another.

The contemporary livestock sector is also increasingly associated with entrepreneurship. Dairy farming, commercial poultry, goat and sheep production, piggery, fodder production, feed manufacturing, artificial insemination services, animal-health services, milk collection, processing and value-added livestock products provide opportunities beyond conventional farm-level production. The National Livestock Mission, for example, specifically promotes entrepreneurship and breed development in rural poultry, sheep, goats and pigs, including support for individual entrepreneurs, Farmer Producer Organisations and Self-Help Groups.

Livestock as an Engine of Economic Transformation

The economic importance of livestock has increased considerably during the last decade. According to the Economic Survey 2024–25, livestock output reached approximately ₹17.25 lakh crore in FY2023, with milk alone accounting for more than ₹11.16 lakh crore. The livestock sector contributed 5.5% of total GVA and approximately 30.23% of agriculture and allied-sector GVA in FY2023.

More recent animal-husbandry statistics reinforce this trend. The Department of Animal Husbandry and Dairying reports a 12.77% CAGR in the livestock sector at current prices during 2014–15 to 2023–24, with the sector contributing 5.5% to national GVA in 2023–24. India remains the world's largest milk producer and is also among the leading global producers of eggs and meat.

This transformation is significant because livestock production is dispersed across millions of rural households rather than being concentrated exclusively in large commercial farms.

Consequently, growth in the livestock economy has the potential to distribute economic activity across villages, generate employment close to the household and strengthen local value chains.

Contribution to Food and Nutritional Security

A developed nation requires not only sufficient food production but also access to diverse and nutritious diets. Livestock products provide high-quality protein and important micronutrients and therefore have an important role in nutritional security.

Milk remains particularly important in the Indian dietary system. According to the latest estimates, India's per-capita milk availability increased from 390 g/day in 2018–19 to 471 g/day in 2023–24. This increase reflects the continuing expansion of India's dairy sector and its contribution to national food availability.

The role of livestock in nutrition extends beyond milk. Eggs and meat provide high-quality protein and several micronutrients while poultry, goat and sheep enterprises can provide relatively accessible sources of animal-source food for rural households. Strengthening production, cold chains, processing, food safety and distribution can therefore simultaneously address nutritional requirements and create economic opportunities.

For Viksit Bharat, the objective should consequently shift from simply increasing the quantity of animal products to improving availability, affordability, quality, safety and nutritional value across the livestock-food system.

Livestock as a Source of Income and Employment

Livestock enterprises have considerable potential to generate employment at multiple stages of the value chain. Employment is created not only through animal rearing but also through breeding services, feed and fodder production, veterinary services, transportation, milk collection, processing, packaging, marketing and retail.

Dairy production is particularly relevant to smallholders because milk can generate regular cash income. Small ruminants and poultry offer additional opportunities where land availability is limited. Such enterprises can complement crop production and provide income during periods when crop-based earnings are unavailable.

The livestock sector can also contribute to rural entrepreneurship among young people. The expansion of organised value chains, digital livestock services, veterinary telemedicine, precision feeding, breeding technologies, animal identification and traceability create opportunities for technically trained rural youth.

Women are especially important participants in livestock production. Many routine activities associated with feeding, milking, animal care and household-level processing are undertaken by women. Consequently, improving women's access to technology, credit, training, producer

organisations and markets can transform livestock from a subsistence activity into a source of economic empowerment.

The Department of Animal Husbandry and Dairying explicitly identifies employment and livelihood support for women and marginalised groups among its livestock-development objectives.

Livestock and Women's Economic Empowerment

The livestock sector offers a particularly relevant pathway for inclusive rural development because livestock assets can be managed at household level and do not always require large areas of land.

Women's participation in dairy cooperatives, Self-Help Groups, Farmer Producer Organisations and livestock enterprises can improve their involvement in household economic decisions. Access to direct payment systems, digital financial services, training and organised markets can further strengthen this contribution.

For Viksit Bharat, women should therefore be considered not merely as labour providers in livestock production but as livestock entrepreneurs, producers, managers and owners of value-chain enterprises.

Livestock and Crop–Livestock Integration

The integration of livestock with crop farming represents an important pathway towards resource-efficient agriculture. Crop residues can provide feed resources whereas animal manure can return nutrients and organic matter to agricultural fields.

Such integration improves resource recycling and can reduce dependence on external inputs. Livestock also provide a means of converting materials that have limited direct human-food value into nutritionally valuable products.

Future development should therefore encourage integrated farming systems involving crops, dairy animals, small ruminants, poultry, fodder, agroforestry and appropriate waste-management technologies. Such systems can improve resource-use efficiency while diversifying household income.

Breeding and Genetic Improvement

Genetic improvement remains central to increasing livestock productivity. However, future breeding programmes must simultaneously consider productivity, fertility, disease resistance, adaptability, longevity and climate resilience.

The Rashtriya Gokul Mission (RGM) is directed towards conservation and development of indigenous bovine breeds, genetic upgradation and improvement of milk productivity. The programme includes expansion of artificial insemination, use of sex-sorted semen, high-genetic-

merit animals and implementation of the National Digital Livestock Mission. The revised RGM received an additional ₹1,000 crore in 2025, taking the total outlay for the 2021–22 to 2025–26 period to ₹3,400 crore.

The future breeding strategy should increasingly integrate genomic selection, reproductive biotechnology, accurate performance recording, disease resistance and climate adaptability. At the same time, conservation of indigenous genetic resources remains essential because these populations contain traits valuable for adaptation to India's diverse production environments.

Feed and Fodder Security

Feed and fodder availability is a fundamental determinant of livestock productivity, as animals cannot fully realize their genetic potential without adequate supplies of energy, protein, minerals, vitamins, and clean water. A Viksit Bharat-oriented livestock development strategy should therefore focus on strengthening fodder resources, improving the scientific utilization of crop residues, and expanding the production of quality silage and hay.

Balanced ration formulation and adoption of improved feeding practices can enhance animal health, productivity, and reproductive performance. Modern technological interventions, including ration balancing software, feed-quality analysis, precision supplementation, utilization of agricultural by-products, and cultivation of improved forage varieties, can significantly improve feed efficiency and reduce production costs.

Encouraging local production of quality fodder, feed supplements, and value-added feed products can further reduce dependence on external supplies while creating employment and entrepreneurship opportunities in rural areas. Such integrated approaches can strengthen livestock sustainability, farmer incomes, resource efficiency, and rural economic development.

Animal Health and Disease Control

Animal health is directly connected with livestock productivity, household income, food safety and public health. Disease outbreaks can cause mortality, production losses, reproductive failure, trade restrictions and substantial economic damage. Modern livestock development therefore requires a transition from predominantly reactive treatment towards preventive animal-health management. Regular vaccination, disease surveillance, biosecurity, early diagnosis, laboratory support, veterinary extension and systematic disease reporting are essential components.

The Department of Animal Husbandry and Dairying currently implements the Livestock Health and Disease Control Programme, alongside other sectoral programmes as part of the national livestock-development framework. Digital technologies can further improve disease surveillance and animal-health management through electronic identification, geo-tagging, digital health records and real-time reporting.

Digital Transformation of Livestock

The livestock sector is increasingly entering the digital era. The integration of animal identification, electronic databases, artificial intelligence, geographic information systems, mobile applications and digital extension can improve the accuracy and speed of livestock-service delivery.

The Bharat Pashudhan digital ecosystem under the livestock-development framework represents an important step towards creating a more integrated livestock information system. The revised RGM also incorporates the National Digital Livestock Mission. The latest Basic Animal Husbandry Statistics further demonstrate this transition: the 2025 edition reports that data for milk, meat, egg and wool production were collected electronically through the e-Livestock Integrated Sample Survey (eLISS). Such digitalisation can support evidence-based breeding, disease control, livestock insurance, productivity assessment, traceability and policy planning.

Value Addition and Modern Livestock Supply Chains

Increasing production alone does not guarantee higher returns to farmers. The major opportunity lies in improving the value captured by producers through processing, branding, quality assurance, cold chains and organised marketing. Milk can be transformed into cheese, yoghurt, fermented products, milk powder and other specialised products. Meat and poultry can be processed into hygienic, packaged and value-added products. Goat milk, indigenous dairy products, eggs, wool, hides and other livestock-derived products can also create specialised market segments.

Farmer Producer Organisations, cooperatives, dairy unions and private enterprises can connect small producers with modern markets. Improved collection infrastructure, testing facilities, refrigeration, transportation and digital marketing are essential for this transformation. The transition from production-oriented livestock farming towards value-chain-oriented livestock enterprises can increase both farm income and rural employment.

Livestock, Climate Resilience and Sustainability

Climate variability increasingly threatens livestock production through heat stress, fluctuating feed availability, water shortages, changing disease patterns, and extreme weather events. These pressures can reduce animal health, productivity, fertility, and overall farm income. Smallholder farmers are particularly vulnerable because they often have limited financial resources, infrastructure, and access to support services needed to manage sudden production shocks. Building climate-resilient livestock systems therefore requires improved breeds, better feeding and water management, disease preparedness, early-warning systems, and adaptive farming practices.

Livestock can nevertheless contribute to livelihood resilience by diversifying household income. Climate-resilient livestock systems should therefore emphasis on heat-tolerant breeds, improved housing, water security, fodder banks, nutritional management, disease preparedness and locally adapted production systems. Sustainability also requires improved manure management, biogas production, nutrient recycling, efficient feed utilisation and reduction of avoidable production losses. The objective should be to increase productivity while reducing the environmental intensity of production.

Government Programmes Supporting Livestock Transformation

The current livestock-development architecture includes several programmes addressing different components of the production and value chain. These include the Rashtriya Gokul Mission, National Livestock Mission, Livestock Health and Disease Control Programme, National Programme for Dairy Development, Animal Husbandry Infrastructure Development Fund, and programmes supporting dairy cooperatives and Farmer Producer Organisations.

The National Livestock Mission promotes entrepreneurship and breed development in poultry, sheep, goats and pigs, while the Rashtriya Gokul Mission focuses on bovine genetic improvement, indigenous breed development and reproductive technologies. These initiatives indicate a gradual transition from a narrow production-oriented approach towards a broader framework encompassing genetics, health, entrepreneurship, infrastructure, digitalisation, value addition and market access.

The Livestock Pathway to Viksit Bharat@2047

The contribution of livestock to Viksit Bharat can be understood through six interconnected pathways:

- **Economic transformation:** Higher productivity and value addition can increase the economic contribution of livestock and strengthen rural enterprises.
- **Livelihood security:** Diversified livestock enterprises can provide regular income and reduce dependence on a single agricultural activity.
- **Nutritional security:** Milk, eggs and meat can improve access to high-quality protein and essential micronutrients.
- **Employment and entrepreneurship:** Livestock value chains can create employment in production, processing, veterinary services, feed, breeding, logistics and marketing.
- **Women's empowerment:** Greater ownership, financial inclusion, skills and market access can strengthen women's participation in livestock-based enterprises.

- **Sustainable rural development:** Crop–livestock integration, nutrient recycling, climate-resilient production and digital technologies can contribute to resource-efficient agriculture.

From Vision to Transformation

The transformation envisioned under Viksit Bharat@2047 requires moving beyond isolated interventions. Livestock development must be integrated with agriculture, rural infrastructure, nutrition, skill development, entrepreneurship, digital public infrastructure, research and environmental sustainability. The central challenge is therefore not simply to increase the number of animals or the quantity of livestock products. The objective should be to increase productivity per animal, income per household, value captured by producers, resilience per enterprise and efficiency per unit of resource used.

Research institutions and veterinary universities have a critical role in this transformation. Future research should focus on genomics, reproductive technologies, precision livestock farming, animal nutrition, disease diagnostics, antimicrobial stewardship, climate resilience, animal welfare, product quality and value addition. Extension systems must translate these technologies into practical solutions suitable for smallholder farmers. Similarly, livestock professionals will increasingly require interdisciplinary skills combining veterinary science with data science, economics, entrepreneurship, food technology, environmental management and digital technologies.

Conclusion

Viksit Bharat@2047 represents a long-term transformation in which economic prosperity must reach rural households and productive opportunities must extend beyond conventional crop agriculture. Livestock is uniquely positioned within this transformation because it simultaneously contributes to food and nutritional security, household income, employment, entrepreneurship, women's participation and agricultural resilience.

Recent official statistics demonstrate that livestock has already become a major component of India's agricultural economy, accounting for 5.5% of national GVA and more than 31% of agricultural GVA in 2023–24. The continued expansion of milk, meat and egg production, together with advances in breeding, animal health, digital livestock management and value addition, provides a strong foundation for the next phase of development.

The future of Indian livestock should therefore be based on a transition from low-productivity subsistence activity to productive, technology-enabled, market-linked and climate-resilient enterprise. When smallholders are connected with better genetics, scientific nutrition, preventive healthcare, digital services, finance, infrastructure and remunerative markets, livestock can

become a powerful instrument for inclusive rural transformation. In this way, the livestock sector can contribute not only to producing more milk, meat and eggs, but to creating healthier families, stronger rural enterprises, empowered women, skilled youth and resilient villages—all of which are essential components of India's broader journey from vision to transformation and towards Viksit Bharat@2047.

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VIKSIT BHARAT@2047: BRIDGING POLICY VISION AND DEVELOPMENT OUTCOMES

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Abstract

Viksit Bharat @2047 sets out India's ambition to become a developed country by the centenary of independence, but the distance between a national vision and lived outcomes is closed by implementation rather than declaration. This chapter examines what the vision requires in economic, institutional and rural terms, and argues that the binding constraint is implementation capacity: institutions that work, participation that is real, and monitoring that measures outcomes rather than outputs. Agriculture and rural India are the test case. Drawing on official data and recent studies, the chapter shows that digital public infrastructure and farmer producer organisations have scaled quickly in numbers, that evidence on their effects on incomes, yields and resilience is still thin, and that the policy environment of prices, subsidies and land shapes what they can achieve. It closes with a seven-point roadmap and a set of outcome indicators.

Keywords: Viksit Bharat @2047, Implementation Capacity, Agricultural Transformation, Digital Public Infrastructure, Farmer Producer Organisations, Outcome Monitoring.

1. Introduction

In 2047 India will complete a hundred years of independence, and the Viksit Bharat @2047 vision commits the country to developed-nation status by then. The ambition is widely shared; its delivery is unproven. Official statements tie the vision to growth, social progress, sustainability and good governance, and the Economic Survey 2024–25 gave it an arithmetic: growth of around 8 per cent a year at constant prices, on average, for about a decade or two, with the investment rate rising to about 35 per cent of gross domestic product (GDP) from about 31 per cent (Ministry of Finance, 2025).

Arithmetic of this kind says what must be achieved, not how institutions will achieve it. India's recent record shows why the difference matters. Multidimensional poverty has fallen sharply (NITI Aayog, 2024), yet agriculture still employed about 45.8 per cent of the workforce in 2023 (Ministry of Finance, 2024) while contributing nearly one-fifth of national income (Ministry of Finance, 2026). The gap between those two shares is a productivity gap, and closing it depends

on jobs outside farming, on higher farm incomes and on public institutions that reach the people they are meant to serve.

This chapter argues that implementation capacity is the binding constraint on Viksit Bharat, and that agriculture and rural India make the constraint visible. Programmes in this sphere have scaled quickly in numbers: 10,000 farmer producer organisations (FPOs) have been registered and more than 7.63 crore digital Farmer IDs issued. What is far less clear is what they have done for incomes, yields and resilience. The chapter therefore asks of each initiative not how many, but with what effect. Section 2 defines the destination and Section 3 the starting point. Sections 4 to 7 examine agriculture, digital infrastructure, farmer collectives and the policy environment. Section 8 turns to institutions and participation, Section 9 sets out an outcome framework, Section 10 a roadmap, Section 11 limitations and research directions, and Section 12 concludes.

2. What “Developed” Means

The vision is usually described in multidimensional terms, but any serious assessment needs a reference point for income. The most common external benchmark is the World Bank’s high-income category, defined by gross national income (GNI) per capita converted by the Atlas method: more than US\$13,935 in the 2026 classification, with thresholds adjusted annually for inflation. India remains in the lower-middle-income group (World Bank, 2026). Reaching the threshold would therefore require not only sustained growth but a sustained rise in average incomes per person.

Income, however, is a threshold rather than a definition. Official statements describe a developed India as one with quality employment, capable public services, resilience to climate risk and accountable governance. This chapter accordingly reads Viksit Bharat as the attainment of high-income status together with the institutional quality that sustains it. The chapter also follows the recent emphasis on States. The theme of the 10th NITI Aayog Governing Council in May 2025, “Viksit Rajya for Viksit Bharat”, called on States to prepare long-term, inclusive vision documents with time-bound targets, using data-driven and outcome-based approaches supported by monitoring and evaluation cells (PTI, 2025). That is, in effect, an institutional definition of the task.

3. The Starting Point: Real Gains and a Structural Gap

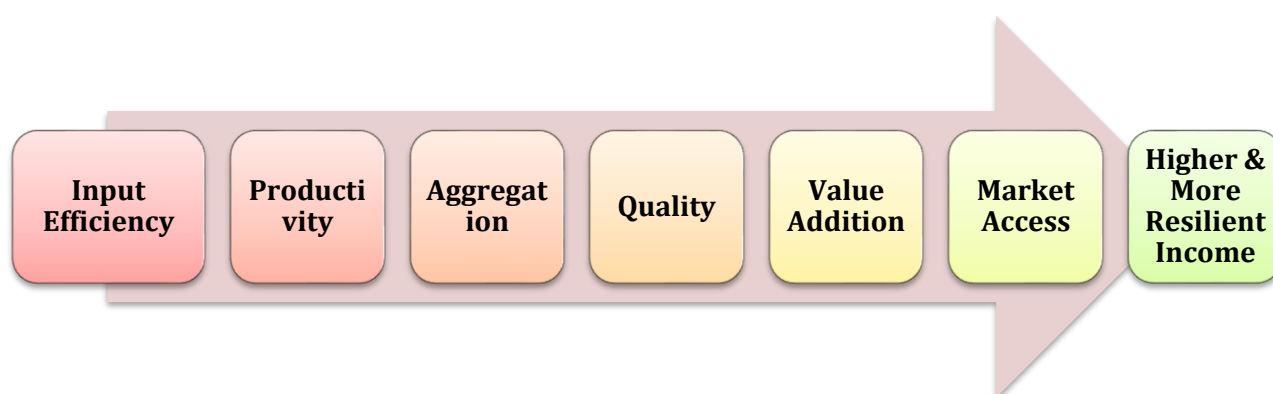
India’s gains are real. NITI Aayog estimates that the multidimensional poverty headcount ratio fell from 29.17 per cent in 2013–14 to 11.28 per cent in 2022–23, with about 24.82 crore people moving out of multidimensional poverty. The estimates for those two end-years are projections from survey rounds conducted in 2005–06, 2015–16 and 2019–21, and should be read as such

(NITI Aayog, 2024). Growth has also been strong: official estimates released in 2026 put growth in FY2025–26 at 7.7 per cent (IANS, 2026b), close to, but still below, the 8 per cent benchmark. The structural gap lies in where people work. The Economic Survey 2023–24 noted that agriculture accounted for about 45.8 per cent of the workforce in 2023, projected the share to fall to 25 per cent by 2047, and estimated that the economy must generate nearly 78.5 lakh non-farm jobs a year until 2030 (Ministry of Finance, 2024). Those numbers make the agenda concrete. Non-farm employment must expand faster than the workforce, and agriculture must become productive enough that a shrinking share of workers can earn a rising share of national income. Manufacturing, services, rural enterprise and agri-food value chains all have to grow together for that to happen.

4. Agriculture in the Transition

Agriculture is both the largest source of employment and a sector with visible strengths. The Economic Survey 2025–26 records decadal growth of about 4.5 per cent a year between 2015–16 and 2024–25, the highest of any decade compared, but the growth came mainly from livestock (7.1 per cent) and fisheries (8.8 per cent) rather than crops (3.5 per cent). It also finds that crop yields remain considerably lower than they could be, and points to fragmented landholdings, inadequate marketing and storage infrastructure and uneven access to quality seeds and credit, adding that climate change poses a significant challenge (Ministry of Finance, 2026).

Scale is the underlying problem. Nearly 86 per cent of farmers are small or marginal, with average holdings of less than 1.1 hectares (Ministry of Agriculture and Farmers Welfare, 2021). Small holdings raise the cost per farmer of extension, credit, marketing and technology, which is why the policy response has centred on two instruments: digital public infrastructure (DPI) to lower the cost of reaching farmers, and collectives to lower the cost of acting together. Sections 5 and 6 assess each in turn. The transition they are meant to support can be summarised as a chain from farm efficiency to farm income:



5. Digital Public Infrastructure for Agriculture: Promise and Evidence

The Digital Agriculture Mission, approved on 2 September 2024 with an outlay of ₹2,817 crore (including a central share of ₹1,940 crore), is built around AgriStack, the Krishi Decision Support System and soil-profile mapping. AgriStack comprises a Farmers' Registry, geo-referenced village maps and a Crop Sown Registry, all maintained by the States. Each farmer receives a Farmer ID linked to the State's land records, crops sown and benefits availed, with a target of 11 crore IDs phased as 6 crore in FY2024–25, 3 crore in FY2025–26 and 2 crore in FY2026–27 (Ministry of Agriculture and Farmers Welfare, 2024).

Delivery so far is substantial. An official statement in February 2026 reported more than 7.63 crore Farmer IDs and 23.5 crore crop plots surveyed, together with a Kisan e-Mitra chatbot that had answered more than 93 lakh queries (IANS, 2026a). Against the original phasing, which implied about 9 crore IDs by March 2026, the count was still short in February, though the financial year was not over. The same statement reported that a pilot monsoon-onset forecast sent by SMS reached 3.88 crore farmers in 13 States, and that 31 to 52 per cent of surveyed farmers adjusted sowing and land-preparation decisions (IANS, 2026a). That is the kind of outcome-oriented figure that programme reporting needs more of, although the statement does not describe how the survey was conducted.

Evidence on whether digital advisories raise yields is limited and context-specific. A randomised evaluation of a free, two-way voice advisory service among 13,675 rice farmers in five districts of Odisha found significant gains in knowledge and adoption of recommended practices, a modest increase in rice yield and harvest, and a large reduction in the likelihood of crop loss, with the effects concentrated in areas hit by weather shocks (Cole *et al.*, 2025). Two lessons follow. Advisories appear to work best when they help farmers respond to specific risks, and the evidence comes from one State and one crop. It should not be generalised to the national platform without further evaluation.

A design question also deserves attention. Because the Farmer ID is linked to State land records, a farmer's ability to be registered depends on how those records treat them. The Cabinet release states that the DPI will include cultivators and tenant farmers "as per the policy of the State Government" (Ministry of Agriculture and Farmers Welfare, 2024). Inclusion of tenants is thus a State-level policy choice, not a given. This matters more if registry status becomes a condition for benefits: the Economic Survey 2023–24 recommended using AgriStack to target fertiliser subsidies to identified farmers on the basis of land ownership and crops (Ministry of Finance, 2024). Whether tenant cultivators would be covered under such targeting is an open question that the mission's reporting should address.

6. Farmer Collectives: Scale, Sustainability and Reach

The Central Sector Scheme for Formation and Promotion of 10,000 FPOs, launched on 29 February 2020 with an outlay of ₹6,865 crore until 2027–28, offers each FPO up to ₹18 lakh towards management costs over three years, matching equity grants and credit guarantees for project loans (Ministry of Agriculture and Farmers Welfare, 2025). By 1 March 2026, 10,000 FPOs had been registered, of which 1,175 had 100 per cent women membership, with 23.55 lakh women farmers registered under the scheme (Indian Cooperative, 2026a). As of 1 January 2026, 56.32 lakh farmers had been enrolled, of whom 21.96 lakh were women (Indian Cooperative, 2026b).

These are formation numbers, and the picture on performance is less clear. Official turnover figures differ by source and reporting basis: a Rajya Sabha reply reported a combined turnover of ₹5,035.5 crore as of 30 June 2025 (Indian Cooperative, 2025), while the Agriculture Secretary cited about ₹9,000 crore for 2024–25, with some reports still pending, and noted that working capital remains a critical constraint (News Arena, 2025). Neither figure says how many FPOs are profitable or what members earn. Studies point the same way. A synthesis of 22 studies, complemented by focus groups with FPO farmers, identifies capital shortage as a main hindrance and finds that farmers regard sustainability as a “mirage” without good leadership and upskilling (Suresh and Sreejith, 2024). Another study reports that 45 per cent of farmer producer companies older than five years had become dormant (Pabba and Ponnusamy, 2024).

Reach is the second question. On the Agriculture Secretary’s estimate of 12 to 13 crore farmers (News Arena, 2025), the 56.32 lakh enrolled farmers represent roughly 4 to 5 per cent of the total (author’s calculation). FPOs may therefore be valuable to their members without being a mass instrument. This does not weaken the case for collectives, but it argues for judging the scheme by member incomes and business viability, and for being modest about how much of the smallholder problem it can solve. The Agriculture Secretary’s own statement that the scheme will need to be extended for 2026–31 and that FPOs “have to be handheld” (News Arena, 2025) points to the same conclusion.

7. The Policy Environment Around Farm Institutions

FPOs and digital services operate inside a policy environment that largely determines farm incomes. Three parts of it matter most here.

- i. Price support and procurement.** Government procurement is heavily concentrated on wheat and rice, with limited procurement of other crops (Gupta *et al.*, 2021). In 2019–20, three States accounted for 85 per cent of wheat procurement while producing 46 per cent of the country’s wheat, and six States accounted for about three-quarters of rice

procurement while producing 40 per cent of the rice (PRS Legislative Research, n.d.). The picture is not static. Procurement has spread to Madhya Pradesh, Chhattisgarh and Odisha, and the majority of farmers who sell to procurement agencies are small and marginal, although larger farmers are over-represented relative to their share of marketed surplus (Gupta *et al.*, 2021). The implication for the value-chain agenda is that a diversification signal must reach farmers through prices as well as through advisories.

- ii. **Input subsidies.** The Economic Survey 2023–24 noted that the nitrogen–phosphorus–potassium (NPK) consumption ratio moved from 4:3.2:1 in 2009–10 to 7:2.8:1 in 2019–20, reflecting heavy use of subsidised urea and consequent soil-quality concerns (Ministry of Finance, 2024). Subsidy design therefore pulls against the resource-efficiency and climate-resilience goals that the Viksit Bharat agenda also sets. The Survey’s proposal to target subsidies through AgriStack shows how DPI and subsidy reform are linked.
- iii. **Land and markets.** Fragmented holdings (Section 4) limit scale and mechanisation, and tenancy arrangements, as noted in Section 5, affect who is visible to the state. Marketing is regulated largely through State-level laws, and attempts at national-level reform in 2020 proved contentious (Gupta *et al.*, 2021). FPOs that depend on collective marketing therefore depend on regulatory space that the Centre and States must create jointly.
- iv. These constraints do not weaken the case for collectives and digital services, but they qualify it. Aggregation raises incomes only if farmers face prices and incentives that reward quality and diversification, and digital targeting improves outcomes only if intended beneficiaries are on the registry.

8. Institutions, States and Participation

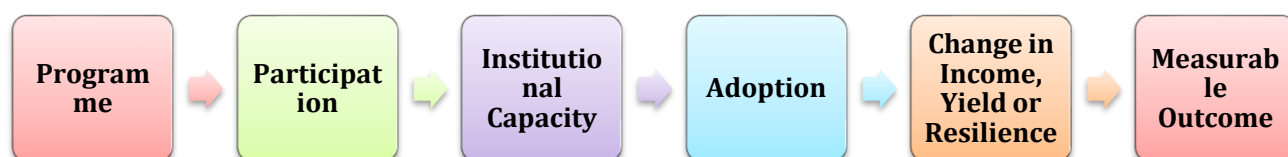
If implementation is the binding constraint, institutions are the unit of analysis. Three features stand out. First, States are the main delivery agents. AgriStack registries are created and maintained by State governments, tenancy recognition depends on State policy, and procurement and marketing rules vary by State. The “Viksit Rajya” framing (PTI, 2025) reflects this reality, and it implies that national targets need State-specific pathways rather than uniform prescriptions.

Second, institutional capacity determines whether instruments deliver. The evidence in Sections 5 and 6 points to the same pattern: platforms and organisations are created quickly, but their effect depends on assisted access, professional management, working capital and member participation. Third, participation is a source of information as well as legitimacy. Farmer collectives, self-help groups and local governments can reveal who is excluded from registries,

which FPOs are failing and why, and whether advisories are useful, but only if feedback is built into programme design. The women-only FPOs and the 23.55 lakh registered women farmers mentioned earlier show formal participation at scale; whether women influence decisions within these organisations is a different question that current data do not answer. A State-level outcome dashboard would make these points operational: for each State, the share of farmers registered (by tenancy status and farm size), the share of FPOs that are active and profitable, and the change in farm income and crop loss over time. Such a dashboard would give States the evidence base for the time-bound vision documents that the Governing Council asked them to prepare (PTI, 2025).

9. From Vision to Outcomes: An Outcome Framework

The argument so far implies a simple test for every initiative: does the chain from programme to outcome hold at each link?



Most current reporting stops at the first link. Table 1 contrasts the output figures now reported with the outcome measures needed to judge transformation.

Table 1: Outputs now reported and outcomes still to be measured

Initiative	Output Currently Reported	Outcome Indicator to Add
Digital Agriculture Mission	7.63 crore Farmer IDs; 23.5 crore crop plots surveyed	Share of tenants and small farmers registered; time taken to receive benefits; effect on yield, income and crop loss
Digital advisories	93 lakh chatbot queries answered	Adoption of practices; yield and crop-loss effects from independent evaluation
FPO scheme	10,000 FPOs registered; 56.32 lakh farmers enrolled	Share of FPOs active and profitable; member income; share of farm households reached
Poverty reduction	Multidimensional poverty headcount of 11.28 per cent (projected, 2022–23)	Quality of non-farm employment; real earnings; regional gaps

Source: Author's synthesis of figures cited in Sections 3 to 6.

9.1 Why Outputs Dominate, and What Would Change It

Outputs dominate reporting for understandable reasons. They are available immediately, easy to attribute to a programme and cheap to collect, whereas outcomes lag, depend on weather and prices, and require comparison groups. Three changes would shift the balance. First, evaluation should be planned when a programme is designed rather than after it has scaled: the Odisha study could measure effects because the rollout of the service was randomised (Cole *et al.*, 2025), and a staggered district-by-district rollout of other digital services would offer similar opportunities. Second, the registries themselves can supply data. AgriStack links farmers to land, crops and benefits, so with appropriate privacy safeguards it could allow researchers to compare outcomes for registered and unregistered farmers, and for tenants and owner-cultivators. Third, reporting standards should be set: figures such as FPO turnover should state whether they are annual or cumulative and which organisations they cover, so that sources can be reconciled (Section 6).

10. Roadmap

Seven priorities follow from the analysis. Each is tied to an indicator in Table 2 so that progress can be judged by outcomes.

10.1 Productivity First

Crop productivity is the weakest link in agricultural growth (Section 4). The priorities are seed, soil health, irrigation efficiency, mechanisation and post-harvest management, alongside continued support for livestock and fisheries, where growth has been strongest. Because holdings are small, technologies must be priced and delivered for smallholders, or productivity gains will accrue mainly to larger farms.

10.2 Build Human Capabilities

Non-farm employment on the scale described in Section 3 requires skills, and rural youth and women need pathways from training to enterprise and credit. Skills programmes should be judged by placement, earnings and enterprise survival rather than by the number of people trained.

10.3 Make Institutions Viable

FPOs and local bodies should be supported according to business performance, member participation and value addition rather than formation. Given differences in capacity across States, targets and support should be differentiated by State and district, and any extension of the FPO scheme should be tied to published performance data, including how many FPOs are active and profitable.

10.4 Use Digital Infrastructure as a Public Foundation

Digital services should be designed for assisted access and local-language use, governed by clear privacy and data-use rules, and accompanied by coverage data disaggregated by farm size and tenancy status, so that exclusion can be detected and corrected.

10.5 Shift from Production to Value Creation

Retaining more value in rural areas requires aggregation, processing, quality certification and logistics. These measures work only if farmers face prices that reward diversification, so they should be sequenced with reform of procurement, subsidy design and tenancy recognition

10.6 Mainstream Climate Resilience

The evidence in Section 5 suggests that advisory services deliver most when weather shocks occur. Resilience can therefore be built into existing instruments by screening major agricultural and infrastructure investments for climate and water risk, and by evaluating advisory services by the losses they avert.

10.7 Measure Outcomes

Adopt the indicators in Table 2, report them by State, and commission independent evaluations of flagship schemes before further scale-up.

Table 2: Roadmap priorities and outcome indicators

Priority	Core Action	Outcome Indicator
Productivity first	Seed, soil, water, mechanisation, diversification	Crop yields; farm income per household
Human capabilities	Skills, health, pathways to enterprise	Quality non-farm employment; women's participation
Viable institutions	Performance-based support; State differentiation	Share of FPOs active and profitable
DPI as public foundation	Assisted access; privacy rules; coverage data	Coverage of tenants and small farmers; service utilisation
Value creation	Aggregation, processing, price signals	Share of value retained by producers
Climate resilience	Risk screening of investments	Yield and income variability; water-use efficiency
Outcome measurement	Independent evaluation; outcome dashboards	Evaluations published; indicators reported by State

Source: Author's synthesis.

11. Limitations and Research Directions

This chapter relies on published official statements, press reports of parliamentary replies and a small number of studies, and it has not analysed primary data. Several of its figures are therefore second-hand and differ by source, and it does not assess State-level variation in detail. Four research directions follow. First, panel studies of FPO finances that separate active from dormant organisations and track member incomes. Second, coverage analysis of AgriStack by tenancy status, farm size and gender across States. Third, independent multi-State evaluations of digital advisories, extending the Odisha evidence to other crops and regions. Fourth, comparisons of how State procurement and marketing arrangements interact with FPO performance. Each would replace inference with evidence on questions the chapter has identified as decisive.

Conclusion

Viksit Bharat @2047 is best judged as an implementation challenge. India has real strengths, including a strong growth record, rapid poverty reduction and capable digital infrastructure, but reaching high-income status with quality jobs and resilient rural livelihoods depends on institutions that deliver. Agriculture shows both sides. Digital public infrastructure and farmer collectives have scaled quickly, evidence from a large randomised trial shows that well-designed advisories can help, and policy debate has begun to recognise the role of States. Yet the effects of these initiatives on incomes remain largely unmeasured, tenant and small farmers may be under-covered, and procurement, subsidy and land policies continue to shape what is possible.

The evidence base has limits. Many of the initiatives discussed are recent, official figures are output statistics that differ by source, and several studies cover single States or small samples. Those limits are themselves part of the argument for outcome-oriented monitoring and independent evaluation. The credibility of Viksit Bharat @2047 will rest on the experience of farmers, workers and rural entrepreneurs, not on the size of the numbers reported about programmes.

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FROM CUSTODIANS TO CURATORS: LIBRARIES AS DATA-DRIVEN KNOWLEDGE INFRASTRUCTURES

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Abstract

Libraries are undergoing a structural transformation as prominent as any in their long institutional history, shifting from custodians of physical collections toward architects of data-driven knowledge infrastructure. This chapter synthesizes recent empirical and standards-based literature on artificial intelligence in library services, digital library architecture, open science and FAIR data stewardship, digital preservation, and library-based innovation spaces such as maker spaces. Drawing on systematic surveys of library AI adoption, international preservation standards, and recent scholarship on digital library infrastructure, the chapter argues that the library's enduring value lies not in the format of what it holds but, in its capacity, to make knowledge findable, trustworthy and reusable across time. The chapter reviews evidence on AI-assisted cataloging and discovery, examines the standards architecture underpinning trustworthy digital repositories, considers the ethical stakes of patron data analytics, and proposes a synthesis framework for institutions redesigning collections, services, space, governance, and workforce for a data-intensive knowledge environment. The chapter concludes with recommendations for library leaders, policymakers, LIS educators, and technology developers.

Keywords: Digital Libraries, Library Innovation, Artificial Intelligence in Libraries, FAIR Data, Digital Preservation, Research Data Management, Makerspaces, Knowledge Infrastructure, Information Governance.

1. Introduction

For most of their history, libraries have been defined, in the public imagination and often in their own founding charters, by the physical collections they hold. Yet the professional literature of library and information science has long recognized that a library's core function is not the book

as an object but the organized, trustworthy access to knowledge that the book, and now the dataset, the repository record, and the digital object, are made to carry (Buckland, 1992). The chapter's premise is that this underlying function — organizing knowledge so that it can be found, trusted, and reused has become dramatically more complex and more consequential as libraries take on responsibility for research data, born-digital heritage, algorithmic discovery systems, and community innovation spaces alongside their traditional print collections.

This transformation is documented across several converging bodies of evidence. Surveys of library professionals show artificial intelligence adoption accelerating year over year, standards bodies have matured a rigorous architecture for trustworthy digital preservation, and research funders increasingly require that library-managed repositories make data Findable, Accessible, Interoperable, and Reusable. At the same time, libraries have become sites of considerable innovation beyond information retrieval, hosting makerspaces, data-literacy programs, and immersive-technology learning stations that extend the library's mission from access to creation. This chapter treats these developments not as separate trends but as expressions of a single underlying shift: the library reconceived as a data-driven knowledge infrastructure rather than a building organized around a collection of books.

The chapter proceeds as follows. Section 2 sets out the conceptual foundations connecting classical library and information science theory to the current data-intensive environment. Section 3 reviews the evidence on artificial intelligence and machine learning in library services. Section 4 examines digital library architecture and information infrastructure in depth, drawing substantially on recent systems-oriented scholarship. Section 5 addresses open science, FAIR data, and research data management services. Section 6 turns to digital preservation and long-term stewardship standards. Section 7 discusses libraries as innovation hubs through makerspaces and community data literacy. Section 8 addresses the ethics and governance of library and patron data. Section 9 presents illustrative institutional snapshots. Section 10 proposes a synthesis framework and notes limitations in the current evidence base, and Section 11 offers recommendations for stakeholders before the chapter concludes.

Methodologically, the chapter draws on a narrative synthesis of recent professional surveys, systems-oriented scholarship on digital library infrastructure, international preservation and metadata standards documentation, and empirical studies of library data ethics published between 2016 and 2026. Where quantitative findings are reported — adoption percentages, efficiency gains, or survey results they are drawn from named, published sources rather than generated for illustrative purposes, so that readers and fellow contributors to this volume can trace claims back to their originating studies. The chapter is deliberately cross-sectoral in scope,

drawing examples from academic, public, and national or heritage library contexts, reflecting the reality that the underlying technologies and standards discussed increasingly move across these institutional boundaries rather than remaining confined to a single library type.

2. Theoretical and Conceptual Foundations

The idea that a library's value lies in organized access rather than physical holdings has deep roots in library science. S. R. Ranganathan's five laws of library science, first articulated in 1931, framed the library as a growing organism whose purpose is to save the time of the reader by connecting every reader to their book and every book to its reader — a functional definition of librarianship centered on connection and access rather than on the object itself (Ranganathan, 1931). Michael Buckland's influential critique of library service design extended this reasoning explicitly into the digital era, arguing that as information increasingly exists independently of any physical carrier, library services should be redesigned around the informative function they perform rather than around the format of the materials that happen to carry it (Buckland, 1992).

R. David Lankes advanced this line of thinking further with the argument, developed in the *Atlas of New Librarianship*, that the mission of librarians is to improve society through facilitating knowledge creation in their communities a formulation that explicitly locates the library's value in facilitation and community knowledge-building rather than in the maintenance of a collection (Lankes, 2011). Read together, these theoretical strands anticipate much of what this chapter documents empirically: as knowledge creation increasingly happens through data, algorithms, and collaborative digital platforms, a library faithful to its own founding logic should extend its infrastructure and expertise into exactly those domains, rather than treating them as peripheral to its print-centered mission.

This theoretical continuity matters because it reframes the developments discussed in this chapter AI-assisted discovery, FAIR data repositories, digital preservation standards, makerspaces — not as a departure from the library's traditional identity but as its logical extension under changed technological conditions. As Mishra, Mishra, and Agarwal (2026) argue in their treatment of knowledge organization and information retrieval in the digital age, the historical progression from card catalogs to online public access catalogs to AI-assisted discovery layers represents a continuous effort to reduce the friction between a knowledge seeker and the information they need, with each technological generation attempting to solve the same underlying problem find ability under progressively more complex conditions of scale and format diversity. This framing, more than any single technology reviewed below, is the conceptual thread running through the remainder of the chapter.

It is worth noting that this reframing is not merely rhetorical. Debates within library and information science about disintermediation the concern that search engines and AI assistants might render professional information intermediation unnecessary have recurred with each new wave of information technology, from the online public access catalog through the commercial web search engine to the current generation of generative AI tools. The evidence reviewed in Sections 3 through 8 of this chapter suggests a more nuanced pattern than either full disintermediation or full continuity: routine, well-structured information retrieval tasks are increasingly handled by automated systems, while the tasks that most depend on professional judgment collection development, complex reference consultation, data curation, and ethical oversight of data practices remain firmly within the library's professional domain and, if anything, grow in relative importance as the volume and complexity of managed information increases.

3. Artificial Intelligence and the Reinvention of Library Services

Adoption of artificial intelligence across library services has accelerated markedly in recent years. A global survey of library professionals across 109 countries found that 67 percent of libraries were exploring or implementing AI tools in 2025, up from 63 percent in 2024, with libraries on average pursuing a broader range of AI objectives an average of four objectives per institution in 2025 compared with three in 2024 as they gained experience with the technology (Liblime, 2025). Figure 1 illustrates this year-over-year growth. The same survey found that budget constraints had become the leading concern for AI adoption, cited by 62 percent of respondents and up from 56 percent the previous year, while privacy and security concerns remained the dominant issue specifically for public libraries, cited by 65 percent of respondents in both years.

A parallel body of research documents the specific functions within library operations that AI is reshaping. Reviews of Library 4.0 developments report that AI-powered automated cataloging and classification systems have reduced processing time by roughly 45 percent in adopting institutions, and that recommendation engines built on reading and citation history are increasingly standard in discovery layers (Library 4.0 review, 2025). The same body of research documents that 73 percent of academic libraries surveyed were actively implementing AI technologies as of the 2020-2025 study period, alongside a 17 percent year-over-year increase in global digital library checkouts, which exceeded 739 million in 2024, indicating that AI-enabled discovery is occurring against a backdrop of substantially rising digital engagement rather than in isolation from it.

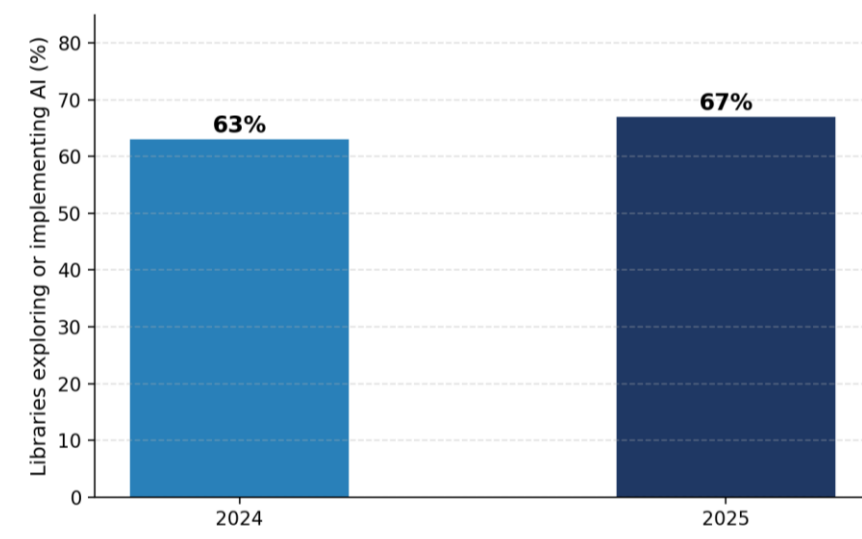


Figure 1: Percentage of surveyed libraries exploring or implementing AI tools, 2024-2025.

Source: Liblime (2025), global library AI survey across 109 countries

Reviews framing this shift within the broader Industry 4.0 paradigm describe an emerging 'smart library ecosystem' in which Internet of Things sensors and mobile applications allow patrons to locate materials, reserve study space, and access digital collections remotely, while AI-driven virtual assistants provide real-time, always-available support for routine queries (Innovative Technologies in Libraries under Industry 4.0, 2025). Crucially, adoption is not uniform across library functions or staff roles: the same survey evidence shows that librarians working in collection management are comparatively more pessimistic about AI's likely benefits and more concerned about job displacement than staff in other roles, a pattern consistent with the intuition that AI's effect on any given professional function depends on how automatable that specific function is, rather than on a single verdict about the profession as a whole (Liblime, 2025). Table 1 summarizes the principal AI and data tools reshaping core library functions alongside their reported effects.

Reviews of AI adoption in libraries emphasize that its benefits are not automatic but depend on several critical conditions. Successful implementation of AI-assisted cataloging and information discovery requires high-quality and consistent metadata, continuous staff training, adequate technological infrastructure, and strong institutional support. AI tools should be viewed primarily as decision-support systems that complement professional expertise rather than replace human judgment. Librarians remain essential for evaluating accuracy, relevance, ethical considerations, and contextual appropriateness. This human-centered approach is particularly important in collection development and library analytics, where decisions may significantly influence resources, services, user experiences, and institutional priorities discussed further in Section 8 (Innovative Technologies in Libraries under Industry 4.0, 2025; Liblime, 2025).

Table 1: AI and Data Tools Mapped to Core Library Functions

Library Function	Representative AI/Data Tools	Reported Effect
Cataloging and metadata creation	AI-assisted automated cataloging and classification systems	Cataloging processing time reduced by roughly 45% in reporting institutions
Discovery and search	Semantic search, natural-language discovery layers, recommendation engines	Personalized recommendations based on reading and citation history; improved relevance ranking
Reference and user support	AI chatbots and virtual reference assistants	Real-time, round-the-clock triage of routine queries, freeing staff for complex reference work
Collection development and analytics	Usage-pattern analytics; predictive acquisition models	Data-informed acquisition decisions; identified as an area of significant ethical sensitivity
Repository and archival infrastructure	Institutional repositories; OAIS-compliant preservation systems; persistent identifiers	Long-term findability and reusability of digital collections under standards-based governance
Physical-digital hybrid services	IoT sensors, RFID, VR/AR learning stations, makerspace fabrication tools	Remote resource location and reservation; VR/AR instruction associated with high positive learning-outcome rates

4. Digital Libraries and the Infrastructure of Knowledge

If Section 3 examined the services layer of library transformation, this section addresses the deeper architectural layer beneath it: the systems, standards, and organizational commitments that allow digital collections to remain findable and usable over time. Mishra, Mishra, and Agarwal (2026), in a systems-oriented treatment of this subject, argue that digital libraries and their underlying information infrastructure constitute the technical and organizational foundation of contemporary knowledge institutions, and that this infrastructure should be evaluated across several interacting layers: core repository architecture, standards-based interoperability, metadata frameworks, and preservation and trust models. This layered framing is useful precisely because it resists treating 'digitization' as a single, completed event; a digitized collection that lacks standards-based metadata, interoperable access protocols, or a credible preservation commitment has not actually achieved the durability that print collections achieved almost by default through physical permanence.

A companion analysis by the same authors extends this argument to the question of stewardship specifically, examining how repository and library-services platforms, metadata frameworks, and trust models interact to determine whether a digital library can fulfill its custodial function over decades rather than years (Mishra, Mishra, & Agarwal, 2026, *The Infrastructure of Knowledge*). This distinction between short-term digital access and long-term digital stewardship is a recurring theme in the professional literature on digital libraries and is addressed in greater depth in Section 6 of this chapter, which examines the specific preservation standards that operationalize it.

Interoperability, in particular, deserves emphasis because it is frequently underestimated relative to its practical importance. A digital library that cannot exchange records, harvest metadata, or expose its collections through standard protocols effectively becomes an information silo, however large its holdings, because it cannot be discovered by the search systems, aggregators, and cross-institutional platforms that increasingly mediate how researchers and the public find information. The systems view of digital libraries developed by Mishra and colleagues treats interoperability not as a technical afterthought but as a first-order design requirement, on the same footing as the acquisition and cataloging decisions that have traditionally received more professional attention (Mishra, Mishra, & Agarwal, 2025, *Digital Libraries and Information Infrastructure*). This argument connects directly to the FAIR data principles discussed in Section 5, which formalize interoperability and reusability as explicit, assessable properties of a well-designed repository rather than incidental features.

A further architectural consideration, increasingly salient as AI tools are integrated into cataloging workflows, concerns the provenance of machine-generated metadata itself. When an AI system automatically generates subject headings, abstracts, or classification codes for a digital object, that generated metadata becomes part of the object's permanent descriptive record, yet it may embed errors or biases from the underlying model that are considerably harder to detect than errors in traditionally hand-cataloged records, precisely because automated systems can generate plausible-sounding but incorrect metadata at scale and with apparent confidence. The systems perspective advanced by Mishra and colleagues implies that repository architecture should therefore include explicit provenance tracking for AI-generated versus human-generated metadata fields, allowing future users and auditors to distinguish the two and apply appropriate scrutiny — a design requirement that did not exist in earlier generations of digital library architecture and that most current systems do not yet implement as a standard feature (Mishra, Mishra, & Agarwal, 2026, *The Infrastructure of Knowledge*).

5. Open Science, FAIR Data, and Research Data Management

Academic and research libraries have become central actors in the open science movement, which encompasses open access publishing, open data, and adherence to the FAIR principles — that data and the systems that manage them should be Findable, Accessible, Interoperable, and Reusable by both humans and machines (Wilkinson *et al.*, 2016). The FAIR principles do not require that all data be openly available to everyone; rather, they establish that data and rich descriptive metadata should be discoverable and usable under clearly stated conditions, an important distinction often summarized as making data 'as open as possible, as closed as necessary' (OpenAIRE, 2026).

Research libraries have adopted the FAIR principles as an organizing framework for research data management services, including the assignment of persistent identifiers such as DOIs, the use of open metadata licensing, and the provision of machine-readable interfaces for harvesting and indexing repository content (LIBER, 2024). Guidance developed for research libraries under this framework recommends specific, actionable practices: ensuring repositories issue persistent identifiers, making interfaces accessible to both human users and automated harvesting systems, and sharing metadata under open licenses such as Creative Commons, so that the discoverability benefits of FAIR compliance extend beyond a single institution's own search interface (LIBER, 2024).

The stakes of this work extend well beyond convenience. Reviews of the broader open science movement argue that openly accessible, FAIR-compliant research data are a precondition for reproducible science and for evidence-informed policymaking, since research claims that cannot be independently checked against the underlying data provide a weaker basis for both scientific progress and public decision-making (Umbach, 2024). For libraries specifically, this has translated into an expanding professional role: research data management has moved from a specialized service offered by a handful of well-resourced research libraries to an increasingly standard expectation across the academic library sector, driven substantially by funder mandates such as those of the U.S. National Institutes of Health, which now require formal data management and sharing plans for funded research (Science Editor, 2024).

6. Digital Preservation and Long-Term Stewardship

Digital preservation addresses a problem that print collections, for all their vulnerabilities to fire, flood, and decay, did not face in the same acute form: the rapid obsolescence of file formats, storage media, and the software required to render digital objects usable. The foundational architecture for addressing this problem is the Open Archival Information System (OAIS) reference model, formalized as ISO 14721, which defines the functional entities and information

flows a repository must implement to accept, manage, and disseminate digital content reliably over the long term (Baucom, 2019). Building on OAIS, the Trustworthy Repositories Audit and Certification framework, subsequently formalized as ISO 16363, provides an auditable standard that allows a repository's claim to trustworthiness to be independently verified across organizational, technical, and financial dimensions, rather than taken on faith (OCLC/RLG, 2002; Baucom, 2019).

Table 2: Standards and Governance Frameworks for Digital Knowledge Stewardship

Standard / Framework	Domain	Core Function
OAIS Reference Model (ISO 14721)	Digital preservation architecture	Defines the functional entities and information flows required for a repository to preserve digital objects over the long term
TRAC / ISO 16363	Repository certification	Provides an auditable standard for certifying a repository as trustworthy across organizational, technical, and financial dimensions
PREMIS / METS	Preservation and structural metadata	Standardizes the technical and provenance metadata needed to manage and exchange digital objects across systems
FAIR Principles	Research data management	Establishes that data and metadata should be Findable, Accessible, Interoperable, and Reusable by both humans and machines
LOCKSS / CLOCKSS	Distributed preservation networks	Uses peer-to-peer replication across cooperating libraries to guard against loss of licensed and open-access scholarly content
ALA Code of Ethics / Library Privacy Principles	Patron data governance	Establishes confidentiality of patron records and informed-consent expectations for data collected through library systems

Complementing these architectural and audit standards, metadata frameworks such as PREMIS (Preservation Metadata: Implementation Strategies) and METS (Metadata Encoding and Transmission Standard) provide the technical vocabulary needed to document a digital object's provenance, technical characteristics, and preservation actions over time, and to exchange that documentation between repositories that may use different underlying systems (Library of Congress, cited in Baucom, 2019). At the network level, distributed preservation systems such as

LOCKSS and its dark-archive counterpart CLOCKSS use peer-to-peer replication across cooperating libraries to guard against the loss of both open-access and subscription-licensed scholarly content, operating on the principle that a preservation strategy relying on a single copy in a single location is inherently fragile, however well-resourced that single location may be (NASIG, 2024; CLOCKSS, 2025). Table 2 summarizes these standards and frameworks alongside their core functions.

Guidance developed specifically for libraries building preservation strategies emphasizes that these standards should be treated as a coherent system rather than adopted piecemeal: a library should set explicit preservation goals, prioritize content by value and risk, assign clear staff roles and accountability, and select file formats and metadata practices with long-term reuse in mind from the point of content creation rather than retrofitting preservation considerations after the fact (CLOCKSS, 2025). This proactive orientation echoes the systems perspective on digital library infrastructure discussed in Section 4: preservation is most effective when it is designed into a repository's architecture from the outset, not layered on as a remediation exercise once obsolescence has already begun to erode a collection's usability.

7. Libraries as Innovation Hubs: Makerspaces and Data Literacy

Beyond information infrastructure, libraries have become physical and programmatic sites of innovation in their own right, most visibly through the maker movement. Library makerspaces variously called maker studios, fabrication labs, or hackerspaces provide patrons with hands-on access to tools such as 3D printers, laser cutters, and electronics kits that most individuals or even small organizations could not otherwise justify purchasing for occasional use, with the library's role as a shared-access institution making it a natural host for this kind of resource pooling (American Library Association, n.d.). For public libraries, makerspaces function primarily as community-engagement infrastructure, bringing together patrons of varied backgrounds around shared projects; for academic libraries, they more often serve as extensions of coursework and research, providing students and faculty a sanctioned space for hands-on prototyping (American Libraries Magazine, 2013).

Research on the social function of library makerspaces argues that they can retain and reinvigorate core professional values of librarianship knowledge creation, equitable access, and support for lifelong learning while extending those values into domains of physical creation rather than only information consumption (Koh, Abbas, & Willett, 2018). Case studies of academic library makerspaces document collaborations that extend well beyond STEM fields, including partnerships between library fabrication labs and campus cultural centers to produce community-facing creative projects, illustrating that the innovation function of a modern library

need not be narrowly technical (PressReader Business, 2026). A 2025 survey of academic makerspace managers identified sustainability practices and expanded community collaboration, including hackathons and cross-departmental group projects, as the leading trends shaping the next generation of library makerspace design (Journal of Creative Library Practice, 2025).

Immersive technologies extend this innovation function into instructional space as well. Reviews of virtual and augmented reality applications in library education report that 92 percent of empirical studies found positive learning outcomes associated with VR/AR-based instruction, a figure reflected in Figure 2 alongside other reported efficiency and engagement gains discussed elsewhere in this chapter (Library 4.0 review, 2025). Taken together, the evidence in this section supports treating the library's innovation function as continuous with, rather than separate from, its information-infrastructure function: both are expressions of the same underlying mission articulated in Section 2 facilitating knowledge creation in the communities libraries serve, whether that knowledge takes the form of a dataset, a 3D-printed prototype, or an immersive learning experience.

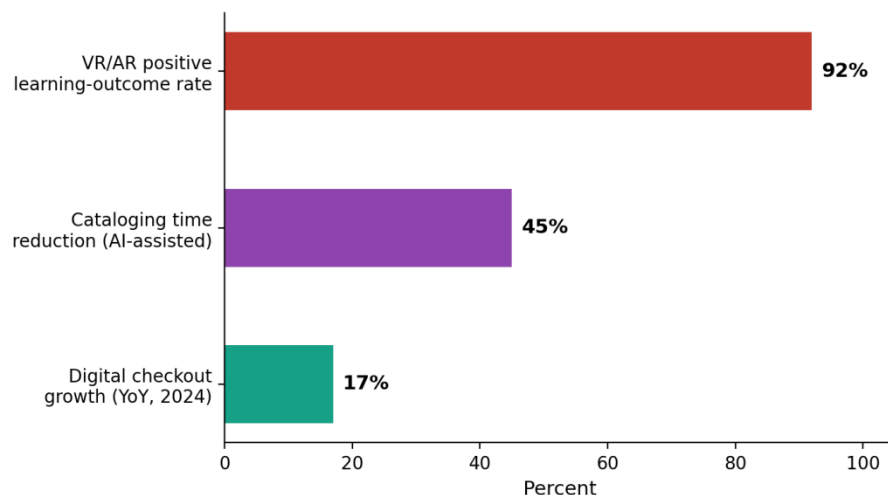


Figure 2: Reported efficiency and engagement gains from library digital-transformation initiatives: digital checkout growth, AI-assisted cataloging time reduction, and VR/AR positive learning-outcome rate

Data literacy programming deserves particular emphasis within this innovation function, because it addresses a capability gap that becomes more consequential as more of civic, academic, and economic life is mediated by data and algorithmic systems. Public and academic libraries have increasingly positioned themselves as venues for teaching patrons to interpret datasets, evaluate the reliability of AI-generated content, and understand how their own data is collected and used by the platforms they interact with daily a natural extension of the information-literacy instruction libraries have offered for decades, adapted to a data-intensive information

environment. This positions the library not merely as a beneficiary of data-driven innovation but as an active participant in building the public's capacity to navigate it critically, a role with few comparably trusted and non-commercial institutional alternatives.

8. Ethics, Privacy, and Governance of Library Data

The same data capabilities that enable AI-assisted discovery, collection analytics, and personalized recommendation also generate significant ethical exposure, because they typically depend on collecting and analyzing detailed records of what patrons search for, borrow, and read. Library professional ethics have long treated this kind of behavioral data as especially sensitive; the American Library Association's Intellectual Freedom Committee frames patron privacy as the right to open inquiry without having the subject of one's interest examined or scrutinized by others, a formulation that predates the current data-analytics era but applies to it directly (cited in Library Publishing Coalition, 2024).

Recent research suggests that library practice has not always lived up to this stated ethical commitment. A 2024 study of library learning analytics research using student library-behavior data to assess contributions to student success found that much of this published research failed to document adherence to human-subjects research ethics, library-specific confidentiality norms, or student data-privacy expectations, and that very few of the reviewed projects produced direct benefits to the libraries whose patrons' data had been used (Salo, 2024). The study's author called explicitly for ethics reforms at every stage of the research and publication pipeline, arguing that gaps in editorial review and upstream ethics guidance had allowed this pattern to persist largely unchecked (Salo, 2024). This finding is a useful corrective to any assumption that library data analytics are inherently benign simply because they occur within an institution historically associated with intellectual freedom; the ethical commitment has to be actively operationalized in each new data practice, not assumed to transfer automatically from the profession's traditional values.

Interviews with library information-technology professionals responsible for implementing analytics systems echo this concern from a practitioner perspective, with respondents emphasizing the importance of anonymizing any data gathered for business or service-improvement purposes, developing clear patron disclosure statements explaining what data is collected and why, and investing in both patron and staff education about privacy protections (Chin *et al.*, cited in Journal of Intellectual Freedom & Privacy). Complicating this picture further, libraries increasingly rely on third-party vendors for discovery, authentication, and analytics services, which introduces a governance challenge that individual library privacy policies cannot fully resolve on their own: vendor data practices, and the terms under which

patron data is shared with publishers and platform providers, now sit alongside internal library policy as a determinant of how well patron privacy is actually protected in practice (American Libraries Magazine, 2024).

These findings collectively suggest that library data governance requires deliberate, ongoing institutional attention rather than a one-time policy statement. Practical toolkits developed for public libraries recommend mapping the full data lifecycle collection, storage, access, reporting, retention, and deletion for every system that touches patron data, explicitly to surface the points at which re-identification risk or scope creep in data use are most likely to occur (Public Library Privacy Project, cited in library privacy toolkit literature). Table 3 summarizes the opportunities and corresponding risks discussed across Sections 3 through 8 of this chapter.

Table 3: Opportunities and Challenges of Data-Driven Library Transformation

Opportunities	Challenges and Risks
Scalable, always-available discovery and reference support through AI assistants	Patron behavioral data collected for analytics or vendor authentication raises confidentiality risks
Standards-based digital preservation extends the effective lifespan of at-risk digital content	Format obsolescence, vendor lock-in, and funding instability threaten long-term digital stewardship
FAIR-aligned repositories increase the discoverability and reuse of research outputs	Achieving genuine interoperability requires sustained investment in metadata quality and staff training
Makerspaces and data-literacy programming position libraries as community innovation hubs	Equipment, staffing, and space costs can be difficult to sustain, especially in under-resourced libraries
AI-assisted cataloging and collection analytics reduce routine workload and support evidence-based decisions	Much published library-analytics research has been found to fall short of data-ethics best practice
Immersive (VR/AR) instruction reports strong positive learning-outcome rates in early studies	Collection-management staff report comparatively higher pessimism about AI's effect on their roles

It is also worth noting that vendor dependency compounds these governance challenges in ways specific to the contemporary library technology market. Discovery layers, authentication systems, and analytics platforms are increasingly supplied by a small number of commercial

vendors serving many libraries simultaneously, which means that a single vendor's data-handling practices can affect patron privacy across a large number of institutions at once, and that any individual library's ability to negotiate stronger privacy protections is constrained by its relative bargaining power against a much larger commercial counterpart. Panel discussions among library professionals on this topic have raised the question of whether, given that most patrons have already accepted extensive data collection by other commercial platforms in their daily lives, meaningful protection of library-specific data is still achievable — a question this chapter does not attempt to resolve, but one that underscores why library data governance cannot be treated as a solved problem simply because professional ethical codes have long emphasized patron confidentiality.

9. Illustrative Institutional Snapshots

Because the pace and character of data-driven transformation differ meaningfully across library types, this section offers three brief, illustrative snapshots not a systematic comparative study showing how the developments reviewed above tend to manifest differently in academic, public, and national or heritage library contexts. Table 4 summarizes these snapshots alongside the dominant innovation priority observed in each.

Table 4: Illustrative Institutional Snapshots of Data-Driven Library Transformation

Library Type	Characteristic Adoption Pattern	Dominant Innovation Priority
Academic / research libraries	Institutional repositories, research data management services, FAIR-aligned open-access infrastructure, and growing AI literacy instruction	Supporting open science and research data stewardship across the campus research lifecycle
Public libraries	Makerspaces, digital literacy programming, and community-facing AI chat assistants, constrained by budget and privacy concerns	Equitable community access to technology and protection of patron privacy
National / heritage libraries	Large-scale digitization, OAIS-compliant preservation infrastructure, and participation in distributed preservation networks	Long-term stewardship and authenticity of the digitized cultural and scholarly record

These snapshots illustrate a point relevant to institutions of every type and size: the specific manifestation of data-driven transformation is shaped as much by institutional mission and resourcing as by the underlying technology itself. A research library's FAIR-compliant repository infrastructure and a public library's mobile makerspace are at the level of underlying

logic, the same institutional response extending organized, trustworthy access to knowledge and the tools to create it expressed through very different service portfolios appropriate to very different communities.

10. Toward the Data-Driven Knowledge Institution: A Synthesis Framework

The evidence reviewed in this chapter supports organizing library transformation planning around five interacting layers: collections, services, space, governance, and workforce. Table 5 contrasts typical present-day library practice with the data-driven orientation suggested by the literature reviewed above for each layer, offered as a planning reference for institutions engaged in strategic redesign rather than as a prescriptive model to be adopted uniformly.

Table 5: A Synthesis Framework for the Data-Driven Knowledge Institution

Design Layer	Present-Day Practice	Emerging Data-Driven Orientation
Collections	Physical holdings supplemented by licensed digital content	Hybrid physical-digital collections governed by FAIR and OAIS-aligned repository infrastructure
Services	Desk-based reference and circulation	Blended human-AI reference, data-literacy instruction, and research-support consultations
Space	Reading rooms and stacks	Makerspaces, immersive-learning labs, and hybrid physical-virtual programming spaces
Governance	Institution-level collection and IT policy	Multi-level governance spanning standards bodies, institutional privacy policy, and staff data-ethics training
Workforce	Discipline-specific cataloging and reference expertise	Expanded LIS competencies in data curation, metadata engineering, and AI-tool evaluation

Three cross-cutting principles emerge from this synthesis. First, technology adoption in libraries delivers its strongest documented benefits when it is treated as infrastructure — standards-based, interoperable, and designed for longevity — rather than as a collection of point solutions purchased independently of one another; the interoperability arguments reviewed in Section 4 and the preservation standards reviewed in Section 6 both illustrate that piecemeal adoption tends to recreate the information silos that a genuinely integrated digital library is meant to eliminate. Second, the library workforce's role shifts toward curation, data stewardship, and ethical oversight precisely as routine cataloging and reference tasks become more automatable, echoing the pattern observed in the education literature on AI-augmented professional roles more broadly and reinforcing the case for treating LIS workforce development as a load-bearing element of any transformation strategy rather than an afterthought. Third, data governance and

patron privacy cannot be addressed after the fact; the ethics findings reviewed in Section 8 indicate that institutions adopting data-intensive tools without parallel investment in privacy-by-design practices and staff ethics training risk exactly the kind of unexamined patron-data exploitation that recent research has documented.

10.1 Limitations of the Current Evidence Base

Several limitations in the literature synthesized above warrant acknowledgment. First, much of the quantitative evidence on AI adoption and efficiency gains comes from vendor-adjacent surveys and single-institution case studies rather than from independent, peer-reviewed comparative research, which may inflate the apparent average benefit relative to what a typical, resource-constrained library can expect to realize. Second, definitions of key terms — smart library, Library 4.0, AI adoption — vary considerably across the sources reviewed, complicating direct comparison of the adoption statistics cited in Sections 3 and 7. Third, the library-analytics ethics literature reviewed in Section 8 is itself a relatively young field, and its findings, while concerning, are based on a limited citation-chain sample rather than an exhaustive census of library data practice. Readers applying the framework proposed above to their own institutional context should treat the reported statistics as indicative of direction and general magnitude rather than as precise, universally transferable benchmarks.

11. Recommendations for Stakeholders

11.1 For Library Leaders and Institutional Policymakers

- Adopt established preservation and interoperability standards (OAIS, TRAC/ISO 16363, PREMIS/METS) rather than developing bespoke digital-repository architecture from first principles.
- Fund AI and digital-infrastructure adoption with an explicit budget line for staff training, recognizing that budget constraints and skills gaps, not the technology itself, are the leading barriers reported by libraries.
- Require a documented data-lifecycle and privacy-impact review before deploying any new patron-facing analytics or AI system.

11.2 For Funders and Policymakers

- Tie research-funding data-management mandates to sustained infrastructure funding for the libraries expected to implement FAIR-compliant repository services, rather than treating compliance as a cost-free requirement.
- Support distributed preservation network participation (e.g., LOCKSS, CLOCKSS) for smaller and under-resourced libraries that cannot independently sustain OAIS-compliant infrastructure.

11.3 For LIS Educators and Practicing Librarians

- Integrate data curation, metadata engineering, and AI-tool evaluation explicitly into LIS curricula, reflecting the expanded workforce competencies identified in Section 10.
- Treat AI recommendation and cataloging tools as decision-support systems requiring professional review, particularly in collection-development contexts where staff report the greatest concern about automation.
- Build explicit staff training in library-specific data ethics, given documented gaps between stated professional privacy commitments and actual analytics practice.

11.4 For Technology Developers and Vendors

- Design AI and analytics tools for libraries with privacy-preserving defaults and transparent, auditable data practices, given the elevated sensitivity of patron behavioral data relative to typical consumer contexts.
- Build interoperability with open metadata and preservation standards into core product architecture, rather than treating standards compliance as an optional enterprise-tier feature.
- Support longitudinal, independent evaluation of AI tool performance in library settings to strengthen an evidence base currently weighted toward vendor-adjacent reporting.

Conclusion

This chapter has argued that the transformation of libraries documented across AI-assisted services, digital library infrastructure, open science and FAIR data stewardship, digital preservation, and community innovation spaces is best understood as a single, coherent extension of the library's oldest institutional purpose: organizing knowledge so that it can be found, trusted, and used, now under conditions of unprecedented scale, format diversity, and technological capability. The empirical literature reviewed here demonstrates genuine and, in several domains, substantial gains from this transformation, from AI-assisted cataloging efficiency to strong reported learning outcomes for immersive instruction. Yet these gains are consistently reported as conditional on deliberate infrastructure design, sustained workforce investment, and rigorous attention to the ethical stewardship of patron and research data, an area where the evidence reviewed in this chapter suggests the profession's practice has not always matched its stated commitments. For the contributors and readers of this volume, the most productive path forward is not a further debate over whether libraries belong in the data economy, a question that adoption statistics suggest has already been settled empirically, but the accumulation of practical,

standards-based knowledge about how to build library infrastructure that is genuinely worthy of the trust patrons and researchers continue to place in it.

Appendix: Glossary of Key Terms

The following brief glossary is provided for readers of this volume who may be encountering some of the technical terms used in this chapter for the first time.

Term	Working Definition
Digital library	An organized collection of digital objects, together with the systems, standards, and services needed to make that collection findable, accessible, and usable over time.
FAIR principles	A framework specifying that research data and metadata should be Findable, Accessible, Interoperable, and Reusable by both humans and machines.
OAIS reference model	An ISO standard (14721) defining the functional entities and information flows required for a repository to preserve digital content over the long term.
Trusted/trustworthy digital repository	A repository that meets independently auditable standards (e.g., ISO 16363 / TRAC) for organizational, technical, and financial reliability in long-term digital stewardship.
PREMIS / METS	Complementary metadata standards for documenting the preservation history and structural organization of digital objects, enabling exchange between repository systems.
LOCKSS / CLOCKSS	Distributed, peer-to-peer digital preservation networks in which cooperating libraries replicate content to guard against loss from any single point of failure.
Makerspace	A library-based space providing shared access to fabrication and prototyping tools (e.g., 3D printers, laser cutters, electronics kits) for hands-on creation and learning.
Library learning analytics	The collection and analysis of student or patron library-behavior data, typically to study or demonstrate contributions to academic or institutional outcomes.

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SCIENTOMETRIC MAPPING OF INDIAN KNOWLEDGE MANAGEMENT

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Abstract

The present research aims to provide academics with an overview of published publications on the subject of Indian Knowledge Management. As a result, the evaluation looks at the countries and organizations are most engaged in the field of study. Histcite and VoS Viewer software were used to compile the documents downloaded from Web of Science core collection from 2001 to till August 2025 and to identify the of greatest significance networks. The findings showed that 2023 has a large number of publications in the growing field of Indian Knowledge Management literature. India and USA being top on the publications.

Keywords: Indian Knowledge Management, Scientometrics, Degree of Collaboration, Web of Science.

Introduction

Indian Knowledge Management generally refers to approaches that draw on India's indigenous knowledge traditions and value frameworks to guide modern knowledge creation, organization, sharing, and use, especially in education, business, and governance. It integrates classical Indian philosophical ideas and traditional knowledge systems with contemporary knowledge management tools and practices. Indian Knowledge Management (IKM) builds on Indian Knowledge Systems (IKS), which are the long-evolving body of Indian philosophical, scientific, artistic, and practical traditions. IKM focuses on how this reservoir of wisdom is preserved, structured, transmitted, and applied to present-day problems in areas such as management, education, technology, and public policy. Indian Knowledge Systems today is also the name of an official division/cell under the Ministry of Education at AICTE, tasked with promoting research and dissemination of India's traditional knowledge across domains such as arts, agriculture, basic sciences, engineering, architecture, management, and economics. In many academic contexts, "Indian Knowledge Management" is positioned as the management-oriented subset or application of this broader IKS framework to contemporary institutional and societal

settings. A modern company can implement Indian Knowledge Management (IKM) by embedding Indian value-based, holistic ideas about knowledge (jnana) into its culture, leadership, and KM processes, while still using contemporary digital tools and metrics. Practically, this means designing KM so that it supports both performance and dharma: ethical conduct, stakeholder welfare, and long-term sustainability.

Review of Literature

The study uses quantitative bibliometric methods (publication counts, citation analysis, author/journal productivity, country and institutional contributions) to describe how IKS research has evolved over two decades. It also appears to include mapping elements such as keyword co-occurrence or thematic clusters, in line with similar IKS-related bibliometric work that uses VOSviewer or Biblioshiny to identify clusters like “IKS & Vedic Mathematics”, “IKS & Ayurveda”, and “IKS & Holism”. [1]

The study analyzes 1,980 Scopus-indexed documents on indigenous knowledge in India published between 2003 and 2022 to chart growth, collaboration patterns, and thematic evolution using standard scientometric tools and visualization software. It measures publication and citation trends, identifies prolific authors, institutions, and countries, and maps keyword co-occurrence to reveal intellectual and thematic structures. [2]

The analysis retrieves 4,396 Web of Science-indexed papers on medicinal plants from India (2020-2024), identifying 59 highly cited papers (HCPs; ≥ 100 citations each, totaling 10,884 citations). Tools like Biblioshiny and VOSviewer map trends, co-authorship, institutions, journals, and collaborations via title searches ("medicinal plants" AND "India"). [3]

Scientometric analysis of scientific articles on green libraries examines publication trends, authorship patterns, and thematic evolution in research on environmentally sustainable library practices, such as energy-efficient designs and waste reduction. These studies often use databases like Scopus or Web of Science, applying tools like VOSviewer for visualization. Research growth has accelerated since the 2010s, reflecting global sustainability priorities. [4]

Scientometric analyses of gastritis research quantify global publication trends, authorship patterns, and thematic hotspots in studies on this stomach lining inflammation, often using Web of Science data and tools like VOSviewer or CiteSpace. Key studies cover periods like 2002–2021 for open-access literature and 2011–2021 for atrophic gastritis, revealing steady output with peaks around 2012 and growth in China-led contributions. [5]

The study "Open Access scholarly literature on Gastritis (2002-2021) in Web of Science: A Scientometric Analysis" by Amir Amanullah and S. Rajeswari quantifies global open-access publication productivity on gastritis using Web of Science data, focusing on trends, document

types, and citation patterns over 20 years. It reveals steady growth in output, with articles dominating (around 70%) and English as the primary language (over 97%), aligning with broader gastritis scientometric patterns.[6]

Objectives of Study

- To examine the current status of research productivity of Indian Knowledge Management.
- To examine the year wise growth of the research output of Indian Knowledge Management.
- To study the authorship pattern.
- To identify the Degree of Collaboration.
- To determine the geographical distribution of Institution and country.

Methodology

The Web of Science (WoS) is the most widely used database in scientometric and Bibliometric research. The WoS core collection database, with index dates covering the years 2001 to till August 2025 provided as the search's data source downloaded from WoS on October 2025. The search strategy was "Topic = Indian Knowledge Management". The outcome was discovered in 2235 publications. All the data were downloaded from the WoS Core Collection and imported into software for analysis. In this study, Histcite and VoS viewer software were used to perform scientometric analysis. VoS viewer was used to identify the co-author's countries, organizations, a co-authorship network and to cluster visualization of co-occurrence keyword analysis.

Search terms Image

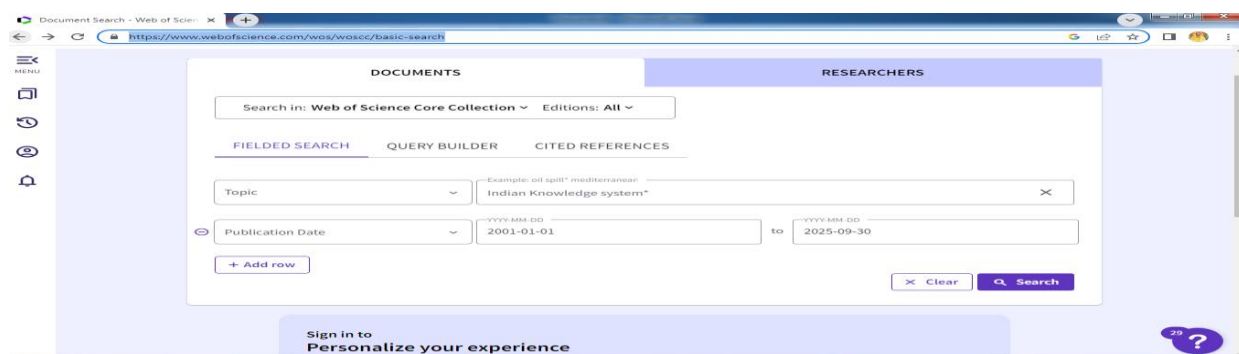


Figure 1: Web of science Image

Result and Analysis

Main Information

The data collection of duration from 2001 to October 2025 has been analyzed. The outputs from this analyzed shown in Table 1 indicate that Time span is 24 Year 9months. 2235 documents are collected from Web of Science, 5 Types of Documents, 12 Language, 169 Keywords, 52 countries, 123 Institutions and 66857Citatoins (Table 1).

Table 1: Data Sample

Rank	Details of Sample	Observed Values
1	Duration	2001-till August 2025
2	Time Span	24 Year 9months
3	No. of Publication	2235
4	Document Type	5
5	Language	12
6	Frequency of Keywords	169
7	Collaborated Institutions	123
8	Collaborated Countries	52
9	Citation	66857

Annual Productivity

Table 2 shows that 2235 publications were recorded during the study period. The publication trend shows a positive growth in the study period. The maximum number of productivities recorded during 2022 with 200 publications and the minimum recorded in the year 2003 with 17 publications.

Table 2: Annual Productivity

Year	Publication	Citation
2001	20	1788
2002	25	1103
2003	17	684
2004	18	989
2005	38	3552
2006	28	2855
2007	38	1698
2008	31	3597
2009	67	2018
2010	52	3712
2011	70	2957
2012	65	2922
2013	67	6299

Year	Publication	Citation
2014	73	2620
2015	82	3371
2016	97	3298
2017	99	4088
2018	115	3382
2019	138	3305
2020	165	3986
2021	174	3164
2022	200	2935
2023	199	1670
2024	177	666
2025	180	198
Total	2235	66857

Documents

A total of 2235 papers on Indian Knowledge Management research have been published in the 25 years between 2001 and 2025. Out of the 2235 publications, about 1828 came out as articles 386 as Review and rest belongs to Editorial Materials, Meeting Abstract and NewsItem (Table 3).

Table 3: Type of Documents

Rank	Documents	Publication	Citation
1	Article	1828	42973
2	Review	386	23536
3	Editorial materials	19	347
4	Meeting Abstract	1	0
5	News Item	1	1
		2235	66857

Languages

Table 4 illustrates the distribution of literary contributions by language, indicating that English is the predominant language, comprising of the total 2235 articles. With 2193 publications in English, it far surpasses the total of all other languages combined. Russian occupies the second position with just 11 publications succeeded by Portuguese, French and Spanish publications.

Table 4: Languages

Rank	Language	Publication	Citation
1	English	2193	66696
2	Russian	11	3
3	Portuguese	8	79
4	French	7	35
5	Spanish	4	5
6	Chinese	3	36
7	Korean	3	0
8	German	2	1
9	Afrikaans	1	0
10	Croatian	1	0
11	Lithuanian	1	0
12	Polish	1	2
		2235	66857

Keywords

In this section, we examined the contribution of numerous keyword occurrences inside this research domain, and the results are shown in Fig.2 shows a network depiction of the contributions of various keyword occurrences. The investigation found that the most relevant terms ranged from 2001-till August 2025. The analysis of keyword co-occurrence revealed significant insights into the field's main challenges, offering estimated routes for future research. Keywords are India, Climate Change, Indian Ocean, Sustainability, Conservation and Traditional Knowledge.

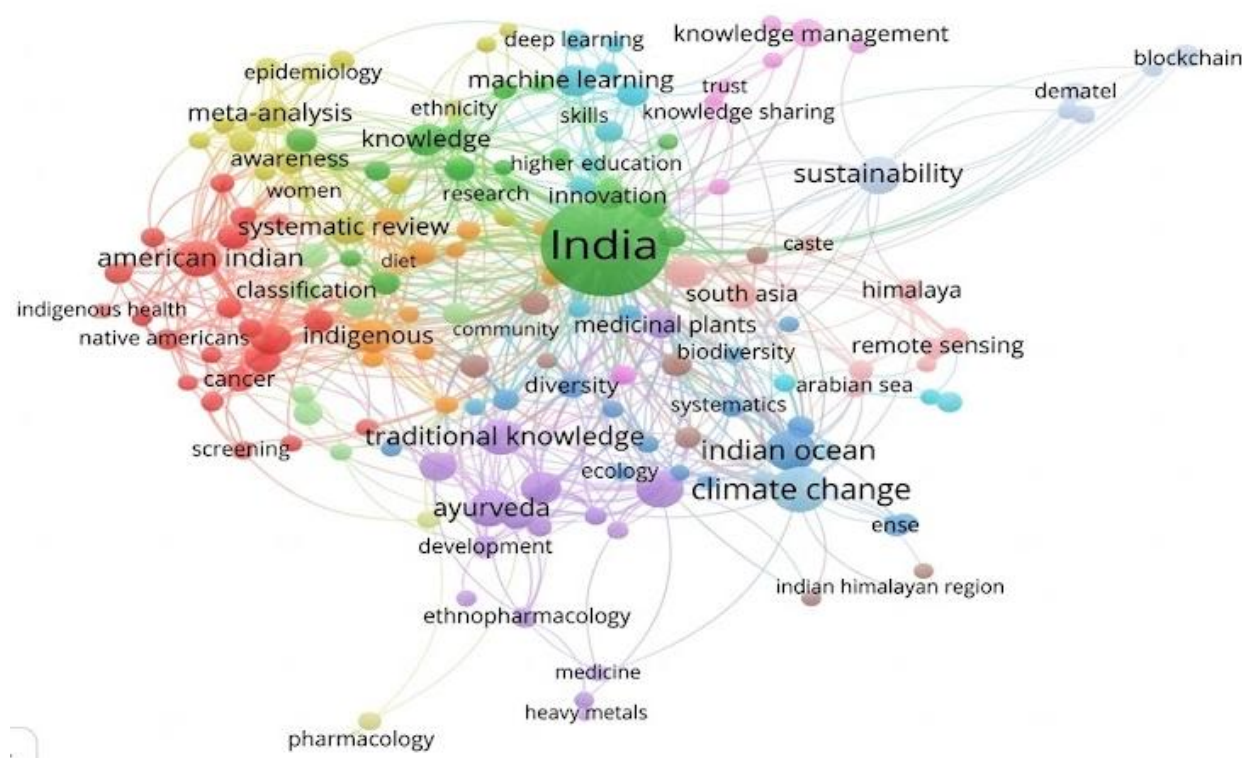


Figure 2: Network Visualizing Occurrence of Keywords

Institution

Institution analysis facilitates the researchers to identify the dominating institutions working actively in the specified research domain for their posdoctoral studies, research exchange activities and study tours. Institution have participated in the studies related to Indian Knowledge Management during the period of 2001-till August 2025. Top institutions are shown in Fig. 3. Indian institute technology has contributed highest publication occupy first place. Chinese academy science has attained second place and All India Institute of Medical Science has occupied third place.

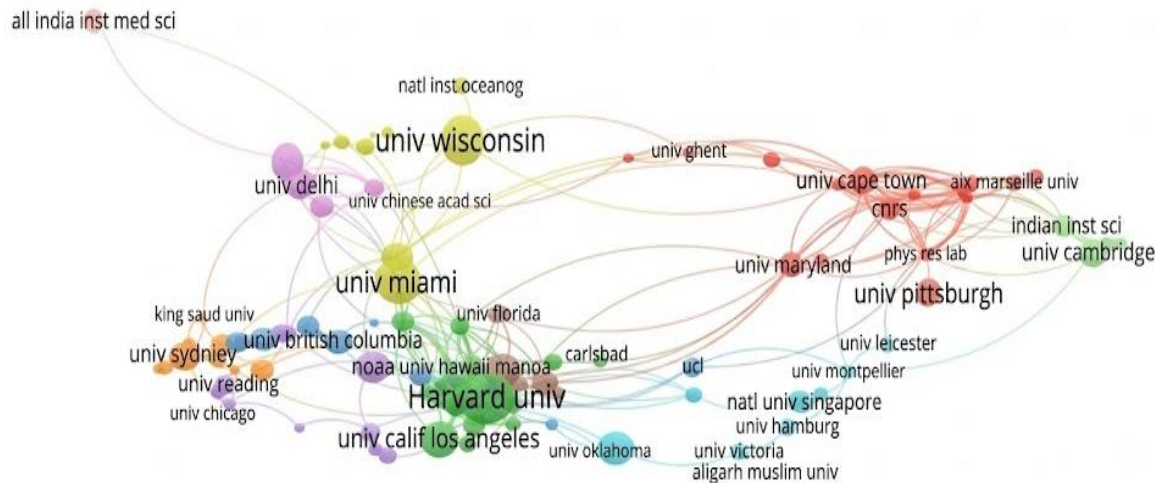


Figure 3: Networks visualizing Institution

Countries

The country affiliation provides the information on workplace of a researcher, the nation in which a researcher works within a particular organization producing certain research papers under the affiliation of the organization. If the paper is multi-authored then each author affiliation is considered to be very significant in evaluating the research output of a researcher. Now, the co authorship analysis on the basis of countries is very important indicator indicating the network of the countries collaborating and by default the collaboration of organizations and authors. The countries contributions are shown in the fig 4. The leading two countries productivity more than 500 publications. India is the first place and second place occupied USA. England obtained Third position.

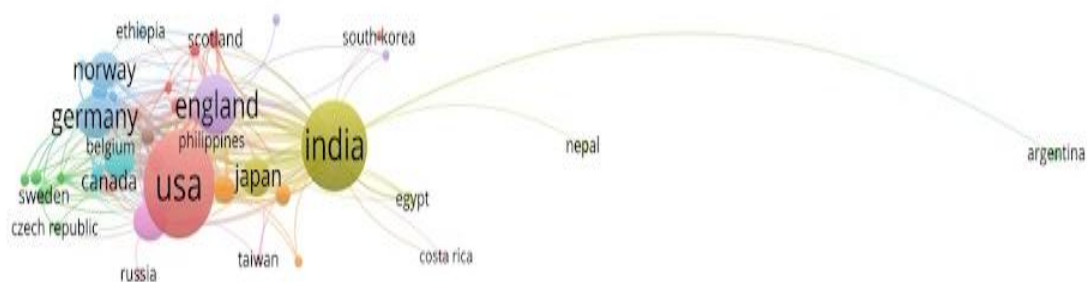


Figure 4: Networks visualizing countries

Authorship Pattern

Table 5 identified that year wise authorship pattern in the field of Indian Knowledge management research during the 24 Year 9 months study period. From the study, it is identified that, out of 2235 research publications, 278 research publications are contributed by single

authors and remaining 1957 research publications are multi author's contributions. From the multi authors publications, maximum of 422 research publications are contributed by Double authors, followed by 359 publications are contributed by three authors, 305 publications are four authors, 237 publications are five authors.

Table 5: Authorship pattern

Rank	Authors	Publication	%
1	Single Authors	278	12.43
2	Double Authors	422	18.89
3	Three Authors	359	16.06
4	Four Authors	305	13.65
5	Five Authors	237	10.6
6	Six Authors	181	8.1
7	Seven Authors	115	5.15
8	Eight Authors	93	4.16
9	Nine Authors	62	2.77
10	Ten Authors	47	2.1
11	Above Ten Authors	136	6.09
		2235	100

Degree of Collaboration (DC)

In order to identify the degree of collaboration, the researcher has adopted K. Subramanyam's (1983)¹¹ formula.

$$DC = \frac{Nm}{Nm + Ns}$$

Where,

C = Degree of collaboration in a discipline

Nm = Number of multiple authored papers

Ns = Number of single authored papers

Table 6 represents the Degree of Collaboration in disaster management. The study found that the Degree of Collaboration is 87.57, indicating that multiple-author contributions are significantly higher than single-author papers. This reflects a strong tendency toward collaborative research practices among scholars. Overall, the findings demonstrate very high collaborative research activities in global Indian Knowledge Management, highlighting the importance of teamwork, knowledge sharing, and collective scholarly efforts in advancing research.

Table 6: Degree of Collaboration

Authors	Publication	%
Single	278	12.43
Multiple	1957	87.57
	2235	100

Conclusion

The study aimed to conduct a scientometric analysis of Indian Knowledge management research to understand the growth of literature, patterns of publications, and research impact. Using publication data from the Web of Science database, this study provides a quantitative and qualitative description of Indian Knowledge management research covering a period of 15 years. India ranks highest in the world in Indian Knowledge management research. Hence, stakeholders should pay special attention to academic and research organizations, encouraging them to undertake more new research projects and programmes in collaboration with international hubs in Indian Knowledge management research.

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VIKSIT BHARAT@2047: PATHWAYS TO INCLUSIVE, SUSTAINABLE AND DEVELOPED INDIA

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Abstract

Viksiti Bharat 2047" is the vision of India to become a developed nation by celebrating the 100th anniversary of Independence. The vision is not just about economic growth; it is about inclusive development, technological advancement, human capital development, environmental sustainability, good governance, and a better quality of life. Recent policy documents recognise India's journey towards a high-income, innovative, resilient and globally competitive economy as a multi-dimensional process with constant reforms and coordinated actions. NITI Aayog has linked the 2047 vision with a USD 30 trillion economy and has also highlighted the need to enhance the education, skills, health, infrastructure, innovation and social inclusion (NITI Aayog, 2025a). Digital public infrastructure, the green transition and sustainable agriculture and human-capital development have increasingly become key elements in this transition. This review looks at the key pillars of Viksit Bharat@2047 as well as the opportunities and challenges in making the vision into measurable development outcomes. The analysis suggests that success of the vision is going to be achieved through the enhancement of productivity, creation of quality employment, inclusive technology, boosted research and innovation, and commitment to protecting the environment and effective implementation at state and local levels.

Keywords: Viksit Bharat@2047, Developed India, Inclusive Growth, Digital Public Infrastructure, Sustainability, Innovation, Human Capital, Governance.

1. Introduction

As India moves closer towards the 100-day milestone of Independence Day in 2047, the country is on a path to a pivotal moment in its development journey. The idea of Viksit Bharat@2047 is a long-term vision for India to become a developed country. The vision is broader than achieving a particular economic size. It covers better living standards, social inclusion, technological capability, modern infrastructure, environmental sustainability and enhanced global engagement (NITI Aayog, 2025a). To shift from a developing to a developed economy, a continuous process of productivity growth and structural transformation is needed. The recent analysis by NITI

Aayog suggests that India needs to sustain real GDP growth of over 7% for an extended period of time and enhance the skills and productivity of the workforce and labour force participation rates (NITI Aayog, 2025a). Hence, the term Viksit Bharat is not just a growth of National Income, but a process of changes in economic, social, technological and institutional structures in the long run. The Sustainable Development Goals (SDGs) are an important stepping stone in the transition. The vision to achieve SDG and the vision of Viksit Bharat are increasingly linked in India's development strategy, for example, the emphasis on poverty reduction, health, education and gender equality, infrastructure and environmental sustainability, etc. (NITI Aayog, 2025b).

2. Review Approach

The review mostly relies on the latest policy reports and the official publications of NITI Aayog and Government of India related to economic development, sustainability, digital public infrastructure, agriculture, human capital and governance. The literature was analysed qualitatively and thematically to identify the key elements of the Viksit Bharat@2047 and challenges in making the vision a development outcome.

3. Results and Discussion

3.1 Economic Transformation and Productive Employment

Economic growth is an integral part of Viksit Bharat@2047. Growth needs to create jobs and increase incomes at the household level, however. There has been significant structural adjustment in India but sectoral disparities between output and employment are still significant policy issues. NITI Aayog has highlighted the importance of enhancing productivity, investments, competitiveness of manufacturing, services, entrepreneurship and labour force participation for the next phase of development (NITI Aayog, 2025a). There is also an opportunity in the demographic structure, especially as a large working-age population has the potential to benefit the economy. But demographic advantage is significant only if backed by quality education, employable skills and appropriate employment opportunities. In the recent NITI Aayog efforts of skilling, it is noted that the development of the country is dependent on the capability of its people and training them according to the evolving technological and industrial needs (NITI Aayog, 2026a).

3.2 Human Capital and Social Inclusion

Human development, in addition to economic growth, is needed in a developed country. Therefore, education, healthcare, nutrition, gender equality and social protection are a primary concern of Viksit Bharat. The aim is to widen the reach and enhance quality and outcomes at the same time. This is especially important in the case of women's involvement in economic activity.

More education, skills, entrepreneurship, finance and employment can be a benefit to household welfare and to the productivity of the nation. Likewise, narrowing inequalities in the region between rural and urban areas is key as development would not be deemed complete if opportunities were concentrated geographically. Hence, the Viksit Bharat framework needs to be human-centric with economic development turning into capability-building and a better life. India's Voluntary National Review also aligns the 2030 SDG agenda with the longer term 2047 development journey (NITI Aayog, 2025b).

3.3 Digital Transformation and Innovation

Digital technologies are increasingly emerging as important tools for inclusive development. India's journey with DPIITY illustrates the possibilities of digital public infrastructure (DPI) in terms of creating access to identity, payments, public services and economic opportunities. The recently released DPI@2047 roadmap envisions to go beyond mere digital inclusion and advance towards productivity-led and livelihood-oriented development (NITI Aayog, 2026b). The innovation ecosystem in India can be further strengthened by Artificial Intelligence, Biotechnology, Advanced Manufacturing, Clean Technologies and/or Data-driven Services. However, technological advances need to be inclusive. Digital access, data protection, cyber security and digital literacy and affordability are essential to avoid the creation of new inequalities due to technological change.

3.4 Sustainable Development and Green Transition

Economic growth can not be realized without environmental sustainability. India has several long-term development problems like climatic changes, energy security, efficiency in the utilization of resources, pollution and ecological degradation. Recently, NITI Aayog's scenarios explored how economic growth can go hand-in-hand with a transition of energy systems to reduce carbon emissions, such as increasing electrification, renewable energy, energy efficiency, and emerging technologies like green hydrogen (NITI Aayog, 2026c). Sustainability has a special role for agriculture, manufacturing and transport and urban development. The transition to circular economy practices, renewable energy and sustainable production and resource efficient technologies are part of the solution to achieve economic growth without adding to environmental pressures.

3.5 Agriculture, Rural Transformation and Local Development

The agricultural sector is still playing a significant role in the socio-economic fabric of India. The modernization of technology, access to markets, value addition, water management, climate change adaptation in agriculture, and diversification into other livelihoods are needed for transforming rural India. The debate on Viksit Bharat has always been about how traditional

knowledge, innovation and modern technology play together in agriculture. (Government of India, 2026) Development too should be local. States, districts and municipalities and village level institutions are the ones that play a significant role in providing education, healthcare, infrastructure and welfare services. Thus, for achieving the Viksit Bharat, the cooperation of both central, state & local institutions is needed, not just one is enough.

3.6 Governance and Institutional Capacity

The only way to achieve measurable outcomes from policy ambitions is through good governance. Good management of public institutions, transparency and accountability, evidence-based policy making and timely implementation can enhance the effectiveness of public expenditure and development programmes. More effective coordination among government, universities, research institutions, industries and civil society is also essential in the framework of Viksit Bharat. The developmental issues at the national and local level must be increasingly the focus of research and innovation, and universities can play a role in this through entrepreneurship, technology transfer, skilled human resources and through its engagement with the community.

4. Major Challenges

There could be some challenges that impact speed and quality of change for India's transformation. These include the need for greater access to technology, a lack of skills, job creation, urbanisation, environmental stress and regional imbalances, and a need for better research and innovation output. Investments, productivity gains will also play a key role in achieving high economic growth over the next few decades (NITI Aayog, 2025a). A lack of equitable opportunity distribution to support economic expansion may not result in equal gains in human development. Similarly, new inequalities may emerge during the technological process, unless the necessary institutional precautions are taken. Therefore the 2047 pathway should be continually tracked with measurable social, economic and environmental indicators.

Conclusion

The vision of Viksit Bharat@2047 is a comprehensive development vision, which ranges from economic transformation to human development and technology to sustainability to governance. Economic growth is not enough to bring about the transition to a developed India. It needs productive jobs, quality education and health care, innovative industries, sustainable infrastructure, modern agriculture and technology integration, and effective institutions and digital inclusion. The evidence gathered indicates that India has great opportunities due to its demographic, digital infrastructure, innovation ecosystem and its growing economic capabilities. The magnitude of the 2047 target also demands a continuous policy implementation process and

coordination between the government, academia, industry and citizens. The ultimate test of the journey from vision to transformation will be whether or not national aspirations are translated into tangible gains in productivity, human potential, environmental quality and living standards.

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BUILDING FUTURE READY EDUCATION FOR VIKSIT BHARAT@2047 THROUGH ARTIFICIAL INTELLIGENCE, SKILLS AND HUMAN CAPITAL DEVELOPMENT

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Abstract

Viksit Bharat@2047 envisions India's transformation into a developed, inclusive, innovative and technologically capable nation by the centenary of its independence. Education is fundamental to this transformation because sustainable national development increasingly depends on skilled human capital, technological literacy, creativity, research capability and lifelong learning. Artificial Intelligence (AI) provides significant opportunities to transform conventional education into personalized, adaptive, inclusive and data-informed learning environments. Technologies including Machine Learning (ML), Natural Language Processing (NLP), Generative AI, Intelligent Tutoring Systems (ITS), adaptive learning and learning analytics can support individualized instruction, intelligent assessment, multilingual learning, academic assistance and educational decision-making. AI can additionally augment teachers by supporting selected routine and analytical activities while allowing educators to concentrate on mentoring, creativity, critical thinking and meaningful learner interaction. However, AI adoption introduces concerns involving academic integrity, data privacy, algorithmic bias, misinformation, accessibility, digital inequality and technological dependence. Responsible implementation therefore requires human oversight, ethical governance, teacher preparedness, AI literacy and equitable digital infrastructure. This chapter examines the evolution of education towards intelligent learning, major AI technologies, transformation of teaching and assessment, future skills and employability, inclusive and responsible AI adoption, and a strategic roadmap for AI-enabled education towards Viksit Bharat@2047. It argues that India's future educational ecosystem should be based on human–AI collaboration in which intelligent technologies strengthen rather than substitute human capability, thereby contributing to innovation, skilled human capital and sustainable national development.

Keywords: Viksit Bharat@2047, Artificial Intelligence in Education, Smart Education, Generative AI, Personalized Learning, Future Skills, Human Capital, Digital Education, Inclusive Education.

1. Introduction

India's aspiration for Viksit Bharat@2047 represents a long-term national transformation towards becoming a developed, inclusive, innovative and technologically capable nation by the centenary of independence. Such transformation requires more than economic expansion and physical infrastructure. It depends substantially on India's capacity to develop knowledgeable, skilled, creative, ethical and adaptable citizens capable of contributing to a rapidly evolving economy and society.

Education has continuously evolved in response to changing social requirements, pedagogical practices and technological developments. Traditional education predominantly depends on classroom instruction, textbooks, predetermined curricula and periodic assessment. This approach offers important advantages, including direct teacher–student interaction, structured learning and social engagement. However, individualized instruction becomes challenging when learners differ significantly in prior knowledge, ability, learning pace, motivation and academic requirements.

The expansion of Information and Communication Technology (ICT) considerably changed this educational environment. Computers, internet connectivity, Learning Management Systems (LMS), multimedia resources, digital libraries, mobile applications and virtual classrooms enabled online, blended and flexible learning. Digital education therefore extended learning beyond the physical classroom. Nevertheless, converting educational materials into digital formats does not necessarily produce personalized education because identical resources may continue to be delivered to learners with substantially different educational requirements.

Artificial Intelligence represents a further stage in this transformation. AI-enabled systems can perform functions involving pattern recognition, prediction, natural-language interaction, recommendation, adaptation and content generation. Major applications of AI in higher education include profiling and prediction, assessment and evaluation, adaptive systems, personalization and intelligent tutoring (Zawacki-Richter *et al.*, 2019). AI in Education therefore extends educational technology beyond information delivery towards intelligent support for teaching, learning and decision-making (Hwang *et al.*, 2020).

Machine Learning can analyse educational data and identify patterns in learner performance. NLP enables language-based interaction between learners and digital systems. Intelligent Tutoring Systems can provide individualized guidance, while adaptive systems modify educational activities according to learner requirements. Learning analytics assists educators in interpreting learner progress. More recently, Generative AI and Large Language Models have

enabled conversational generation of explanations, questions, examples, summaries, feedback and instructional resources (Kasneci *et al.*, 2023).

These developments have particular significance for India's educational transformation. The National Education Policy 2020 recognizes technology as an important mechanism for improving teaching-learning, assessment, educational planning and access. It also advocates digital educational resources in major Indian languages and accessibility for learners in remote areas and learners with disabilities (Government of India, 2020).

AI can therefore contribute to Viksit Bharat@2047 by supporting educational quality, personalization, multilingual learning, teacher capability and future workforce preparation. However, technology alone cannot guarantee educational transformation. Effective education also requires pedagogy, human relationships, motivation, ethical judgement, contextual understanding and meaningful intellectual engagement.

The educational objective should consequently be teacher–AI collaboration rather than teacher replacement. Teachers contribute empathy, mentoring, pedagogical judgement, creativity and contextual understanding, while AI can support analysis, personalization and selected routine activities. Research on AI in higher education similarly indicates the importance of considering educators, pedagogical practices and institutional context alongside technological capabilities (Crompton and Burke, 2023).

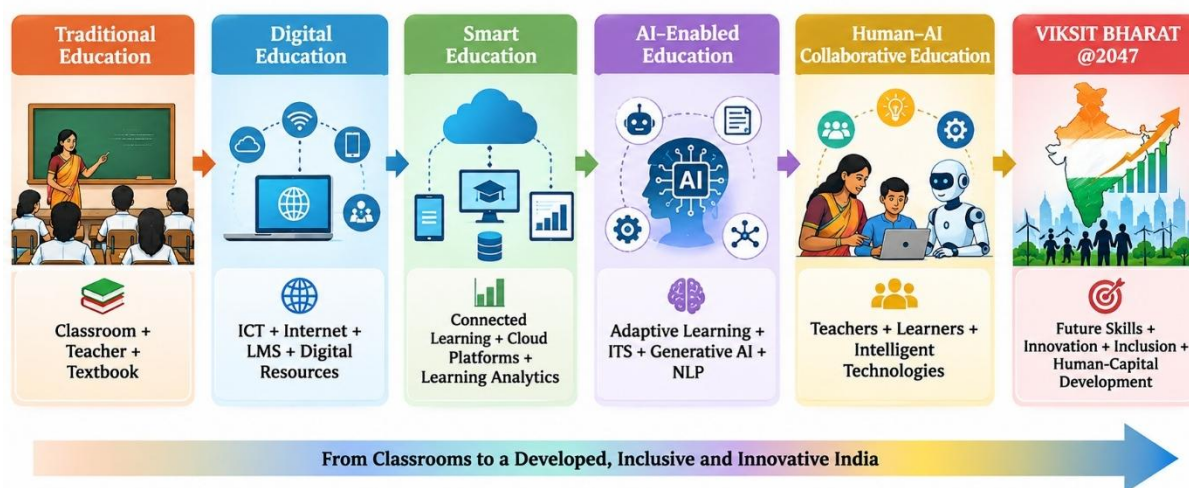


Figure 1: Evolution of Education towards Viksit Bharat@2047

Recent evidence also cautions against equating successful completion of AI-assisted tasks with genuine learning. General-purpose Generative AI may improve immediate task performance without necessarily producing corresponding learning gains when learners outsource cognitive effort. Educational benefits are stronger when AI use is intentionally aligned with pedagogical objectives (OECD, 2026).

For Viksit Bharat@2047, AI-enabled smart education should therefore be understood not simply as technological modernization but as a human-capability development strategy.

2. Evolution of Education towards Viksit Bharat@2047

Educational transformation can be understood as a progression from conventional classroom instruction towards increasingly digital, connected, data-informed and intelligent learning environments. Each stage introduces additional capabilities while retaining valuable elements of previous educational approaches.

2.1 Traditional and Digital Education

Traditional education emphasizes direct teacher–student interaction, classroom instruction, textbooks and scheduled assessment. Its strengths include structured learning, immediate human guidance, social interaction and teacher observation. However, individualized instruction can be difficult in large and diverse classrooms.

Digital education expanded educational access through computers, internet technologies, LMS platforms, multimedia resources, digital libraries, mobile learning and virtual classrooms. Learners gained greater flexibility to access resources beyond physical classrooms.

India's National Education Policy 2020 supports technology integration, digital repositories, online platforms and technology-based educational resources. It specifically calls for educational software in major Indian languages and resources accessible to remote and Divyang learners (Government of India, 2020).

Nevertheless, digital delivery alone provides limited personalization. A digital textbook remains standardized if every learner receives identical material irrespective of individual understanding.

2.2 AI-Enabled Future Education

AI-enabled environments extend smart education through prediction, personalization, natural-language processing, adaptive support and content generation.

Adaptive learning systems analyse learner performance and modify learning activities according to demonstrated needs. Learners experiencing difficulty may receive additional explanation or practice, while those demonstrating mastery may progress towards more advanced content. Systematic research on AI-enabled adaptive learning demonstrates substantial interest in intelligent systems capable of responding to individual learner requirements (Kabudi *et al.*, 2021).

Generative AI introduces another dimension because learners can interact conversationally with educational systems, request alternative explanations, generate examples and obtain preliminary feedback.

Table 1: Evolution of Educational Approaches towards Viksit Bharat@2047

Parameter	Traditional	Digital	Smart	AI-Enabled
Learning	Classroom-based	Online/blended	Connected	Personalized/adaptive
Content	Printed	Digital	Interactive	AI-generated/adapted
Assessment	Periodic	Online	Continuous	AI-assisted/adaptive
Feedback	Teacher-based	Digital	Data-supported	Personalized
Data use	Limited	Recorded	Analysed	Predictive
Language support	Primarily fixed	Digital	Multimedia	AI-supported multilingual
Teacher role	Instructor	Facilitator	Learning designer	Mentor + AI-supported educator
Learner role	Knowledge receiver	Digital learner	Active learner	Creator/problem solver
Primary outcome	Knowledge	Access	Engagement	Skills and capabilities

The principal transformation is therefore not merely from offline to online education. It represents movement from standardized content delivery towards personalized capability development.

3. Artificial Intelligence Technologies Transforming Education

AI-enabled education combines technologies supporting analysis, prediction, adaptation, interaction and generation. Their integration creates an educational ecosystem capable of responding dynamically to learner requirements (Crompton and Burke, 2023).

3.1 Generative AI and Intelligent Tutoring Systems

Generative AI can produce explanations, examples, questions, summaries, images, code and learning activities through natural-language interaction. Students can request simpler explanations, alternative examples or more advanced interpretations.

Teachers can similarly use Generative AI for preliminary lesson preparation, question generation, formative exercises and differentiated instructional resources.

However, AI-generated outputs may contain inaccurate information, bias or inappropriate simplification. Educational use therefore requires verification and critical evaluation (Kasneci *et al.*, 2023).

Intelligent Tutoring Systems provide more structured individualized assistance through learner modelling, feedback, hints and scaffolding. Systematic research indicates that AI-supported intelligent tutoring can contribute to personalized and sustainable educational practices (Lin *et al.*, 2023).

For India's educational ecosystem, such systems can provide supplementary academic assistance beyond scheduled classroom periods, while teachers retain responsibility for pedagogical decisions.

3.2 Adaptive Learning and Learning Analytics

Adaptive learning systems modify educational activities according to learner performance. When students experience repeated difficulty, systems may provide remedial explanation or additional practice. Students demonstrating mastery may progress towards more advanced material.

Learning analytics complements adaptation by analysing assessment results, participation and interaction patterns. Predictive approaches may help identify learners requiring additional academic support.

However, prediction should initiate human investigation rather than automatic judgement. Educational performance may be influenced by circumstances not represented adequately within digital data.

3.3 Evidence on Major AI Application Areas

A meta-systematic review by Bond *et al.* (2024) analysed 66 reviews of AI in higher education. Among the reviews, 54.5% reported findings related to adaptive systems and personalization, 48.5% profiling and prediction, 39.4% assessment and evaluation, and 21.2% intelligent tutoring systems (Bond *et al.*, 2024).

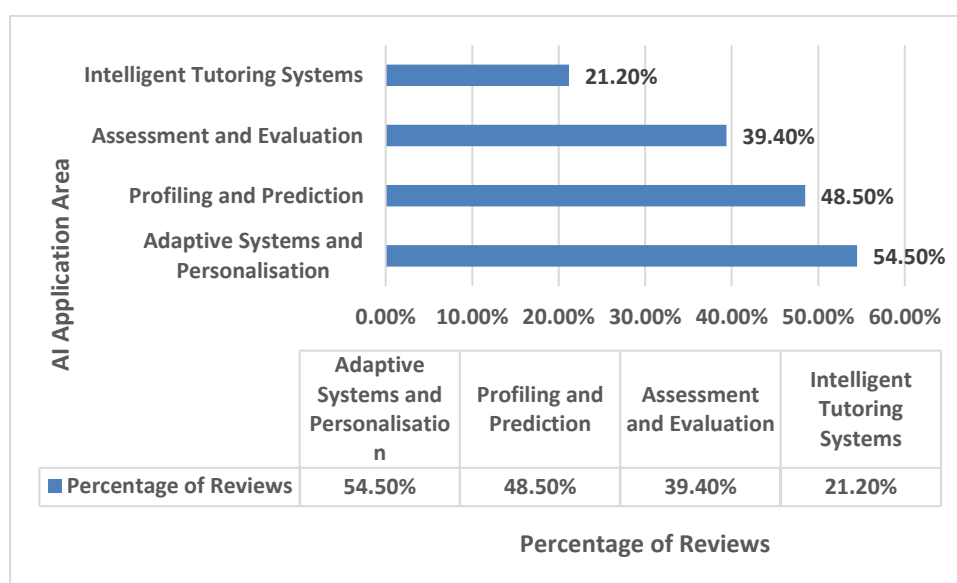


Figure 2: Major AI Application Areas Reported in Higher-Education Reviews

The evidence demonstrates the prominence of adaptive systems and personalization within the reviewed literature. For Viksit Bharat@2047, personalization has strategic relevance because educational systems must address large populations with diverse learning requirements.

4. AI-Enabled Transformation of Teaching, Learning and Skills

AI can transform not only the delivery of educational content but also teaching, learning, assessment and skill development. The value of AI becomes greater when intelligent technologies improve educational processes rather than merely automate existing activities (Chiu *et al.*, 2023).

4.1 Personalized and Student-Centred Learning



Figure 3: AI-Enabled Personalized Teaching–Learning Cycle

Conventional educational systems frequently follow common curriculum sequences and instructional pacing. However, learners differ considerably in prior knowledge, ability and educational requirements. AI-supported personalization can modify content, sequence, difficulty, practice and feedback according to learner progress. Generative AI further enables learners to request different explanations and examples (Kasneci *et al.*, 2023). Personalization should remain teacher-guided. Educators are required to interpret learner difficulties and determine whether algorithmically recommended interventions are educationally appropriate.

4.2 Teacher–AI Collaboration

The future teacher should not be viewed as competing with AI. Humans and intelligent technologies possess fundamentally different strengths. AI can support rapid information processing, preliminary content creation, question generation, routine feedback and learner-data

analysis. Teachers contribute pedagogical judgement, empathy, motivation, ethics, creativity and contextual understanding. UNESCO's AI Competency Framework for Teachers identifies 15 competencies across five dimensions: human-centred mindset, ethics of AI, AI foundations and applications, AI pedagogy, and AI for professional learning (Miao and Cukurova, 2024).

Future teachers may increasingly function as learning designers, mentors, facilitators, ethical guides and evaluators of AI-generated information.

4.3 Future Skills, Employability and Innovation

Viksit Bharat@2047 requires an educational system capable of developing competencies for professions increasingly interacting with intelligent technologies.

AI literacy should extend beyond knowing how to operate AI applications. Learners should understand AI capabilities and limitations, evaluate generated information critically, recognize potential bias and determine when human judgement is essential. UNESCO's AI Competency Framework for Students defines 12 competencies across four dimensions: human-centred mindset, ethics of AI, AI techniques and applications, and AI system design (Miao *et al.*, 2024). Future-ready education should therefore develop critical thinking, creativity, problem solving, digital and AI literacy, communication, collaboration, interdisciplinary thinking, entrepreneurship and lifelong learning.

OECD (2026) emphasizes that pedagogically purposeful Generative AI can support learning and skills such as critical thinking, creativity and collaboration, whereas simply outsourcing cognitive tasks may improve immediate performance without equivalent learning gains.

Table 2: Challenges and Responsible AI Strategies

Challenge	Potential Impact	Responsible Strategy
Academic integrity	AI-generated submissions without genuine learning	Authentic/process-based assessment
Inaccurate output	Misconceptions	Teacher and source verification
Privacy	Learner-data exposure	Data governance and safeguards
Algorithmic bias	Unfair recommendations	Human review and auditing
Digital divide	Unequal educational opportunity	Equitable infrastructure
Language barriers	Learner exclusion	Multilingual resources
Teacher readiness	Ineffective implementation	Continuous AI-literacy development
AI dependence	Reduced independent thinking	Critical and independent tasks
Accessibility	Exclusion of learners with specific needs	Inclusive-by-design systems

5. Inclusive and Responsible AI-Enabled Education

AI-enabled education can contribute meaningfully to Viksit Bharat@2047 only when technological advancement is accompanied by inclusion, accessibility, ethics and human responsibility.

5.1 Inclusive and Accessible Education

AI can potentially improve educational accessibility through captioning, speech technologies, translation, alternative explanations and differentiated learning materials.

Adaptive systems may provide additional practice for learners requiring reinforcement while enabling others to progress more rapidly.

However, inclusion requires equitable access to devices, connectivity, digital literacy and appropriate language support. UNESCO advocates a human-centred approach to Generative AI that protects human agency and promotes ethical, safe, equitable and meaningful use (Miao and Holmes, 2023).

Accessibility should therefore be incorporated into educational technology design from the beginning rather than treated as an additional feature.

5.2 Rural and Multilingual Learning

India's geographical, socio-economic and linguistic diversity makes equitable digital access particularly important. AI-enabled educational transformation should not create a system in which technologically advantaged learners receive sophisticated intelligent assistance while disadvantaged learners remain excluded. Technology strategies should therefore consider affordable devices, reliable connectivity, low-bandwidth platforms, offline educational resources, shared infrastructure, regional-language resources and accessible technologies.

NEP 2020 explicitly calls for educational software in major Indian languages and accessible resources for remote and Divyang learners. It also identifies platforms including DIKSHA and SWAYAM as important components of technology-enabled education (Government of India, 2020). Multilingual AI represents a significant opportunity. Learners could potentially request explanations in regional languages and transition between local-language and wider knowledge resources. However, generated regional-language material requires human validation because technical terminology, cultural context and linguistic accuracy may vary.

5.3 Bias, Digital Divide and Teacher Readiness

AI systems may reproduce biases present in training data. Automated predictions and recommendations should therefore remain subject to human review, particularly when they influence important educational decisions.

The digital divide creates a parallel concern. Unequal access to connectivity, devices and advanced platforms can increase educational inequality rather than reduce it.

6. Roadmap for AI-Enabled Education towards Viksit Bharat@2047

Transition towards AI-enabled education should be systematic rather than technology-driven. The central question should not be *Which AI tool should an institution adopt?* but rather *Which educational problem needs to be solved, and can AI contribute appropriately?*

6.1 Building AI-Ready Educational Institutions

An AI-ready institution requires more than software. It requires digital infrastructure, reliable connectivity, secure data practices, governance mechanisms, institutional policies and appropriate teacher capability.

A responsible implementation pathway can follow:

Educational Need → Pedagogical Suitability → Technology Selection → Ethical/Privacy Review → Teacher Preparation → Controlled Implementation → Human Validation → Outcome Evaluation → Continuous Improvement

India already possesses an important policy foundation. NEP 2020 emphasizes technology integration, digital educational platforms, multilingual content, teacher professional development and accessible educational resources (Government of India, 2020).

Institutional AI policies should establish expectations concerning acceptable use, academic integrity, verification, data privacy and human oversight.

6.2 AI Literacy and Future-Ready Teachers

Teacher capability represents one of the most important requirements for sustainable AI adoption.

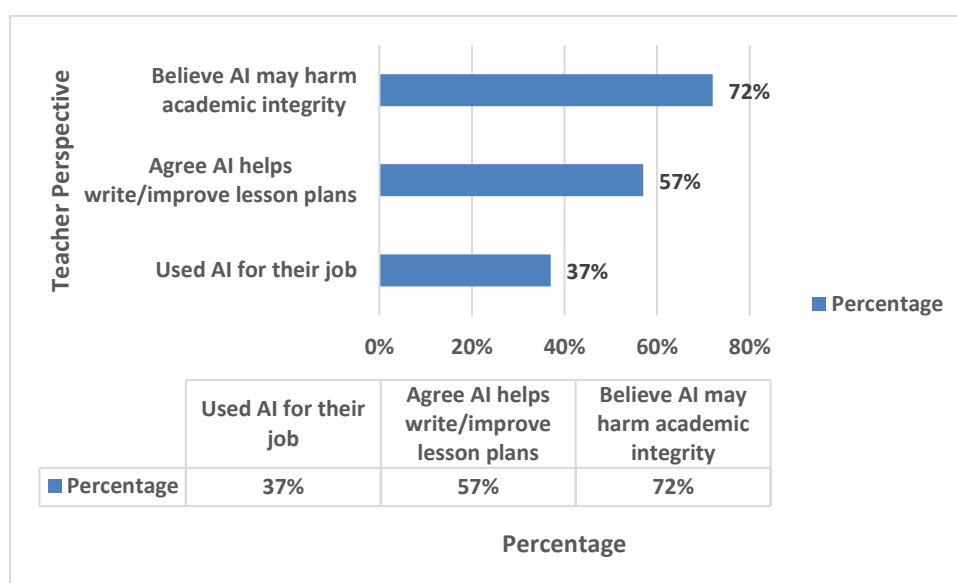


Figure 4: Selected Teacher Perspectives on AI in Education

Future-ready educators require more than technical familiarity with AI applications. They must be capable of determining whether AI genuinely contributes to intended learning outcomes.

Professional development should therefore cover AI fundamentals, effective interaction with Generative AI, verification of generated information, ethical and privacy considerations, bias awareness, assessment redesign, adaptive learning and responsible student AI use.

The UNESCO AI Competency Framework for Teachers organizes these capabilities across human-centred mindset, ethics, AI foundations and applications, AI pedagogy and professional learning (Miao and Cukurova, 2024). Current international evidence illustrates both teacher adoption and continuing concern regarding AI. OECD (2026), drawing on TALIS 2024, reports that 37% of lower-secondary teachers had used AI for their job, 57% agreed that AI helps write or improve lesson plans, while 72% believed AI can harm academic integrity by enabling students to present AI-generated work as their own.

These findings demonstrate that teacher engagement with AI is accompanied by significant concern regarding responsible use. AI-literacy development must therefore address both practical capabilities and ethical judgement.

6.3 Vision for Education in India by 2047

The educational vision for 2047 should not be defined by the quantity of technology available in classrooms. It should be defined by the quality and inclusiveness of human capability developed through education.

Five transformation pillars can guide this direction.

Table 3: Five Pillars of AI-Enabled Education for Viksit Bharat@2047

Transformation Pillar	Direction towards 2047
Access	Quality learning opportunities across geographical and socio-economic boundaries
Personalization	Learning pathways responsive to individual requirements
Future Skills	AI literacy, creativity, critical thinking, problem solving and lifelong learning
Inclusion	Multilingual, accessible and affordable intelligent education
Human–AI Collaboration	Technology augmenting rather than replacing teachers and learners

Conclusion

Artificial Intelligence is transforming education from standardized instruction towards personalized, adaptive, interactive and data-informed learning. Technologies such as Machine

Learning, Generative AI, Intelligent Tutoring Systems, adaptive learning and learning analytics can enhance teaching, assessment, feedback and individualized learner support. For Viksit Bharat@2047, AI-enabled education can play an important role in developing future-ready human capital equipped with knowledge, digital competence, creativity, critical thinking and problem-solving abilities. However, educational transformation should not be measured by the extent of AI adoption alone. Its value depends on its ability to improve learning outcomes, expand equitable access and strengthen the capabilities of teachers and learners.

Teachers will remain central to this transformation by serving as mentors, learning designers, facilitators and ethical guides. AI should augment rather than replace human judgement, empathy and pedagogical expertise (Miao and Cukurova, 2024). Similarly, learners require responsible AI literacy that enables them to critically evaluate AI-generated information and maintain independent thinking (Miao *et al.*, 2024). Responsible implementation must address academic integrity, privacy, bias, misinformation, accessibility and digital inequality through appropriate governance and human oversight (Miao and Holmes, 2023). India's linguistic and socio-economic diversity further demands multilingual resources, accessible technologies and equitable digital infrastructure, consistent with the technology-enabled and inclusive educational vision of NEP 2020 (Government of India, 2020).

Thus, the pathway towards Viksit Bharat@2047 can be expressed as:

Empowered Teachers + Future-Ready Learners + Intelligent Technologies + Inclusive Access + Responsible Innovation = Education for Viksit Bharat@2047

AI-enabled smart education, when implemented ethically, inclusively and with clear pedagogical purpose, can contribute significantly to transforming India's educational vision into a knowledge-driven and developed Viksit Bharat@2047.

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LIBRARIES FOR NATIONAL DEVELOPMENT: DIGITAL TRANSFORMATION, INNOVATION AND KNOWLEDGE ACCESS

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Abstract

Historically, libraries have been defined by their collections of print material, but the twenty-first century has transformed them into dynamic hubs of digital knowledge, data stewardship, and technological innovation. This paper explores the development of libraries from repositories of books to complex organizations that manage data, provide computing infrastructure and foster online literacy. Based on trends in institutional repositories, big data analysis, artificial intelligence, open access publishing, and makerspace design, the paper contends that the modern library's core value lies not in the physical storage of information but in facilitating discovery, access, and responsible use of knowledge in all its forms. The paper also examines how the role of library professionals is changing and ongoing challenges such as the digital divide, data privacy and sustainable funding, before concluding with recommendations for libraries wanting to stay relevant as knowledge ecosystems continue to develop.

Keywords: Digital Libraries, Information Science, Artificial Intelligence, Open Access, Digital Literacy.

1. Introduction

For centuries the library was the book. Its architecture, staffing, and metrics of success -shelf space, circulation counts, acquisition budgets - were designed around the physical object of print. The digital revolution of the late twentieth and early twenty-first centuries has altered this paradigm fundamentally. Today, libraries are data centres, research laboratories, digital archives and community technology hubs. This is not merely a technological change; it is a redefinition of the core mission of the library, from the custodianship of texts to the stewardship of knowledge in the broadest sense, including datasets, multimedia, software and the skills required to interpret them.

1.1 Purpose and Scope

The paper undertakes an in-depth investigation of different ways in which libraries are innovating their traditional functions. Apart from the issues of digital and data services, the paper

considers new technologies such as artificial intelligence and machine learning, the library as a place of creation, and rethinking the role of the librarian. The paper explores the opportunities and challenges these innovations present to different types of libraries including academic, public, and special libraries. This discussion informs the general trends in the development of libraries as a whole.

1.2 Methodological Approach

The present paper includes a synthesis of the reviewed literature. The current analysis focuses on professional literature, reports, and practice found in academic, public, and national libraries. All of the retrieved information has been sorted and structured according to the common themes. Instead of presenting the collected data in an analysed form, as would have been the case if quantitative research had been used, the current paper synthesizes the reviewed literature in the form of Figure 1 below. The figure can be used to demonstrate how the role of the library professional has evolved, grown into the digital age, transformed, responded to professional changes, and what challenges have emerged alongside these developments. It was necessary to develop this synthesis in order to better guide the target audience rather than testing a hypothesis.

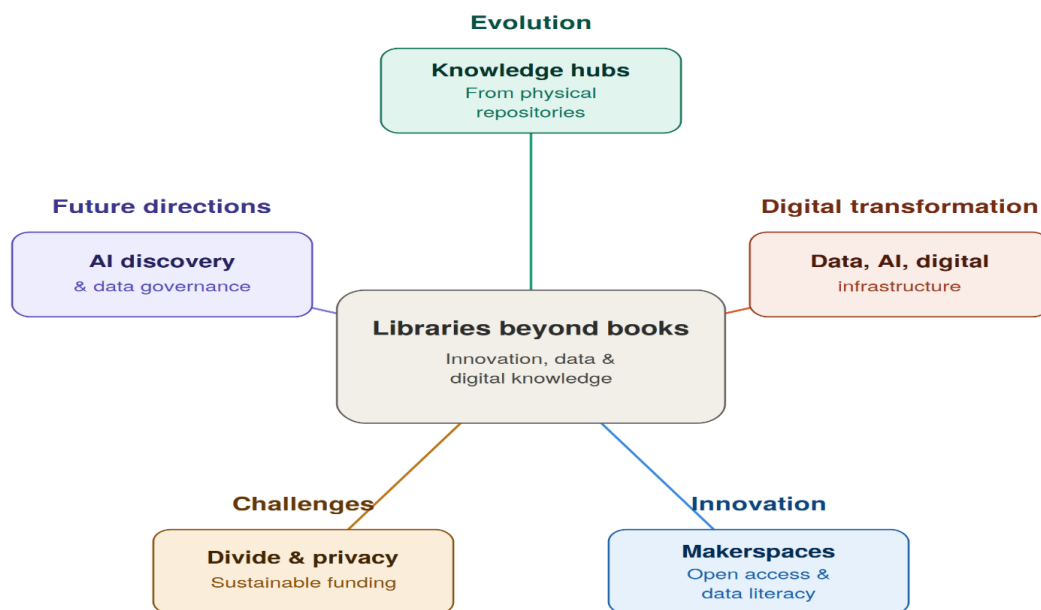


Figure 1: Library's expanding role around five interconnected dimensions

2. The Evolution of Libraries: From Repositories to Knowledge Hubs

The development of society from the first libraries, as repositories of static collections of items, into the dynamic centres of knowledge hubs is reflected in the series of conceptual shifts presented in Figure 2. These shifts are manifested in waves, which do not completely replace previous elements but rather accumulate in the library's capabilities, which means that a modern

library integrates the functions of the print-based library and the automated, networked, and data-driven systems.

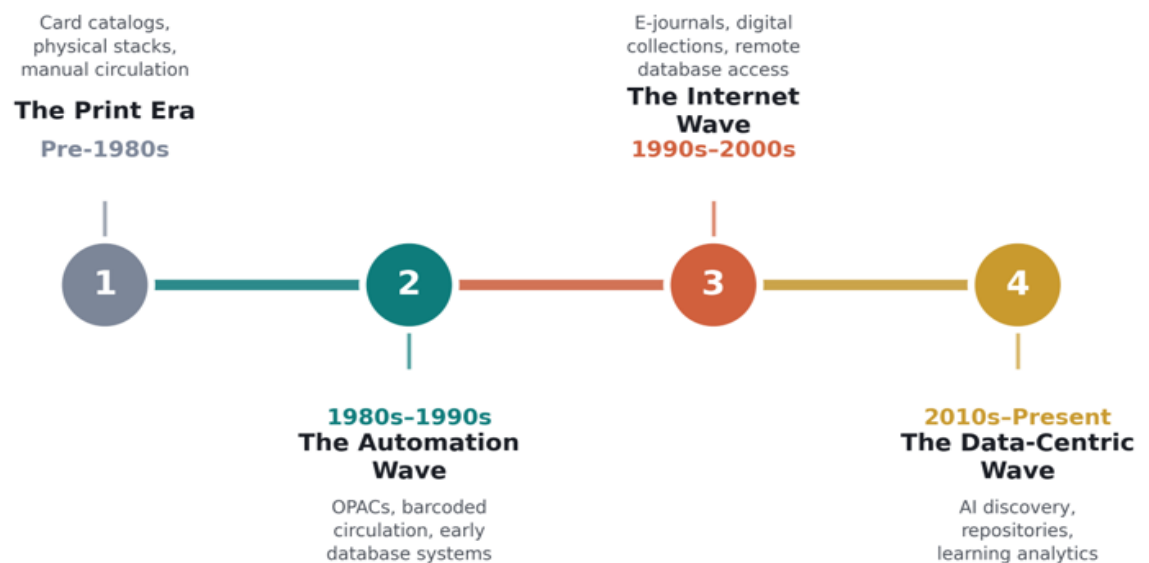


Figure 2: Four waves of library evolution, from the print era to the data-centric present

2.1 The Print Era

Before automation, libraries consisted in part of shelf lists, closed and open stacks, and circulation records. Discovery was largely through browsing and the guidance of reference staff; access was local, in that a patron could not find an item not available in the library's collection.

2.2 The Automation Wave

Beginning in the 1980s and extending through the 1990s, libraries saw the advent of integrated library systems (ILS) which computerized circulation, acquisitions, and cataloguing. The card catalogue was replaced by the Online Public Access catalogue (OPAC) which for the first time permitted keyword and Boolean searching and formed the technical basis for later networked discovery systems.

2.3 The Internet Wave

The rise of the World Wide Web in the 90s and early 2000s saw the extension of the library into the world wide web. Licensed databases, electronic journals, and early digitized collections made research materials available to users from remote locations. Additionally, link resolvers and federated search tools enabled the integration and unification of disparate electronic resources, facilitating unified discovery.

2.4 The Data-Centric Wave

The current wave is about embracing data, or information, as a key library asset type, as well as leveraging institutional repositories that collect research outputs, learning analytics that track

user interactions, and artificial intelligence that catalogues information. The current wave puts the library at the centre of a data economy, rather than as an information distribution channel for the printed word.

3. Digital Transformation in Library Services

3.1 Digital Libraries and Institutional Repositories

Digital libraries are the concept, which covers the organization of digitized or born-digital resources, which can be distributed through networks for easier access. The institutional repositories ensure that works of authors are archived and distributed in order for their further use. These repositories can be used in order to meet the requirements of funding agencies and organizations. They also play a great role in disseminating research results and making sure that works of authors are widely accessible.

3.2 Big Data and Analytics in Library Services

Libraries produce a considerable amount of data from circulation, databases, web sites, and interlibrary loans. By analysing this data, libraries can make decisions about such issues as collection management and hours of operation. Many libraries offer services that facilitate big data research, including providing computer power, statistical analyses, and instruction in using such tools as R, Python, or other data-intensive software.

Moreover, libraries support big data researchers at different stages of their research, as shown in Figure 3. A library can help with organizing and managing your data at the beginning of your research, advise you on what statistical or related software to use when processing and analysing it, and assist in storing, distributing, or even reusing the data afterwards.



Figure 3: Research data lifecycle and the points at which library services intersect with it

3.3 Artificial Intelligence and Automation

Artificial intelligence is being used in diverse ways in libraries. At the highest level, there are already AI-driven discovery layers using semantic search and natural language processing to help users find information and answer simple questions. Meanwhile, chatbots are being used to field routine reference requests. Machine learning algorithms help create metadata, identify duplicates in large data sets, and analyse collections to predict future demand. However, these technologies may create new challenges, such as bias in training data and the need for human librarians to develop specialized expertise in order to effectively manage and supervise complex systems.

3.4 Cloud Computing and Interoperability

Cloud-based library services and shared library management systems lower maintenance costs for local IT infrastructure while enabling resource sharing at the consortial level. The adoption of interoperability standards enables individual libraries to expose their data within wider library networks, increasing the overall findability and visibility of each participating library's resources far beyond what any one library could accomplish on its own. This is achieved, for example, through application of OAI-PMH protocol for repository discovery, and linked-data principles for bibliographic metadata.

4. Innovation in Library Services

4.1 Makerspaces and Creative Labs

Many public and academic libraries have created maker spaces that include 3d printers, laser cutter, recording, studio, and electronics. This has led the library to become a place where people consume information and create it as well. With information and creations like this the library can provide opportunities for entrepreneurship and innovation.

4.2 Data Literacy and Digital Literacy Programs

As data becomes embedded in civic, academic, and professional life, libraries have moved into a leading role in educating their constituents about how to engage with data. From basic digital literacy courses for underserved communities, to graduate-level research data management boot camps, and workshops for academic researchers and students on topics ranging from data visualization to research data management, libraries are playing a critical role in cultivating a data literate society.

4.3 Open Access and Open Data Initiatives

Libraries have positioned themselves at the forefront of the open access publishing movement and the open data movement. By negotiating transformative agreements with publishers, by providing open access journal platforms, and by hosting open data sets, libraries seek to lower

barriers to scientific knowledge and ensure that taxpayer-funded literature is publicly accessible. These efforts intersect with efforts to promote research integrity and reproducibility and to ensure that data are available to meet the demands of replication and transparency.

4.4 Extended Reality and Immersive Learning

A smaller, but significant, number of libraries have embraced the challenge of using these cutting-edge tools for teaching, sharing cultural heritage, and developing skills and competencies - for instance, allowing users to take a virtual field trip to a reconstructed historical site or practice a skill in an immersive virtual reality environment. These libraries are demonstrating their willingness to lead by exploring new technologies for the benefit of their communities, despite the costs and challenges that can arise during implementation.

4.5 Community Engagement and Civic Innovation

In addition to traditional research and educational services, libraries are starting to see themselves as places where citizens can gather for hackathons, meetings of budgetary responsibility, small-business assistance, and open-data events that engage the community with government information. This is an extension of libraries' traditional role as public institutions that serve as neutral grounds for information exchange.

4.6 Traditional vs. Digital/Data-Driven Libraries

Table 1: Key differences between the traditional library model and the emerging digital, data-driven model discussed throughout this paper

Dimension	Traditional Library	Digital / Data-Driven Library
Primary Asset	Printed books and periodicals	Datasets, e-resources, institutional repositories
Access Model	On-site, single-user borrowing	Remote, simultaneous, API-enabled access
Discovery	Card catalogue / OPAC keyword search	AI-assisted semantic and federated search
Staff Role	Custodian and reference guide	Data curator, technologist, learning facilitator
Space Function	Reading and storage	Makerspace, lab, collaboration hub
Value Metric	Circulation counts	Engagement analytics, data reuse, digital literacy outcomes

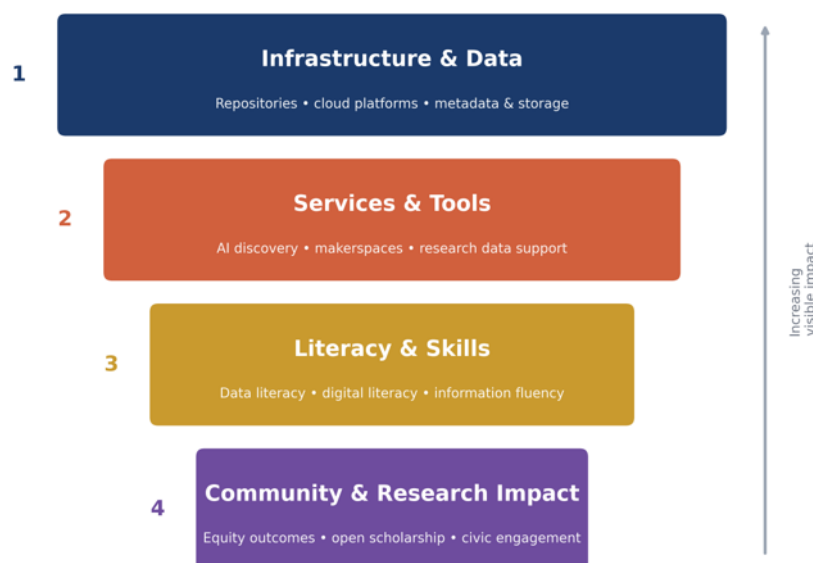


Figure 4: The Library Innovation Stack - four cumulative layers from infrastructure to community impact

5. The Changing Role of the Library Professional

As Figure 4 shows, each of the layers in the library innovation stack is built on top of the previous level, and all require professionals to manage them. In turn, the role of a librarian has expanded tremendously beyond the traditional roles of cataloguing and reference activities.

5.1 New and Emerging Skill Sets

The modern librarian needs to know about data, how to write simple scripts or analyse results with statistical packages, be able to design new interfaces for users, and manage projects, in addition to traditional skills in information organization and instruction. The libraries of today need data services librarians, digital scholarship librarian, and systems librarian, positions that didn't exist a few decades ago.

5.2 Professional Development and Continuing Education

Because technology and data practices are changing rapidly, library associations, graduate schools, and individual institutions have seen an increase in continuing-education opportunities focusing on research data management, applied artificial intelligence, and accessibility. Additionally, many libraries are investing in cross-training initiatives to ensure that staff members without technical backgrounds can gain sufficient proficiency to advise patrons confidently.

5.3 Interdisciplinary Collaboration

Library staff are more likely to work in collaboration with researchers, information technology departments, institutional research offices, and community groups rather than being an isolated entity. This is because the library is able to position its knowledge of metadata, discovery, and

information ethics in a wider research and community-building context rather than waiting for people to come to them.

6. Challenges and Opportunities

6.1 The Digital Divide

Although offering digital services, the availability of broadband, devices, and skills is uneven, which means that not all patrons will be able to benefit from the library's digital transformation. The public library plays an essential role in addressing this issue since it helps to ensure that all members of the community have equal access to its digital services, despite the limitations of the organization.

6.2 Privacy and Data Security

Libraries have long maintained ethical standards of patron privacy, and this issue becomes even more relevant in the context of data analytics. The same tools that can increase the efficiency of libraries and help them serve their clients better can also be used to violate their privacy in terms of behavioural patterns. This is why libraries should consider implementing balanced strategies towards data mining in order to ensure that their benefits from such activities outweigh potential negative implications, including the risks to intellectual freedom.

6.3 Sustainability and Funding

The digital infrastructure, the costs of which libraries have to bear, and the need for staff training present-day challenges to libraries. Libraries with limited budgets set up on print-based cost structures experience contradictions between their own print-based budgets and the costs of ongoing digital transformation, which includes subscription inflation, technology upgrades, and long-term digital preservation.

6.4 Workforce and Organizational Change

Expanding into data and technology services may present challenges to organizations focused on print-based job descriptions and processes. It may also be hard to attract and keep talented professionals who want to work in a different environment where their skill set is in higher demand, and those who stay may feel that their previous contributions were undervalued.

6.5 Equity and Inclusion in Digital Services

Digital transformation has the potential to worsen the digital divide if it is pursued in ways that favour those who are already well-served. Accessible design for people with disabilities, translations for those who do not speak the language of the dominant culture at home, and targeted outreach efforts in the neighbourhoods and communities that the library might not already serve are necessary prerequisites to any program of enhanced data or technology-enabled services. Without them, better access for some is likely to be simply better access for those who were already getting the most out of the library.

7. Illustrative Examples

The patterns described are not abstract things only, but actual practices carried out in many different libraries. The following are all examples of the pattern described by figure 1:

Academic institutional repositories, which collect together research outputs and facilitate deposit to enable compliance with open access mandates, often embedded in research information management systems for evaluating research impact. Public library systems offering 'maker' technologies, coding clubs for children, and workshops in data literacy in addition to their traditional lending and informational services, often in collaboration with local schools and employers. National and research libraries embedding specialist support for research data management, including computational and data advisory services and long-term archive storage, within their remit in close cooperation with relevant academic departments

Library-run digitization projects which seek to make special collections accessible in digital form as part of wider programs of scholarly communication, far beyond the resources of any one institution. Consortia and shared digital infrastructure schemes allowing smaller libraries to offer services which they would not otherwise be able to support by themselves.

8. Future Directions

Looking ahead, libraries are likely to evolve into more data-savvy enclaves, facilitating the exchange of raw data for refined knowledge, and are likely to see an increase in their role as partners with data science and research units, using artificial intelligence for knowledge discovery, and educating the public about evaluating algorithmically generated information; libraries are also natural advisers on broader issues of data ethics and governance.

The very nature of the research library as an intermediary between knowledge producers and consumers will change fundamentally as the boundaries between library, archive, laboratory and classroom become more porous, and the library building itself ceases to be the sole access point to the institution, being joined by virtual reference desks, embedded research assistance, and other digital tools.

8.1 Discussion

Taken together, the trends discussed in this paper indicate a library sector that is rapidly outpacing its own funding models and staffing practices. The evidence suggests that the field is seeing verifiable benefits in areas such as scholarly communication and discovery, civic engagement, and technical scope and scale. At the same time, each of these areas has seen negative consequences or costs, whether in the form of new biases encoded in search algorithms, the loss of privacy in connected services, or the financial and human costs of broadened technical capabilities. This is not to suggest that the turn toward digital services and data is itself a negative force, but rather to indicate that it is a complex set of choices with negative

consequences for areas of importance to libraries. This paper's findings suggest that libraries which approach data ethics, sustainability, and workforce development as enduring issues will be best positioned to benefit from the opportunities identified in this report.

Conclusion

The twenty-first century library is much more than a repository for the books. It is an innovation center focused on curating data, building digital skills, engaging with open science, and providing physical and virtual workspaces for its users. This is not a diminishment of its traditional role as a guardian of the public library values but rather an expansion of them in new directions. As data becomes more important to research, learning, and society more generally, libraries have a unique responsibility, given their professional mandate, to help their communities navigate these emerging arenas.

The most important investment that will enable the library to realize its potential lies not in any particular technology but rather in people, access, and thoughtful governance, all of which underlie each component in Figure 1. These are then connected back to the library's foundational role of connecting citizens to the knowledge they need to participate in society.

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