International Journal of Academic Research
P-ISSN: 2348-7666: Impact Factor: 7.215
Homepage: https://www.ijar.org.in/
Volume-13, Issue-3(2), Jul-Sep-2026
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The Role of Science and Technology in Achieving Viksit Bharat 2047: A Critical Analysis

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Abstract
The vision of Viksit Bharat 2047 envisions India as a developed, self-reliant nation by the centenary of independence, targeting a $30-40 trillion economy, zero poverty, universal healthcare, quality education, and per capita income of $15,000-18,000. Science and technology (S&T) play a transformative role in driving economic growth, sustainable development, and social inclusion through initiatives like Digital India, National AI Mission, and Green Hydrogen Mission. This paper critically analyzes S&T's multifaceted impact on India's developmental trajectory, highlighting integration of emerging technologies such as artificial intelligence (projected to add $967 billion to GDP by 2035), green energy solutions (aiming for 500 GW non-fossil capacity by 2030), biotechnology, and digital infrastructure like UPI and BharatNet.Science and technology clusters emerge as vital hubs, fostering research, innovation, and collaborative ecosystems among government, academia, and industry, accelerating progress in critical sectors including healthcare (e.g., eSanjeevani's 230 million consultations), agriculture (precision farming for 5 million farmers), renewable energy, and smart infrastructure.
The analysis addresses persistent challenges: a digital divide affecting 350 million (rural women at 29% access), inadequate R&D investment (0.7% of GDP versus targeted 3%), cyber security threats (12 million attacks in 2023), and brain drain.Phased milestones outline the roadmap: 2025-2030 for foundational infrastructure and S&T clusters; 2030-2040 for technology acceleration and pollution reduction; 2040-2047 for global leadership in clean energy and knowledge economy. Achieving these ambitious goals demands strategic investment in human capital, robust innovation ecosystems, public-private partnerships, and adherence to "Science for Sustainability" principles to ensure equitable growth without environmental compromise.
Through this critical lens, the paper offers insights and recommendations such as regional clusters, ethical AI governance, and women-led innovations for leveraging S&T to realize an inclusive, prosperous, and sustainable Viksit Bharat by 2047.
Keywords: Viksit Bharat 2047, Science and Technology, Innovation Ecosystems, Digital Divide, Sustainable Development.

1. Introduction

India's Viksit Bharat 2047 roadmap charts a bold path to self-reliance amid global geopolitical shifts, economic disruptions, and climate imperatives, positioning science and technology (S&T) as the indispensable catalyst for transitioning to a high-income economy that serves 1.4 billion people equitably. Articulated through NITI Aayog's vision documents and Prime Minister's addresses, this ambition targets a $30-40 trillion GDP, zero poverty, universal healthcare, and per capita income exceeding $15,000 by the centenary of independence. S&T emerges not merely as an enabler but the core engine, powering leapfrog innovations from legacy challenges like infrastructure deficits to frontier opportunities in digital sovereignty and sustainable manufacturing.

Remarkable strides underscore this momentum: Tele-density surged from 75% in 2014 to 84% in 2024, propelled by digital public goods like Aadhaar now linking 1.3 billion identities and UPI, which processes over 12 billion transactions monthly, revolutionizing financial inclusion for unbanked masses. India's Global Innovation Index ranking climbed from 81st in 2015 to 40th in 2023, reflecting matured ecosystems with over 100 unicorns, bolstered by Startup India and Atmanirbhar Bharat funds totaling ₹10,000 crore. These gains signal S&T's capacity to democratize opportunity, from rural e-governance to urban smart cities.

Yet, critical gaps persist, exposing vulnerabilities that could derail progress. Rural women face only 29% internet access compared to 82% for urban men, perpetuating a digital divide affecting 350 million citizens. R&D investment lingers at 0.7% of GDP far below Israel's 5% or South Korea's 4.8% constraining breakthroughs in core technologies. S&T clusters, such as those in Bangalore and Hyderabad, foster interdisciplinary research in

AI, green energy, and biotech, proving vital for sustainability by slashing R&D duplication and accelerating commercialization.

This paper dissects S&T's role across key sectors from digital infrastructure to space interrogating challenges like cyber security threats and brain drain, while charting pathways forward. Drawing on 18 peer-reviewed journal references, it delivers evidence-based critique emphasizing public-private synergies. Phased goals structure the journey: foundation-building (2025-2030) for infrastructure and clusters; acceleration (2030-2040) for tech adoption and emission cuts; leadership (2040-2047) for global dominance in clean energy and knowledge economies. Failure risks entrenching inequalities; success promises inclusive prosperity, redefining India as a S&T vanguard.

2. India's S&T Landscape

India's science and technology (S&T) ecosystem has matured significantly, underpinning the Viksit Bharat 2047 vision with robust digital and innovation foundations. The country boasts 1.22 billion telecom subscribers, reflecting near-universal connectivity, while BharatNet has connected 1.7 lakh gram panchayats, enabling high-speed internet in remote areas and facilitating e-governance services for over 600 million rural users. Startup India has catalyzed explosive growth, spawning more than 100 unicorns primarily in fintech and agritech, supported by ₹10,000 crore in dedicated funds that have democratized venture capital and fostered homegrown solutions like digital lending platforms and AI-driven crop advisory tools.

The National Education Policy 2020 marks a pivotal shift, targeting to skill 50 million youth through STEM-vocational fusion, integrating multidisciplinary learning and industry apprenticeships to bridge academia-industry gaps. R&D expenditure stands at 0.7% of GDP nationally, though institutional progress shines: IIT Delhi's allocation rose from 0.68% to 1.02%, signaling targeted excellence in premier institutes. Department of Science and Technology (DST) portals like India Science, Technology & Innovation (ISTI) spotlight fellowships, biotech grants, and collaborative platforms, channeling resources to emerging fields.

Metric	2014 Value	2024 Value	Growth %
Tele-density	75%	84%	12%
Unicorns	0	100+	N/A
R&D (% GDP)	0.65%	0.7%	8%

Critically, urban bias dominates, with 70% of investments concentrated in metros, neglecting rural potential where satellite technologies like ISRO's GISAT could bridge connectivity and precision agriculture gaps, ensuring inclusive scaling.

3. S&T in Key Sectors

Science and technology (S&T) integration across key sectors forms the backbone of Viksit Bharat 2047, enabling leapfrog development in economic productivity, sustainability, and inclusivity. From digital ecosystems powering financial inclusion to space missions asserting global prowess, these advancements address India's unique challenges like population scale and resource constraints. However, critical analysis reveals synergies alongside inequities, demanding targeted interventions for equitable scaling.

3.1 Digital Infrastructure and AI

Digital India has revolutionized connectivity, deploying over 200,000 Wi-Fi hotspots through PM-WANI, bridging urban-rural gaps and enabling real-time data access for millions. Complementing this, Unified Payments Interface (UPI) processes 12 billion transactions monthly, democratizing finance rural adoption surged 150% since 2020, reducing cash dependency in remote areas. This infrastructure underpins the $7.8 billion AI market, nurturing 5,000 startups focused on vernacular solutions and sector-specific applications. Healthcare leads with 45% AI adoption, where predictive diagnostics via machine learning models forecast disease outbreaks with 90% accuracy, optimizing resource allocation in overburdened public systems.

AI4Bharat's natural language processing (NLP) tools support 22 Indian languages, empowering non-English speakers in education and governance over 1 million developers have accessed its open-source repositories. Economic projections are staggering: AI could contribute $967 billion to India's GDP by 2035, primarily through automation in manufacturing and personalized services in agriculture.

3.2 Renewable Energy

India's renewable energy sector exemplifies S&T-driven sustainability; achieving 170 GW installed capacity by 2023 up from 35 GW in 2014 while targeting 500 GW non-fossil sources by 2030. The National Green Hydrogen Mission, with ₹19,744 crore investments, positions India as a global exporter, leveraging electrolyzer tech for clean fuel production at scale. Gujarat's Charanka Solar Park, boasting 600 MW, integrates advanced photovoltaic panels and tracking systems, generating power for 500,000 homes annually and creating 10,000 jobs.

Source	2014 (GW)	2023 (GW)	Projected 2030 (GW)
Solar	3	70	300
Wind	21	42	140
Hydro	11	58	60

Growth stems from policy innovations like feed-in tariffs and rooftop solar subsidies, yet intermittency challenges persist solar output varies 40-60% daily. Battery storage solutions, including lithium-ion and emerging sodium-ion tech, are critical; pilot projects aim for 20 GW storage by 2027. Policy silos between states hinder grid integration, while land acquisition delays projects. A critical push for indigenous manufacturing under PLI schemes could cut import reliance from 80% to 30%, ensuring energy security for Viksit Bharat.

3.3 Biotechnology and Healthcare

The biotechnology sector, valued at $92 billion in 2023, underscores S&T's life-saving impact Covaxin vaccinated 250 million during the pandemic, showcasing rapid indigenous mRNA and viral vector platforms. Ayushman Bharat Digital Mission (ABDM) has registered 430 million health IDs, creating a unified ecosystem for seamless records. eSanjeevani telemedicine platform delivered 230 million consultations, reducing urban migration by 30% in rural areas and expanding specialist access.

CRISPR gene-editing advances personalized medicine; trials for sickle cell anemia target 1 million patients by 2030. AI-biotech fusion enables drug discovery in weeks, not years Indian firms like Serum Institute lead global trials. Challenges include regulatory harmonization and cold-chain logistics for vaccines. Scaling via biotech parks in Hyderabad and Bangalore could triple exports to $150 billion, aligning with Viksit health goals of universal coverage.

3.4 Agriculture and Industry 4.0

Precision agriculture leverages drones for 5 million farmers, optimizing inputs via soil sensors and satellite imagery, boosting yields 20-30%. eNAM platform facilitates ₹72,000 crore in trades, linking 1,000 mandis digitally. Production Linked Incentive (PLI) schemes elevated electronics exports 20%, while SAMARTH Udyog Bharat 4.0 upskilled 1,200 MSMEs in IoT and automation.

Technology	Adoption %	Impact on Yield/Output
IoT	35	+25% efficiency
Robotics	28	+18% productivity
Drones	22	+15% water savings

Industry 4.0 integrates cyber-physical systems, but smallholder farmers face data literacy barriers. Blockchain for supply chains could ensure traceability, reducing post-harvest losses from 20% to 5%.

3.5 Space and Defence

ISRO's Chandrayaan-3 lunar landing and Aditya-L1 solar mission attracted ₹1,000 crore in private investments, spawning 200 startups in satellite tech. Geospatial applications aid disaster management, predicting floods with 85% accuracy via INSAT data. Indigenous 6G development targets 100 Gbps speeds by 2030, enabling smart cities.

Defence S&T focuses on drones and hypersonics; DRDO's Agni-VI extends strategic reach. Public-private models like iDEX fund 500 innovators. Critically, export controls limit global integration.

Sectoral synergies AI enhancing renewables, biotech informing agriculture thrive through data interoperability, potentially adding $1.5 trillion to GDP. Exclusionary growth critiques equity: urban hubs capture 70% investments, sidelining 65% rural population. Viksit Bharat demands decentralized S&T diffusion via Jan Aushadhi-like models, ensuring last-mile benefits. Policy must prioritize women (only 15% STEM workforce) and SMEs for holistic transformation.

4. Critical Challenges

Critical challenges within India's science and technology (S&T) trajectory pose serious risks to the realization of the Viksit Bharat 2047 vision. The most visible fault line is the digital divide: nearly 350 million people remain offline, with rural women disproportionately affected due to intersecting barriers of geography, gender norms, affordability, and low digital literacy. This exclusion undermines the very promise of digital public infrastructure Aadhaar, UPI, BharatNet, and telemedicine by restricting access to key services in education, healthcare, finance, and e-governance. When connectivity and devices are concentrated among urban, educated males, digitalization can deepen existing inequalities rather than level them.

Cyber security presents a second structural vulnerability. With an estimated 12 million cyber attacks reported in 2023, targeting financial platforms, government databases, and critical infrastructure, the rapid expansion of digital systems has outpaced the development of robust cyber hygiene and institutional resilience. Frequent phishing, ransomware, and data breach incidents erode citizen trust in e-governance and digital payments, and expose sensitive personal and strategic data. Parallelly, brain drain continues at scale, with around 1.3 million students and professionals emigrating annually for education and high-end jobs. This persistent outflow of skilled talent weakens India's capacity to build and retain globally competitive S&T capabilities at home.

Skill mismatches intensify these pressures. Automation, AI, and Industry 4.0 technologies are transforming job profiles faster than curricula and training systems can adapt, necessitating the reskilling or upskilling of nearly 50% of the workforce by 2027. Without large-scale, targeted skilling in AI, data science, advanced manufacturing, and green technologies, India risks a dual crisis: unemployment among low-skilled workers and shortages of high-skilled professionals. At the macro level, a chronic R&D investment shortfall hovering around 0.7% of GDP, far below innovation leaders stifles breakthrough research and deep-tech development. This underinvestment contributes to continued import dependence in strategic sectors like semiconductors, high-end electronics, and critical materials, which in turn constrains technological sovereignty and exposes the economy to external supply shocks.

Environmental costs add another layer of complexity. The rapid tech boom data centres, electronics manufacturing, battery production, and urban infrastructure has a significant ecological footprint in terms of energy use, e-waste, and resource extraction. Without strong regulatory frameworks and adoption of circular economy models (recycling, reuse, repair ecosystems, green design), S&T-led growth can conflict with climate and sustainability commitments. Overarching these issues is policy fragmentation and a pronounced urban–rural skew: schemes and investments often remain siloed across ministries and are heavily metro-centric, leaving large swathes of rural and aspirational districts under-served. This fragmentation dilutes impact, slows scaling of successful pilots, and undermines the inclusive, balanced development that Viksit Bharat 2047 aspires to achieve.

5. Strategic Recommendations, Case Studies, Future Outlook, and Conclusion

5.1 Strategic Recommendations

To overcome critical gaps and harness S&T's full potential for Viksit Bharat 2047, India must implement bold, multi-pronged reforms. First, triple R&D investment to 3% of GDP through targeted tax incentives such as 200% deductions for private R&D and establishment of 50 new regional S&T clusters by 2030, decentralizing innovation from metros to underserved states like Bihar, Odisha, and the Northeast. These clusters would prioritize deep-tech in semiconductors and quantum computing backed by ₹50,000 crore in seed funding.

Mandate comprehensive AI ethics laws, including bias audits, explainable AI standards, and data sovereignty protocols under the National AI Mission, preventing discriminatory outcomes in hiring and lending. Expand BharatNet to achieve 100% rural broadband coverage by 2028, integrating satellite tech like ISRO's GISAT for last-mile connectivity, thereby closing the digital divide for 350 million offline users. Skill 50 million youth via National Education Policy (NEP) 2020-aligned programs, with 40% quotas for women in STEM apprenticeships and reskilling platforms like Future Skills PRIME, focusing on AI, robotics, and green tech.

A phased roadmap structures progress:

2025-2030 (Foundation): Build critical infrastructure, including three semiconductor fabs under India Semiconductor Mission and indigenous 6G trials for 100 Gbps networks.

2030-2040 (Acceleration): Scale green hydrogen production to 5 million tonnes annually and enforce AI governance frameworks with international benchmarks.

2040-2047 (Leadership): Attain net-zero emissions via advanced storage and lead global space economy through private ISRO partnerships.

Public-private partnerships (PPPs) must drive sovereign capabilities in defence and AI, with models like iDEX funding 1,000 innovators annually. These measures ensure resilience against global disruptions.

5.2 Case Studies: Successes and Lessons

Real-world successes illuminate scalable pathways. Covaxin exemplifies biotech speed: developed indigenously in under a year, it vaccinated 250 million, showcasing mRNA platforms and regulatory agility that cut import reliance by 90% during crises. Lessons include agile clinical trials and public-private collaboration via ICMR-Bharat Biotech ties, urging replication in oncology and rare diseases.

UPI revolutionized financial inclusion, processing 12 billion transactions monthly and onboarding 400 million rural users since 2016, slashing remittance costs by 95%. Its success stems from NPCI's open API architecture, teaching the value of interoperable digital public goods for eNAM and health IDs.

Gujarat's Charanka Solar Cluster boosted 10,000 jobs and 600 MW capacities through academia-industry integration, reducing solar tariffs 70%. Key lesson: Anchor local manufacturing via PLI schemes to capture 30% global value chains.

Collectively, these highlight scaling successes rurally e.g., UPI kiosks in villages and mitigating biases through diverse datasets, preventing exclusion in AI-driven services.

5.3 Future Outlook

By 2047, S&T synergies AI optimizing green energy grids, biotech enhancing agritech yields could add $5-7 trillion to GDP, positioning India as the third-largest economy with leadership in 6G, quantum, and space. AI-green fusions promise 20% emission cuts via predictive maintenance; space economy targets $44 billion via 10,000 satellites.

Global partnerships with Quad nations amplify R&D, while ethical innovation via DPIIT sandboxes ensures trustworthiness. Equity focus remains imperative: rural digital academies and women-led startups (aiming 30% STEM participation) will democratize gains, averting dystopian divides.

6. Conclusion

Science and technology (S&T) unequivocally propels Viksit Bharat 2047 toward inclusive, sustainable prosperity, serving as the engine for a $30-40 trillion economy, zero poverty, and global leadership. Digital revolutions like UPI and BharatNet, AI synergies adding trillions to GDP, renewable scaling to 500 GW, and biotech triumphs like Covaxin demonstrate S&T's transformative power across sectors.

Yet, critical gaps in equity digital divide for 350 million, rural women's 29% access and investment (0.7% GDP R&D) demand closure through bold policies: tripling funding, regional clusters, ethical AI laws, and skilling 50 million youth. Collaborative resolve among government, industry, and academia, via phased roadmaps to 2047, can bridge urban-rural skews and ensure resilience.

By prioritizing "Science for Sustainability," India transcends challenges, positioning itself as a tech vanguard self-reliant, equitable, and innovative by its independence centenary.

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