

INDIA'S AI IMPERATIVE

Building National Competencies
in a New World Order

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Editors





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Editors' Note

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Applications of Artificial Intelligence (AI) could add trillions of dollars to economies globally in the coming years. By 2027, AI adoption is expected to help India achieve its ambitions of becoming a US\$26-trillion economy—the world's third largest.¹ Projections also indicate that up to 2027, India's AI market could grow at a compound annual growth rate (CAGR) of 25-35 percent, with generative AI comprising 33 percent of the market share.² Indeed, AI is already propelling transformations across a broad spectrum of domains such as health, education, agriculture, and smart cities.

The optimism about India's AI advances, however, is often tempered by considerations involving its compute capacity, the availability of data and cutting-edge technical skills, the need to balance innovation with regulatory and legal priorities, and the institutional changes required to effect lasting change.

As India works to integrate and leverage AI capabilities for national economic transformation, it must navigate the currents emanating from the world's centres of AI innovation and regulation. These hubs exert influence and power through resource consolidation, or the extra-territorial scope of their regulations. They also tend to structure the conditions under which India is building its AI capabilities, and provide a context for the country's efforts to craft its roadmap for AI readiness.

Developing national capabilities in AI depends as much on internal capabilities, institutions, and stakeholder networks as it does on geopolitical conditions and relations between the two global leaders in AI innovation, i.e., the United States and China, combined with the impact of AI legislation emerging from the European Union. At the level of deployment and impact, on the other hand, given a suitably enabling environment for tech innovation, AI solutions could transform the domains of social and economic development, as well as those of security, defence, critical technologies, and space.

A number of AI indexes rank India's AI capabilities across different parameters, with widely varying results. For instance, an International Monetary Fund index places the country 72nd among 174 nations;³ a Boston Consulting Group study places it in the top 10 in a group of 73;⁴ and the Stanford AI index highlights India's high rates of skill penetration and GitHub contributions.⁵ Most indexes agree that India's tech workforce and talent are among its key strengths. Yet, they also appear to indicate that more could be done to strengthen other aspects of its national AI ecosystem—such as its infrastructure and regulatory landscape—in order to make it more competitive globally in the AI space.

Understanding India's AI imperative calls for a holistic and nuanced exploration of geopolitical, developmental, strategic and security issues around its development and deployment.

This compendium seeks to contribute to the discourse. The first section, 'India in the AI World Order', contextualises Indian priorities within the emerging global AI order with respect to partnerships with the United States, China's rapidly expanding AI prowess, and the EU's focus on regulating AI. The second section, 'Building

National Competencies', examines core elements of India's AI ecosystem, including governance structures, compute, data, and AI skilling efforts. 'Driving Sectoral Transformations' then investigates India's experience in applying AI to four of the high-priority development sectors identified by its *National Strategy on AI* of 2018. The compendium's concluding section, 'Security and Strategy' reflects on the application of AI to the critical areas of national security, the military, defence, and space.

The volume brings together essays by ORF's experts on geopolitics and international relations, technology and development, and security and strategy. As India takes its place among the world's leading AI powers, it is our hope that the insights and knowledge contained in this compendium will inform public policy deliberations and help shape the country's AI capabilities and governance frameworks.

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I

**India in the AI
World Order**

India, the United States, and the Global AI Order

Vivek Mishra and Pankaj Fanase

The debate over a potential shift to a multipolar world order, involving multiple powerful actors, has become more vociferous. Various factors, including wars and economic shifts, are driving the changes in the global order; the most impactful, however, are the technological advancements, including Artificial Intelligence (AI). Unlike previous technological innovations that acted as tools or enablers, AI functions both as an enabler and a decision-maker, capable of influencing outcomes autonomously. This unique characteristic of AI amplifies its potential to disrupt traditional power structures, making it an important player in shaping the future global order. As AI advances, it will add new dimensions to global competition and cooperation, accelerating the shift in power dynamics worldwide.

AI, as a transformative technology, is reshaping the international system by introducing new processes, issues, and perspectives that redefine power and governance. It creates new sources of power and control,¹ altering the foundations of military and economic strength. The United States (US) and China are in fierce competition for global leadership through tech and AI innovation, influencing alliances as countries align based on their technological abilities as well as their weaknesses.

AI is also reshaping global activities like diplomacy, war, and business. In diplomacy, AI helps leaders make data-driven decisions, predict future events, and analyse global trends. In warfare, AI brings autonomous machines that raise ethical questions while transforming the dynamics of conflict. In the economy, AI-driven automation and algorithms are changing industries, trade, and financial systems. Furthermore, AI presents new rules and challenges for foreign policy, requiring governments to address issues of AI ethics, safeguard data, and protect systems from cyber threats. This data-centric perspective, coupled with the need to engage with tech giants such as Meta, has complicated the foreign policy process.

Addressing these challenges requires management strategies that transcend state borders. AI is transforming security paradigms by enhancing information transparency and accessibility, enabling rapid data analysis for quick decision-making. However, it also introduces complex risks, necessitating stringent safeguards to prevent misuse and protect national and individual data security. Countries are increasingly using AI for gathering information, surveillance, and threat detection, fundamentally altering perceptions and approaches to security. This shift underscores the need for conceptual evolution to understand and manage AI's potential in stabilising or destabilising global security.

The 'Three Worlds'² framework—comprising the Global West, East, and South—adds a new aspect to the global AI landscape. Though loosely aligned with the 'first world', 'second world', and 'third world' classifications, this framework reflects three different paradigms: a liberal, market-driven approach in the West; a state-centric approach in the East; and an inclusivity-focused, society-centric strategy in the Global South. As AI reshapes power dynamics, the rivalry between these three groups is intensifying. However, no one is expected to dominate because of their entrenched political and developmental differences.

The West, with its strong technological leadership, and the East, especially China, with its rapidly advancing AI skills, will compete to influence the South by offering AI-driven solutions for governance, economic growth, and security. This competition

may prove more creative than destructive. For instance, the US CHIPS Act 2023 restricts cutting-edge technology access to companies like Huawei, compelling them to innovate. Huawei's potential success with 5nm chips highlights this creative nature of competition.³

The Superpowers and Evolving Alliances

The US, the European Union (EU), and China are pursuing different strategies to assert leadership in AI development and regulation, reflecting the growing importance of rising power in the global AI landscape. The US leads through legislative frameworks toward a safe and ethical AI landscape. The National Artificial Intelligence Initiative Act of 2020 and President Joe Biden's 2023 executive order address security and liability concerns, with corporations such as Amazon, Microsoft, and Google shaping innovation and governance standards.⁴

The EU positions itself as a normative leader, focusing on a human-centric and ethical approach to AI. Policies like the 2024 AI innovation package focus on supporting startups and SMEs, building an AI ecosystem aligned with EU values and liberal democratic principles.⁵ China integrates AI into its larger economic and security strategies. Initiatives like the New Generation AI Development Plan and the 'AI Plus' framework demonstrate how AI is now part of the pursuit for geopolitical influence in Beijing.^{6,7} These strategies highlight differing approaches to regulation, innovation, and geopolitical leverage, underscoring contrasting aspirations for global AI governance.

At the multilateral level, in January 2023, the US Department of State and the European Commission's Directorate-General for Communications Networks, Content and Technology (DG CONNECT) signed the "Administrative Arrangement on Artificial Intelligence for the Public Good."⁸ The Quadrilateral Security Dialogue (Quad), meanwhile, launched the AI-ENGAGE initiative⁹ to drive innovations in critical technologies such as AI, addressing economic and agricultural challenges in the Indo-Pacific region. The Quad Tech Network (QTN)¹⁰ was established in 2021 to conduct research on AI and cybersecurity, while the Quad Investors Network (QUIN)¹¹ launched in September 2024 aimed to secure the supply of technologies, essential for AI-driven economies. A landmark achievement came in September 2024 when the United States, European Union, and the United Kingdom along with 57 other countries adopted the first legally binding international treaty on AI.¹² The treaty marks an important step toward global consensus for robust international cooperation for the safe, secure, and ethical development of AI.

The US-India Partnership

The US-India Initiative on Critical and Emerging Technology (iCET),¹³ launched in May 2022, is a notable platform driving bilateral partnership. It includes strategic technology collaboration across defence industrial cooperation, trade, and academia. The initiative emphasises mutual benefit, leveraging India's growing tech ecosystem alongside the US's advanced technological capabilities—critical for developing robust, secure, and sustainable semiconductor supply chains. Over the next five years, both governments seek to generate over US\$90 million through the US-India Global Challenges Institute, to fund high-impact R&D partnerships between universities and research institutions. The launch of the US-India Advanced Materials R&D Forum and the Quantum Coordination Mechanism further highlights the depth of collaboration in emerging technologies. Additionally, the Artificial Intelligence Task Force (AI-TF), established by the US-India Business Council (USIBC) in February 2024, represents their mutual commitment to fostering AI leadership and commercialisation.¹⁴

Beyond the government sector, private players play a role in driving innovation. For instance, IBM's integration of its Watsonx platform with India's Airawat supercomputer,¹⁵ demonstrates high-level R&D cooperation to advance AI and semiconductor development. This partnership extends to critical areas like 5G deployment and next-generation telecommunications, with both governments striving to minimise hurdles to technology transfer and enhance high-tech commerce. The US-India partnership on AI and emerging technologies reflects a shared vision of technological leadership and positions AI as a force for global good. This collaboration reflects the geopolitical realities of the twenty-first century, where AI transcends its role as a tool for economic development to become a pillar of a new global order.

Indian Perspective of AI-Based World Order

The Global South often presents a narrative distinct from the dominant global discourse. India, as a leader of the Global South, offers a fresh perspective on the AI world order. India's approach is unique,¹⁶ emphasising development, inclusivity, and ethical governance over dominance or strategic hegemony. While superpowers like the US and China focus on maintaining control over AI technologies to secure geopolitical and economic leverage, India intends to use AI as a mechanism for fostering societal empowerment, bridging development gaps, and promoting equitable growth. The objective of NITI Aayog's National AI Strategy¹⁷ and IndiaAI Mission¹⁸ launched by MeitY is to apply AI in areas like healthcare, agriculture, education, and urban infrastructure. India is pushing for accessible and affordable AI technology for the Global South, reflected in programmes like the 'AI for All'

campaign.¹⁹ India has a vision for reliable and citizen-centric AI order, comprising transparency, accountability, and ethical compliance.

Conclusion

Successfully navigating the emerging AI-led world order requires strategic measures. First, co-governance frameworks are essential, as demonstrated by the legally binding international AI treaty led by 57 countries. This model must be extended through regular multilateral dialogues to ensure ethical AI use and address transnational challenges effectively.

Second, achieving balance between innovation and regulation is crucial. The US and the EU have developed sophisticated legal frameworks that can serve as templates for India and other developing countries. By adopting inclusive, human-centric policies, these countries can avoid over-regulation while fostering equitable access to AI advancements.

Third, developing AI knowledge-sharing and infrastructure in emerging economies and reducing inequalities in AI capabilities and resources. This can be achieved through enhanced South-South cooperation, complemented by traditional North-South partnerships. Strategic alliances, such as the US-India iCET, highlight the potential of bilateral collaboration in driving high-impact R&D and creating resilient supply chains for critical technologies. Finally, superpowers must recognise the importance of supporting AI for social development, aligning with the Global South's priorities of ethical and inclusive growth. By adopting these measures, the AI world order can embrace geopolitical diversity while prioritising responsible, globally beneficial innovation.

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India and the EU in the Global AI Order

Shairee Malhotra

Artificial Intelligence (AI), with its potential to create positive impact in a wide range of sectors, including education, finance, healthcare, agriculture, and public services, can be a game changer for India. However, just as important as maximising AI's societal benefits is considering its risks and unintended consequences, particularly in the form of the proliferation of deepfakes, fraud, and misinformation.

The European Union (EU) and India's strong ties and shared commitment to democracy, rule of law, and equitability present a unique opportunity to cooperate and exchange practices and research on AI.

Efforts are ongoing, with the EU–India Roadmap to 2025¹ exhorting “cooperation on promoting technical and regulatory cooperation on the development of new technologies such as AI,” in addition to working “together to share knowledge and expertise regarding AI.” Both India and the EU are also signatories to the November 2023 Bletchley declaration that promotes global cooperation, dialogue, and research on frontier AI safety.² This complements their partnership on the “operationalisation of an India-EU Joint Task Force on Artificial Intelligence”³ in May 2021 that is now absorbed⁴ within the EU–India Trade and Technology Council working group focused on strategic technologies, digital governance, and digital connectivity.⁵

India and the EU’s intent to cooperate on AI could positively shape the future of AI development, both within the countries’ own jurisdictions and globally.

The EU AI Act

The EU’s AI Act,⁶ which came into force in August 2024, is the world’s only comprehensive legislation on AI regulation so far. The Act adopts a risk-based approach to categorise AI systems along four risks levels, ranging from unacceptable AI systems, such as those for biometric identification and government-driven social scoring, to minimal risk applications, such as chatbots. By setting in place safeguards, requirements, and obligations, the provisions of the Act scheduled for full enforcement by August 2026, aim to ensure responsible AI deployment that prioritises ethics and individual rights.

Implications for India

The EU AI Act has wide-ranging implications for India’s expanding tech industry and AI capabilities.

To begin with, due to the so-called ‘Brussels effect’,⁷ a phenomenon whereby governments and companies outside the EU are forced to comply with EU regulations to gain access to the EU market, the EU approach tends to become the global norm or benchmark. This compels other jurisdictions to adopt similar standards to reduce the burden and costs of having multiple sets of compliance rules.

With its first-mover advantage, the EU’s AI Act could become the blueprint for AI regulation globally, like the EU’s 2018 General Data Protection Regulation (GDPR) designed to protect data privacy.⁸ For Indian businesses with transnational operations, this presents both a challenge and an opportunity. Failure to align with the EU AI Act may become a barrier for trade with the EU, in addition to impacting competitiveness

and scalability in the European market and adding the risk of incurring heavy fines. Therefore, Indian companies such as Wipro, Tata Consultancy Services, and Infosys have already pledged compliance with the Act.⁹ This entails performing assessments, implementing risk management measures, and ensuring overall adaptation of AI systems, all of which incur high operational costs.

On the other hand, compliance with the Act's requirements could enhance a firm's reputation for ethical practices and generate consumer confidence at a time when data privacy concerns have become paramount. The AI Act may also benefit skilled Indians working in the EU, who constitute a key source of talent for Europe's AI domain, by granting them lucrative opportunities and increased responsibilities (and potentially power).¹⁰

AI Regulation in India: Lessons from the EU

India is an active participant in the global debate on responsible AI. During its G20 presidency, it advocated for the creation of a human-centric regulatory AI framework. In December 2023, India convened the Global Partnership on Artificial Intelligence Summit in New Delhi, followed by the Global IndiaAI Summit in July 2024. Though domestic policy has oscillated between a more liberal approach on AI regulation, which emphasises innovation and advancement, and a more cautious, risk-centric one, these debates reveal India's willingness to adopt a more coherent framework rather than simply allowing the technology to evolve without regulation.

As India deliberates its own regulatory framework for AI, the EU's AI Act offers important lessons. Its efficacy and the challenges and outcomes faced by EU member states serve as a useful case study. India should pay attention to the Act's implications in European jurisdictions such as France and Italy that share characteristics with India, particularly in terms of the presence of large numbers of small- and medium-sized enterprises. Further, the EU AI Act is a critical part of the union's wider digital legislative package, which includes the GDPR, the Digital Services Act, and the Digital Markets Act.¹¹ India's AI regulations, too, need to align with other internal policy efforts that have implications for AI systems, such as the recently introduced data privacy laws under the Digital Personal Data Protection Act.¹² India can also learn from the EU's more centralised institutional approach and establish a dedicated authority to oversee AI regulation, such as the EU AI Office.¹³ This would enable easier oversight, rather than having different bodies such as the NITI Aayog, Ministry of Electronics and Information Technology, and the Telecom Regulatory Authority of India regulating various facets of the domain.

At the same time, India's approach, while drawing lessons from the EU AI Act, must be tailored to its own unique socio-economic context and domestic considerations. For instance, unlike EU member states, which have low unemployment rates, India faces an unemployment crisis and AI's potential to replace human labour can result in further job losses, a factor it must take into account when formulating policy. Critics have also warned that the EU's stringent framework could stifle innovation and impact the competitiveness of European startups and firms.¹⁴ Over-regulation could similarly stifle India's vibrant start-up and innovation ecosystem. Thus, a sector-specific and liberal model that adopts a flexible approach in tandem with AI's rapidly evolving nature could be more viable than the EU's sweeping risk-based approach, especially since classifying risks is a subjective task.

A challenge in this regard is the need to implement a whole-of-society approach—involving collaboration between the government, private sector, civil society and academia, besides educating stakeholders and raising AI literacy—to create AI policy in India. Unlike the EU, India currently lacks sufficient expertise or institutions that are engaged in research on AI and its associated risks.

India and the Future of AI

India, the world's most populous nation and fastest growing economy, could well be the greatest beneficiary of AI if deployed correctly. The International Monetary Fund asserts that, "Before the end of this decade, more Indians will use AI every day than in any other country in the world."¹⁵ Indeed, compared to 26 percent of companies using AI globally, 30 percent of Indian companies are already using it, according to a study by the Boston Consulting Group.¹⁶ As these figures are only slated to increase, Indian policymakers' careful assessment of the EU approach would be useful towards enabling India's aspirations to emerge as a global AI hub.¹⁷

The challenge is to formulate a nuanced regulatory framework that balances the twin imperatives of encouraging innovation and deploying regulation that protects fundamental rights and reduces risks. An Indian approach that successfully synergises these aims can offer a model for the Global South, building on its efforts in exporting its successful digital public infrastructure to other developing nations.

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Chinese Domestic Discourse on AI

Antara Ghosal Singh

China's advancements in Artificial Intelligence (AI)—spanning large language models (LLMs), humanoid robots, and intelligent vehicles—are well-documented. A wide range of literature explores China's AI landscape, covering government policies, innovation breakthroughs, and ethical challenges. However, much of this analysis adopts a United States (US) or European Union (EU) perspective, viewing China primarily as a global peer and competitor in the AI domain.

While these studies are useful, they often overlook the ongoing churn in China's domestic discourse on AI, particularly its geopolitical dimensions. This article seeks to address the gap by analysing Chinese-language literature to explore how Chinese scholars, think tank experts, industry professionals, and the general public view the development trajectory of China's AI industry. It examines their perspectives on China's key achievements, the challenges ahead, and how they perceive India as an emerging challenge to China's AI ambitions.

Chinese scholars such as Zhao Zhijun from Chinese Academy of Social Sciences and Zhuang Xinyu from Xinjiang University of Finance and Economics identify three distinct phases in the evolution of China's AI development policy: the initial exploration phase (before 2017); the accelerated development phase (2017-2020); and the application or implementation phase (2021 to present).¹

China's Key Achievements in AI

Chinese scholars acknowledge the progress of China's AI industry in recent years, highlighting its distinct industrial structure compared to the West. According to Tan Ying, Professor at the School of Information Science and Technology, Peking University,² this structure involves not only technology giants like Baidu, Alibaba, and Tencent but also a robust ecosystem of start-ups, universities, and research institutions working together to drive innovation and advance AI technology.

Chinese research³ highlights the rapid expansion of China's AI market. From 2017 to 2021, the market grew from 70.9 billion yuan to 205.8 billion yuan, with an average annual growth rate of 30.5 percent.⁴ There are 4,975 AI companies in China, accounting for 24.9 percent of the world's total, with a focus on intelligent robots, computer vision, and intelligent voice technologies.⁵

China's innovation capacity in AI is increasing rapidly. The 2021 *Global Artificial Intelligence Innovation Index Report* released by the Chinese Institute of Scientific and Technological Information states that China's AI innovation has reached the world's top tier.⁶ In 2021, China filed 87,343 AI patent applications, accounting for 51.69 percent of the world's total, far surpassing the US, the EU and the United Kingdom.⁷

China's scientific research output in AI has grown rapidly, with an increase in both the quantity and quality of AI papers. The country now leads the world in the number of AI journals, conferences, and knowledge base publications. In recent years, China's development in new infrastructure fields such as computing power, chips, and 5G has also shown a trend of rapid growth.

Challenges for China's AI Industry

One of the key challenges facing China's AI industry is the adverse international environment, particularly the tech sanctions imposed by the US and the West. Chinese scholars admit that China remains highly dependent on globalisation and open-source sharing for advanced AI technologies and core algorithms. Therefore, the increased supervision of overseas investment in AI by the US and the West has disrupted technical exchanges and investment cooperation between Chinese and foreign companies, impacting China's AI development to a certain extent.

After experiencing rapid growth from 2018 to 2023, China's AI industry seems to have entered a period of adjustment. Factors such as slowing economic growth, weak investment, and an adverse international situation have dampened enthusiasm for AI start-ups in China.⁸ While China's AI industry still shows strong development momentum and huge market potential, the number of AI-related start-ups established in the past few years has been declining.⁹ Some reports indicate that the number of newly established start-ups in China, including AI start-ups, has decreased by 98 percent in the past six years.¹⁰

Financing in China's AI sector has also declined. From 2013 to 2017, both the volumes of financing and the number of financing companies grew rapidly, peaking in 2017 when financing reached 302.2 billion yuan and 914 companies received funding—a historic high that reflected strong international confidence in China's AI industry. However, since 2018, the financing volumes and the number of financing companies have fluctuated. By 2023, financing had decreased to 72.72 billion yuan, and the number of financing companies had fallen to 590, indicating that investors are now investing in China prudently.¹¹

The number of patent applications has been declining. After 2010, patent applications in China saw rapid growth, especially in 2016, when they surged by an astounding rate of 72.4 percent. However, after 2018, the growth rate slowed, dropping to 6.4 percent in 2022. Notably, in 2023, AI invention patent applications in China showed negative growth, falling by 12.7 percent, despite the total number of invention patent applications remaining high at close to 80,000.¹²

Chinese observers also raise concerns about the scarcity of high-quality data and the underdevelopment of basic technologies in AI development. Other issues include a shortage of high-end talent, industry barriers hindering digital transformation and industrial upgrade, and ethical concerns regarding personal privacy, AI data security, and algorithm security.¹³

The 'India Factor' in AI Development in China

As China-US competition in the high-technology space intensifies, China is closely monitoring India's "development of high-tech industries". A recent report by China International Capital Corporation Limited¹⁴ highlights India as a key player in the China-US AI competition. The report posits that this wave of AI progress could enable Chinese manufacturing to catch up with developed countries in terms of quality, while also offering the US a chance to address labour shortages and India an opportunity to enhance external demand for its manufacturing sector. The outcome, the report suggests, will depend on whether China can leverage its production scale advantage into a data scale advantage, whether the US can use AI to mitigate labour supply constraints, and whether India can capitalise on current global geopolitical shifts to accelerate its manufacturing growth.¹⁵

The report further noted that while India's basic AI capabilities lag behind China, the gap is gradually narrowing. Currently, India leads China in the number of open-source AI projects on GitHub, but the quality of these projects still lags behind China's. The report also highlighted a key difference in AI strategies: while China's AI strategy focuses on maintaining global competitiveness, India's is more concerned about using AI to promote economic growth and social development, and position India as an innovative experimental site for AI.¹⁶

India's achievements in this sector are notable. For example, the proportion of companies actively using AI technology is higher than in China. In non-IT fields, AI penetration rates in financial, retail, and medical companies exceed 50 percent. A 2022 McKinsey survey of entrepreneurs revealed that 62 percent of Indian companies had implemented AI technology, higher than the US (59 percent) and the global average (50 percent).^{a,17} Additionally, public trust in AI, a key driver for AI industrialisation, is among the highest globally. KPMG reports that 93 percent of Indians view AI systems as trustworthy, ahead of the Chinese (87 percent).¹⁸

In other words, many Chinese observers now believe that India has strong potential as a latecomer in AI industrialisation and could achieve rapid progress with the help of its cooperation with the US and other Western countries. From that perspective, Chinese observers have been closely monitoring India-US collaboration in the high-tech sector, particularly the U.S.-India Critical and Emerging Technology Initiative (iCET).¹⁹

a Also see: <https://finance.sina.com.cn/stock/stockzmt/2024-06-29/doc-incakayr7478244.shtml>.

The Chinese side expresses concern over India's semiconductor investment plan, which is currently the most generous globally, offering an overall incentive exceeding 70 percent to enterprises. Given that multinational companies are increasingly looking to diversify their supply chains and production activities away from China to ensure resilience, many Chinese observers believe India is likely to be one of the early beneficiaries of the semiconductor supply chain diversification trend.

China notes that India has already attracted INR 1.5 trillion in semiconductor investments from companies such as Micron, Tata Electronics, CG Power and Kaynes Technology. HCL Technologies has opened a design centre in Hyderabad, while Dickson Technology has reached an agreement with Foxconn on semiconductor assembly and testing. In addition, Tata Electronics has invested heavily in its semiconductor manufacturing plants in Gujarat and Assam, forming partnerships with Taiwan's Powerchip Semiconductor Manufacturing Corp (PSMC) and Renesas Electronics. Recently, Nvidia announced it is forging partnerships with Indian companies to deploy its AI chips and technologies.²⁰

As a countermeasure, China's propaganda machinery has been targeting India, emphasising its disadvantages in developing high-tech industries. There is a growing consensus within China's strategic community that India lacks the necessary conditions and capabilities to develop a semiconductor manufacturing industry.²¹ These observers argue that, as a semi-agricultural society, India is not qualified to be at the high table and play a disruptive role in the China-US AI competition.²²

They further warn that India's blind pursuit of high-tech development could harm its critical software outsourcing industry, thereby negatively impacting its overall economy.²³ Some Chinese observers, like Justin Yifu Lin, professor of economics at Peking University and former chief economist at the World Bank, have publicly advised India to stay away from capital-intensive sectors like semiconductors. He suggested that India should focus on developing labour-intensive manufacturing in the formal sectors, leveraging its abundant supply of cheap labour.²⁴

Overall, China appears poised to unleash the huge potential of AI and integrate it into industries such as manufacturing, healthcare, finance, and education, aiming to enhance production efficiency and innovation, and ultimately lead globally. Meanwhile, it is striving to address challenges in talent development, infrastructure construction, and regulatory frameworks. Moving forward, China's priorities include: 1) promoting original innovation and prioritising diversified, integrated AI applications;

2) establishing a comprehensive AI education system and strengthening the construction of an AI talent team; 3) promoting AI legislation and improving AI security protection and governance capabilities; and 4) focusing global AI competition on the US and China, while preventing countries like India from “playing spoiler” and influencing the competition’s direction.

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III

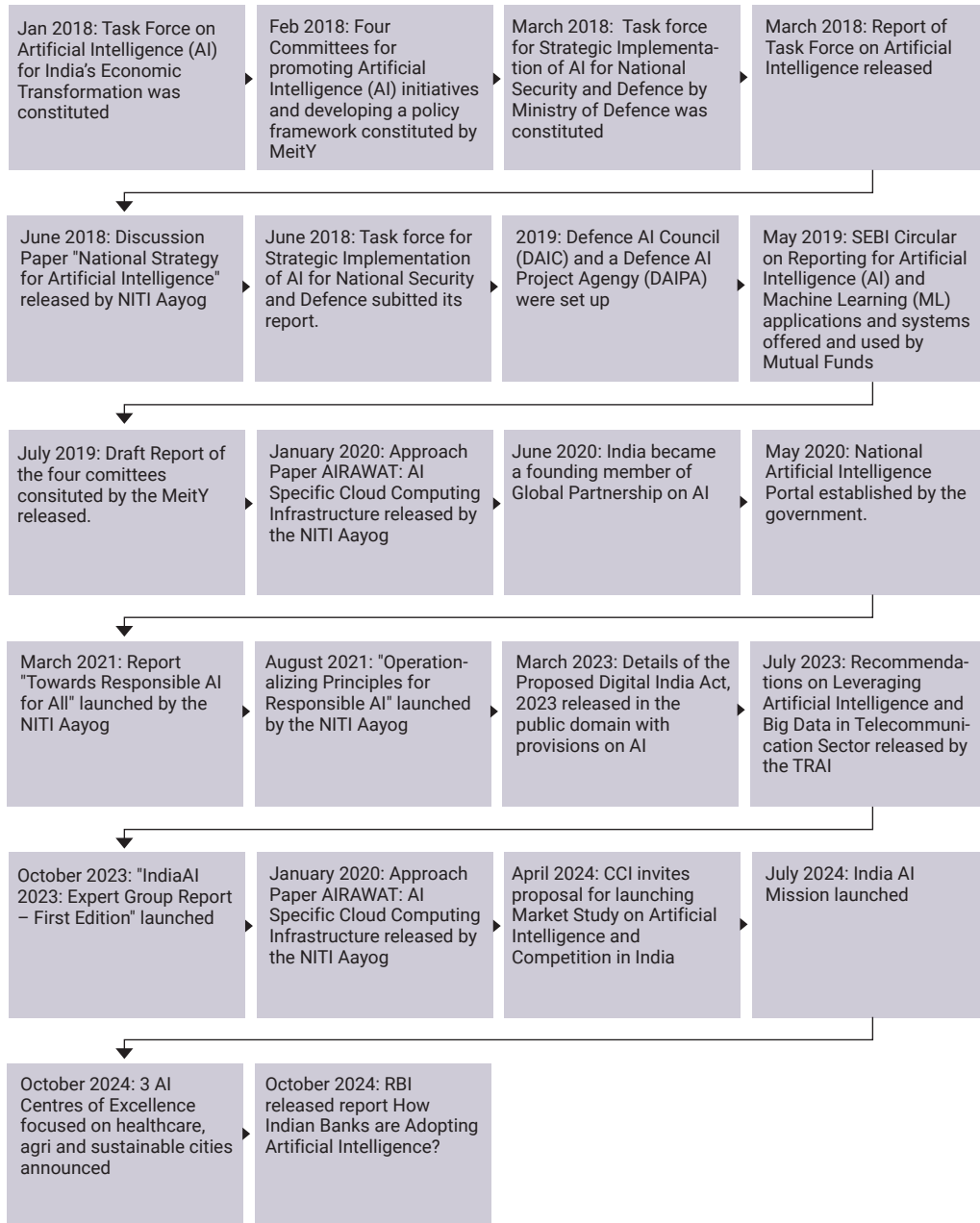
Building National Competencies

Strengthening Institutions and Governance: Building India's AI Competencies

*Anulekha Nandi, Basu Chandola
and Debajyoti Chakravarty*

I ntegrating Artificial Intelligence (AI) into economic processes holds transformative potential to drive economic growth, produce social returns, and improve efficiencies. AI is projected to contribute 10 percent towards India's US\$5-trillion economic target.¹ India strives to lead the world in AI² by actively bolstering its digital ecosystem. The government is pursuing an ecosystem approach to develop AI competencies, emphasising the integration of data, computing resources, skills, research and development, and strategic finance, including public investments in core capabilities.³

Apart from developing competencies across the ecosystem, India is also strengthening efforts in economic transformation, national security, telecommunications, sectoral applications, and responsible development, implementation and use. Figure 1 illustrates the initiatives taken by the Government of India to understand and strengthen the country's AI ecosystem.

Figure 1: Timeline of AI-Related Developments in India

Source: Authors' own

The Expert Group report outlines a roadmap for operationalising institutions and building capacities in AI.⁴ This involves establishing Centres of Excellence to foster academia–industry collaboration and developing the India Datasets Platform to provide access to data for innovation. Governance and institutional frameworks are being strengthened through the National Data Management Office (NDMO).

The innovation ecosystem is expected to be stimulated by designing adequate funding mechanisms, skilling programmes, and access to computing capacity. This includes fostering integration with the electronics sector ecosystem and advancing self-reliance through linkages with the Semiconductor Mission, with the aim of developing national competencies in the AI application as well as the infrastructure and hardware driving AI transformations.

India's approach to AI strikes a balance between state and market-driven strategies, fostering innovations like Digital Public Infrastructure to address societal challenges at scale. This contrasts with the United States (US), where a market-led approach has led to the emergence of dominant tech giants.⁵ These companies have driven key technological breakthroughs in the form of the foundational large language models (LLMs), which have unleashed the era of generative AI and its expanding applications. Given the data-intensive nature of AI technologies, these companies have leveraged their dominance in information economies and social media, gaining access to vast amounts of user-generated content through Web 2.0.⁶

China, meanwhile, adopts a state-led approach for AI innovation among its leading companies, based on core capabilities,⁷ with a national task force of industry leaders. Examples include Tencent in computer vision, Baidu in autonomous driving, and SenseTime for facial recognition. The strategy aims to enable small and medium enterprises to access technology at a lower cost from incumbents. The AI race has also spanned geopolitical posturing, with the US implementing export controls and bans to prevent advanced AI chips from reaching China.⁸ This approach underscores the critical importance of partnerships while highlighting the concentration of power and its potential impact on Global South economies with AI ambitions.

Ascertaining Regulations

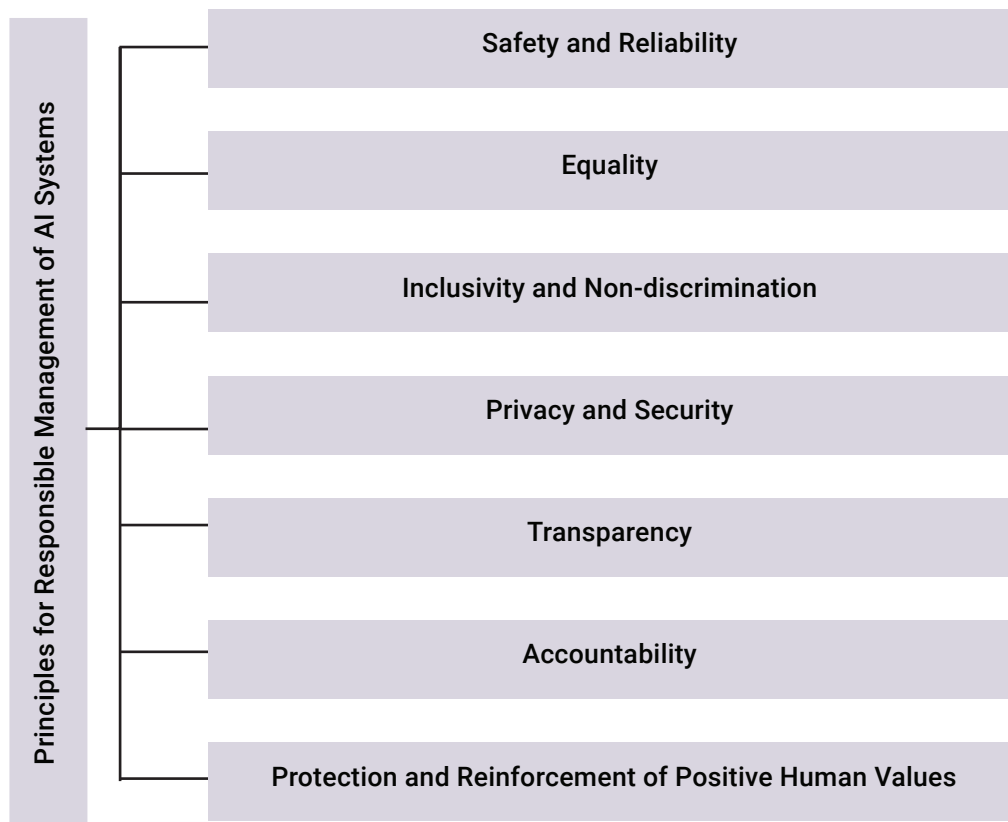
India has yet to develop a comprehensive legal framework to govern AI and its applications.⁹ However, various reports provide important insights into potential regulatory approaches. The Task Force on Artificial Intelligence report¹⁰ highlighted the need for enabling policies to promote AI development and deployment, including the development of data policies, tax incentives, and standard setting by the Bureau of Indian Standards.

NITI Aayog's *National Strategy for Artificial Intelligence* report¹¹ noted that the government needs to be a facilitator, promoter, and owner to ensure successful AI development in India. It emphasised the importance of frameworks to address ethical considerations, data privacy, security, and Intellectual Property related concerns.

The draft report of Committee D on cybersecurity, safety, legal, and ethical issues¹² called for comprehensive guidelines on ethics, including fairness, transparency, and accountability for AI solutions. It also recommended developing flexible principles to guide self-regulatory efforts and enhance accountability.

NITI Aayog's 2021 report, *Towards Responsible AI for All*¹³ and *Operationalizing Principles for Responsible AI*,¹⁴ highlight the need for the government to strengthen regulatory and policy interventions to create a trusted AI ecosystem and promote responsible adoption. These reports also emphasised the government's role in spreading awareness and building capacity. The reports propose Principles for Responsible Management of AI Systems, as depicted in Figure 2.

Figure 2: Principles for Responsible Management of AI Systems



Source: NITI Aayog, *Towards Responsible AI for All*¹⁵

The Proposed Digital India Act, 2023¹⁶ discusses the definition and regulation of high-risk AI, including a legal testing framework to examine regulatory models. It also addresses issues like a safe harbour for AI intermediaries, algorithmic accountability, and zero-day threat and vulnerability assessments. The Act also discusses the ethical use of AI-based tools to protect users' rights and choices. However, progress in developing the Digital India Act has been limited.¹⁷

In March 2024, the Ministry of Electronics & IT (MeitY) issued,¹⁸ and subsequently revised,¹⁹ its AI Advisory. The Advisory mandates that AI intermediaries ensure AI usage does not enable unlawful acts violating the Information Technology Act, 2000, or its associated rules. Further, intermediaries must prevent AI bias or discrimination, take proactive steps to ensure a non-biased electoral process, and inform users about any inherent fallibility or unreliability of AI.

At the G20, India promoted the use of AI for public good and developing a pro-innovation governance approach that maximises benefits while protecting people's rights and safety.²⁰ Its AI governance strategy aims to build a holistic ecosystem that ensures safety and trust, aiding a vision of AI for all.²¹

India's approach to regulating AI has gone back and forth from being "hands-off" to interventionist.²² A number of ministries, regulatory bodies, and state agencies have been working towards understanding and regulating the AI ecosystem.

India is aiming to develop a framework that allows "space for innovation to flourish" while controlling societal harms.²³ While AI regulation and its ethical issues are global concerns, India is focused on fostering robust debate and responsible innovation to tackle these challenges.²⁴ Unlike the European Union (EU) and the US, India does not want to heavily regulate AI.²⁵ Instead, its regulatory approach focuses on managing AI risks through appropriate guardrails.²⁶

The Way Forward

Developing an enabling ecosystem is crucial for AI's success in India. The country needs to define its approach to AI regulation and establish a stable, predictable policy environment. Policies should strike a balanced approach, fostering internal competencies and regulatory governance while securing critical partnerships for success. This reinforces the need for complementarity between policy intent and institutional governance mechanisms, alongside a multi-layered approach to attract talent across various sectors—from engineering and software to business,

administration, and manufacturing. It should also include strategic collaborations on technology transfer and acquisition. The following points outline other key recommendations:

- **Instituting an AI regulatory body:** Spain was one of the first countries to establish an AI supervisory body with oversight and regulatory mandates along with coordination, training, awareness, and regulatory sandboxes.²⁷ Indian policy documents recommend the creation of institutional entities responsible for parts of the ecosystem, like data. However, given the cross-sectoral and general-purpose application of AI technologies, a central coordinating body would be required to ensure, assess, and enforce regulatory compliance and adjudication.
- **Harmonising policy and regulatory priorities:** Different policy documents highlight policy priorities based on ecosystem development, national security, or economic transformation. This also includes efficient coordination among the different Missions such as AI, supercomputing, and semiconductors. However, there needs to be a harmonisation of these policies across two axes: cross-cutting considerations applicable across sectors, industries, and ecosystem imperatives as well as their specific priorities that can help determine and manage regulatory adaptation in these areas as well as help identify the appropriate regulatory approach.
- **Identifying the appropriate regulatory approach:** While the EU has taken a horizontal approach to AI regulation, China's strategy involves regulating specific classes of technologies such as recommendation engines and generative AI, highlighting a vertical approach.²⁸ With the EU instituting the first AI legislation, the risk-based approach used therein has gained traction. However, the risk-based approach can also be prone to ambiguities varying by qualitative interpretation of implementing regulators. This highlights the importance of a responsive and risk-based regulation based on a pyramid of support and sanctions combined with institutional and technical capacity to determine the balance between innovation and safety.²⁹ Therefore, identifying the appropriate regulatory approach that answers to Indian context and policy priorities becomes important.

- **Facilitating partnerships:** India needs international partnerships to build capacities in areas like compute. This requires ensuring national governance mechanisms are also able to support and strengthen bilateral agreements with the US such as the iCET (United States–India Initiative on Critical and Emerging Technology) and USIAI (US-India Artificial Intelligence) Partnership or bolster global partnership and cooperation within the GPAI (Global Partnership on Artificial Intelligence).

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Building India's AI Compute Infrastructure

Anulekha Nandi

Compute infrastructure and hardware—which include chips, supercomputers, and cloud capabilities—are crucial to Artificial Intelligence (AI)-driven transformations that is projected to add billions of dollars to national and global economies.¹ Computing resources form an integral part of AI ecosystem development.² However, the industry is highly concentrated across the supply chain, with a limited number of companies capable of providing the computing power required for high-level AI training.³ Moreover, cloud infrastructure owners hold an unfair advantage in training and deploying their own AI models, thereby gaining a dominant position in multiple markets.⁴

The economies of scale and market power of existing companies have established the United States (US) and China as the leading innovation centres, with AI chips becoming the loci of geopolitical tensions.⁵ Given its monopoly in the chips industry, the US has repeatedly tightened export controls on advanced chips to curb China's AI ambitions.⁶

With AI compute emerging as a strategic asset, it has increasingly featured in risk assessments and security considerations in AI legislation and policies from the European Union (EU) and the US.⁷ The EU AI Act of 2024 and the US Executive Order on Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence (Executive Order 14110, dated 30 October 2023), emphasise compute as a part of their national strategies and policies. These policies are using computing power as a barometer to assess model risks.^a

AI computing also demands substantial economic investments. Given the enormous demand for computing power, this has led to an uptick in investments in chip startups and cloud companies.⁸ Rising demand for computing power, driven by AI adoption, has heightened concerns over potential shortages in chips as businesses pursue AI-driven transformation.⁹ Companies are estimated to spend over 80 percent of their total capital on compute resources.¹⁰ Given the geopolitical vulnerabilities within the supply chain and the need to meet domestic AI demands to remain competitive, countries are investing in building their own compute infrastructure and capabilities.¹¹

In India, three interrelated policies support compute infrastructure—the IndiaAI Mission, 2023, the India Semiconductor Mission (ISM), 2022, and the National Supercomputing Mission (NSM), 2015. The IndiaAI Mission aims to increase compute capacity to 10,000 GPUs through public-private partnerships, with the government offering up to 50 percent subsidy.¹² The NSM, meanwhile, aims to establish supercomputing infrastructure to bolster research, innovation, and development across academia and R&D institutions. In conjunction, India is also planning to become a semiconductor manufacturing hub to achieve self-sufficiency in chip manufacturing.

a For example, if a model crosses a certain threshold of computing power (cumulative compute for training greater than 10^{25} floating point operations or FLOPs), it is deemed to hold systemic risk as under the EU AI Act. See: <https://artificialintelligenceact.eu/high-level-summary/>. Similarly, Section 4(a)(ii) of the US Executive Order on AI requires entities to report acquisition, possession, development, and location of large-scale computing resources. See: <https://www.federalregister.gov/documents/2023/11/01/2023-24283/safe-secure-and-trustworthy-development-and-use-of-artificial-intelligence>

While India is taking nascent steps in laying the foundations of its compute infrastructure, there is a stark reminder of how corporate capacity far outstrips national capacity. For instance, Meta plans to have 600,000 GPU capacity by 2025 compared to India's 10,000 GPU target.¹³ This highlights the importance of assessing India's compute demand, particularly in light of its ambitions for developing indigenous large language models (LLMs). In India, most compute demand arises from downstream AI application development,¹⁴ focusing on inference level rather than training level. Training LLMs like ChatGPT takes three times as long as doing an inference as the training dataset is about 3 million times larger than an inference prompt.¹⁵ As a result, training LLMs requires large compute clusters in data centres, and setting up the primary network clusters becomes a key challenge. Training LLMs like ChatGPT is not just computationally expensive but also financially expensive, costing anywhere between US\$500,000 and US\$4.6 million depending on the hardware. In comparison, the cost of inference is US\$0.0002 and US\$0.0014 for 1,000 tokens.¹⁶

As India looks to develop its internal capacities across the AI value chain, including in foundational models, technical and financial considerations become more important. While national policies aim to democratise AI innovation, they must be refined to navigate cost constraints, enhance computational efficiencies, and align with ambitions of access and capacity building.

To Centralise or To Distribute: That is the Question

Some experts have cautioned against the government incurring sunk costs in computing infrastructure given the gap it still needs to traverse to meet global standards.¹⁷ They argue that managing downstream distribution responsibilities and risks is better suited to private players. With nearly 45 percent of the AI mission's budget dedicated to computing,¹⁸ a critical question is whether the government should invest in domestic capacity or buy and distribute computing power from hyperscalers. This conundrum is compounded by the need for constant GPU upgrades to work towards meeting global standards as well as the recent data loss and maintenance failure with AIRAWAT, India's AI-focused supercomputer.¹⁹

This article advocates for a nuanced approach, emphasising that public investment in infrastructure not only creates assets but also fosters institutional learning. Such investments make resources available to academic R&D institutions, which might otherwise not be able to access such resources for training algorithms. An example of this involves the LLM development by AI4Bharat at IIT Madras in conjunction with Sarvam AI, which uses C-DAC's supercomputing resources for model training and

high-volume data storage, supported by grants from philanthropies and corporations. Access to public resources is crucial for sustainability, enabling foundational AI development without an over-reliance on external funding alone.

This is particularly important for India to build capacity across the full spectrum of AI capabilities. However, it must balance infrastructure development with the growing demand, which could outstrip current capacity. The development of an AI marketplace through the empanelment of data centres, cloud service providers, and start-ups through a bidding process, is a promising step toward offering high computing power at the lowest rates.²⁰ Though the question of determining accessibility at scale still looms large.

To democratise and scale AI innovation, compute accessibility must prioritise both cost efficiency and sustainability. Emerging approaches include the Open Cloud Compute (OCC) project, which onboarded 24 organisations like Dell, AMD, and Tata Communication along with Indian AI start-ups to build and provide a network of interconnected micro data centres across the country to meet the growing needs for computing power.²¹ The aim is to create a network of 10,000 micro datacentres nationwide, reducing latency and increasing cost efficiency by bringing compute resources closer to users.²² However, the project is still at a proof-of-concept stage and requires policy interventions to standardise the concept of micro data centre and contend with current infrastructural inadequacies like power and internet speed beyond Tier I cities.²³

Another key development involves the emergence of start-ups utilising open-source hardware like RISC-V. These startups design chips based on the RISC-V architecture, with the Indian government encouraging its use through the 2022 Digital India RISC-V Programme to strengthen domestic chip design and development.²⁴ This lent support to the Shakti Project at IIT Madras and the VEGA processors at C-DAC.²⁵ However, the scalability of these chips for advanced AI use remains uncertain. In sum, India needs a three-fold strategy of public investment, an AI marketplace, and fostering domestic innovation through supportive policies to leverage existing strengths while building capacities.

Way Forward

National capabilities and partnerships: Acknowledging India's gap in reaching global supercomputing standards, there is a need to invest in infrastructure and leverage both bilateral and public-private partnerships to ensure access to computing power needed for digital transformations. This could include supercomputing access

allocations under bilateral agreements, such as iCET, 2022 between India and the US. These would be complemented by the existing policy approaches of creating the AI compute marketplace and a greater policy push towards innovation in this domain of decentralising compute access through micro data centres and open-source hardware. India must also continue to build its supercomputing capabilities and enhance public institutional capacity since most nations' prowess in this domain comes from installed capacity in public research institutions.

Institutional mechanisms: The Partnership for Advanced Computing in Europe (PRACE), an association of users and HPC (High Performance Computing) Centres in Europe, presented a proposal for a separate user forum with its own governance and membership rules. This forum would facilitate upstream user feedback for the effective management of the supercomputing ecosystem by infrastructure funding bodies like the EuroHPC JU (European High Performance Computing Joint Undertaking) in Europe. This provides a useful template to effectively coordinate and democratically manage access and allocation for users across the board.

Attuning to different scales of innovation: While contextually attuned LLMs are an important foundational capability, small language models and domain-specific models are also key aspects of innovation and transformation. Therefore, not all model training might be computationally heavy. This highlights the need to not just focus on the highest compute capacity but ensure that compute capacity is also available for diversity of uses.

Supporting open innovation and accessibility: To foster open innovation and development of open-source hardware, there is a need for increased policy support and stronger venture capital investment in this domain. There is also scope to enhance accessibility to supercomputers through competitive research grants. These grants should not only ensure the efficient allocation of resources but also align with national priority research areas in the field.

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Endnotes

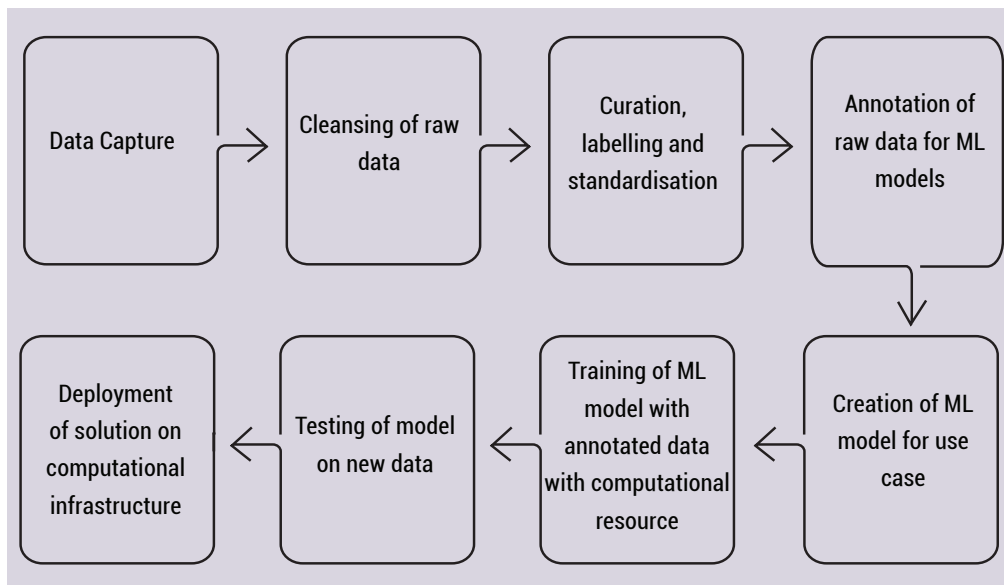
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Data as Fuel for AI Aspirations

Basu Chandola

With advancements in Artificial Intelligence (AI), the importance of data cannot be overstated. After all, data serves as the “bedrock of the AI ecosystem”,¹ as vast amounts are essential for training AI models to improve efficiency, reliability, and personalisation.² Data collected from various sources are cleaned, processed, and annotated to train machine learning (ML) models and thereafter test them. Figure 1 illustrates the role of data in the AI value chain.

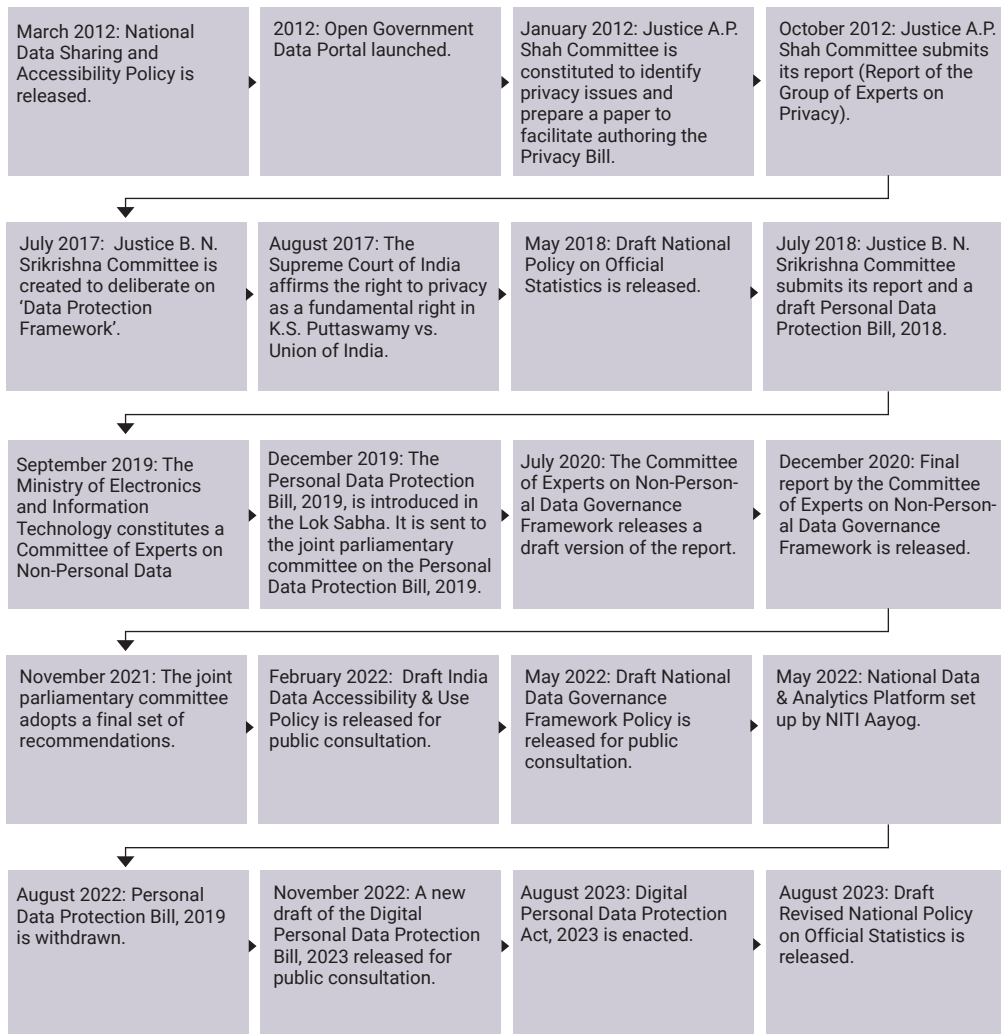
Figure 1: Data in the AI Value Chain

Source: NITI Aayog, "National Strategy for Artificial Intelligence"³

Data availability is essential for the success of AI solutions. As India strives to lead in AI development, establishing a robust data infrastructure is essential, along with ensuring adequate data protection and other safeguards. This chapter examines the policies and initiatives to develop such infrastructure and recommends measures to improve data availability nationwide.

India's Data Ecosystem

India has made progress in developing appropriate data regulations and policies over the years while bolstering its data infrastructure. Figure 2 summarises the pivotal data-related policy developments in the country in the past decade or so.

Figure 2: Key Data-Related Developments in India (2012-2023)

Source: Author's own; Updated from Chandola, "Assessing India's Position on Data Protection"⁴

The Committee of Experts on the Non-Personal Data Governance Framework highlighted the increased traction for AI solutions in India and the need for three distinct datasets—for training, fine-tuning, and testing—to build accurate prediction models.⁵ The Committee of Experts' White Paper on a Data Protection Framework for India, issued in 2018, emphasised that the country's data protection law should strike a balance between innovation and privacy to foster AI growth.⁶ The final report by the committee, chaired by Justice B.N. Srikrishna,⁷ noted that AI is a key driver of economic growth and recommended that a copy of personal data be stored within the country, with critical data confined to India, to fully capture the benefits of AI.

Given the crucial role of data in the AI value chain, ensuring the accessibility of datasets and developing appropriate data infrastructure is essential to support AI growth in the country.

Enhancing Data Accessibility

The National Data Sharing and Accessibility Policy, 2012,⁸ was developed to facilitate access to government-owned shareable data, promoting the wider use of public data. The Policy applies to all data collected using public funds, classifying it as shareable and non-shareable data and categorising it into Open Access, Registered Access, and Restricted Access. The Draft National Policy on Official Statistics 2018⁹ and the Draft Revised National Policy on Official Statistics 2023¹⁰ are also intended to enhance data sharing and improve data accessibility.

The Draft India Data Accessibility & Use Policy (IADUP), 2022, was framed and released for consultation to improve access, quality, and use of non-personal data.¹¹ After criticisms, the IDAUP was withdrawn,¹² and the Draft National Data Governance Framework Policy¹³ (NDGFP) was released for consultation on 26 May 2022. One of the key objectives of the NDGFP was to foster a vibrant AI ecosystem by creating a large repository of Indian datasets. While the Budget 2023-24 intended the enactment of the NDGFP to facilitate access to anonymised data,¹⁴ the policy has yet to be finalised and implemented.

Reports on AI from different government stakeholders highlight the critical role of data in AI's success. The Artificial Intelligence Task Force, constituted by the Ministry of Commerce and Industry, in a report emphasised the need for data availability.¹⁵ It recommends the creation of data banks, exchanges and an ombudsman, along with developing policies on data ownership, sharing rights and usage.

Similarly, NITI Aayog's report, *National Strategy for Artificial Intelligence*, emphasises data's role as a driver of AI solutions and highlights how government data sharing, corporate data sharing, consent-based data sharing, and the digitisation and crowdsourcing of data by the government can address data access issues.¹⁶ The *IndiaAI 2023: Expert Group Report* discusses the creation of India Datasets Platform (IDP) as a unified national data-sharing exchange and proposes the establishment of the National Data Management Office (NDMO) to ensure data integrity, audit, regulation, and management.¹⁷ The NDMO, as recommended, aligns with the India Data Office envisioned under the NDGFP.

The Open Government Data (OGD) Portal was launched in 2012¹⁸ to provide access to government-owned shareable data and information.¹⁹ It was later developed as a key component of creating an open data ecosystem in the country²⁰ under Pillar 6, “Information for All,” of the Digital India Initiative by the National Informatics Centre (NIC) under the Ministry of Electronics & Information Technology (MeitY).²¹ The OGD Portal has over 475,713 resources, 7,621 catalogues, and 247,984 APIs.²² Similarly, the National Data and Analytics Platform (NDAP) was developed by NITI Aayog to improve access and use of government data.²³ The NDAP allows users to work on and download data sets from India’s administrative landscape.²⁴ As of December 2024, the platform hosts over 4,700 datasets from 53 ministries and across 31 sectors.²⁵

The IndiaAI mission, launched in 2024, includes a pillar dedicated to enhancing the availability of datasets. The IndiaAI Datasets Platform aims to increase access to non-personal datasets for Indian startups and researchers to develop AI solutions.²⁶ Scheduled for launch in January 2025,²⁷ the platform is expected to be “one of the largest publicly assembled datasets in the world.”²⁸ The IndiaAI website also hosts a curated collection of datasets to support AI research.²⁹

Reinforcing Data Infrastructure

A Report by India Brand Equity Foundation projects that India’s data centre market value could grow from US\$4.5 billion in 2023 to US\$11.6 billion by 2032, with a Compound Annual Growth Rate (CAGR) of 10.98 percent.³⁰ Over the last few years, India’s data centre industry has expanded rapidly, making it the Asia-Pacific region’s leader in data centre capacity, with around 950 MW capability.³¹ The Government of India has undertaken a number of initiatives to support this growth. The Budget 2020-2021 proposed a policy to enable the private sector to develop data centre parks nationwide.³² Further, the inclusion of data centres in the harmonised list of infrastructure in the Budget 2022-2023 improved credit for the sector.³³

The *National Digital Communications Policy*, 2018 proposed creating regulatory frameworks and incentives to promote the establishment of international data centres, content delivery networks, and independent interconnect exchanges in India.³⁴ Further, the Draft Data Centre Policy, 2020, aimed to position India as a global data hub and streamline clearances for setting up data centres.³⁵ The Telecom Regulatory Authority of India (TRAI) also released recommendations on a regulatory framework for promoting data economy through the establishment of data centres, content delivery networks, and interconnect exchanges.³⁶ Several states have also developed their own data centre policies to drive growth in this sector. With the

growth of AI, strengthening data infrastructure has become critical, and India is actively working to enhance its capacity to meet these demands.

Way Forward

India has undertaken efforts to democratise data and improve accessibility for researchers and startups nationwide. However, government policies primarily enable access to government-owned shareable data, leaving a gap in the availability of proprietary data, which is often controlled by Big Tech. These companies dominate data supply chains through deals with content owners and reliance on data brokers.³⁷ To foster the development of successful AI solutions, it is important to develop alternative data sources accessible to Indian startups, researchers, and companies. The following priorities should be emphasised to enhance dataset accessibility in the country:

- The IndiaAI Datasets Platform should be developed and made operational at the earliest.
- The Platform should host high-quality datasets in Indian languages, and not just in English. This will support the development of AI solutions tailored to Indian populations.
- The National Data Governance Framework Policy should be finalised, and the NDMO made operational to ensure the development of a large repository of Indian datasets. This will facilitate standardised data management and security standards across the government.
- The government must develop policies to build trust in AI systems and ensure that concerns around data privacy and security are adequately addressed.
- As the AI revolution progresses, it is crucial to ensure that all sections are adequately represented in government data. Underrepresentation of certain sections can affect the efficacy of the AI solutions. To achieve this, improving digital connectivity and infrastructure while bridging the digital divide is essential.

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Licence to Skill: Building a National AI Workforce

Anirban Sarma

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ou have the data, you have the talent. This is going to be one of the largest AI markets in the world,” Jensen Huang, CEO of NVIDIA, told Prime Minister Narendra Modi when he visited India in September 2023.¹ To be sure, the size of the Indian tech talent pool gives the country a natural advantage as the era of Artificial Intelligence (AI) advances. At the same time, the growing anxiety worldwide that the demand for AI skills is not being met is also being felt in India.

Estimates indicate that in 2024, AI spending globally breached US\$550 billion, but there was a hiring gap of nearly 50 percent across all required AI positions.² Moreover, around 70 percent of existing AI workers needed a skills upgrade.³ India is witnessing similar trends. By 2027, the domestic demand for AI talent could double to 1,250,000 from the current 600,000-plus AI workers in the country, representing a compound annual growth rate (CAGR) of 15 percent. However, during the period 2022-2027, the Indian AI market is expected to grow at a CAGR of 25-35 percent, signalling a potential demand-supply gap in the labour pool and the need to upskill workers.⁴

Recognising these challenges, India has begun to take corrective measures. For instance, the pan-India *AI Workplace Report* of 2024 found that 79 percent of the organisations surveyed planned to increase their AI budgets beginning in 2025, and on average, their AI spending—including investments in skills, training, and human resource development—would increase by over 40 percent.⁵ These efforts are likely to help build a future-ready workforce and contribute to the nation's overall AI readiness.

The AI Skilling Landscape

The government, private sector, and academic institutions, which often work together, have emerged as the troika driving AI workforce development in India. They work across five different segments of stakeholders, identified in Table 1, each of whom needs different types and levels of skills.

Table 1: Stakeholders and Required Skills

Segment	Skills Needed	Job Roles
AI Experts	<ul style="list-style-type: none"> Highly specialised research and development (R&D) skills around deep learning (DL) models; A focus on neural networks, DL and machine learning (ML) algorithms, parallel and edge computing, graphics processing unit (GPU) architecture and facilities planning; Specialised domain skills in areas such as the Internet of Things and robotics 	<ul style="list-style-type: none"> AI researchers and scientists Specialised domain researchers

Segment	Skills Needed	Job Roles
AI Developers and Architects	<ul style="list-style-type: none"> Core AI programming skills; Using AI frameworks, building models, and refining hardware; Data analysis, various kinds of modelling, and ML techniques; Embedded applications 	<ul style="list-style-type: none"> Engineers specialising in DL, ML, NLP, computer vision, robotics, and hardware AI trainers
AI Integrators	<ul style="list-style-type: none"> Integrating AI services and products using major platforms; Understanding AI tools and models including Generative AI (GenAI) and NLP; Knowledge of basic coding tools; Data science skills; Identifying use cases and solutions 	<ul style="list-style-type: none"> Solutions architects Database architects and administrators Engineers dealing with the cloud, quality assurance, and development operations Application specialists and product managers Data scientists and analysts
AI Users	<ul style="list-style-type: none"> Foundational understanding of AI/ GenAI tools and their impacts and limitations Domain-specific AI skills such as AI-first marketing or finance Understanding of responsible and ethical AI use 	<ul style="list-style-type: none"> Broad spectrum of professionals in areas such as consulting, finance, sales, marketing, customer service, accounting, and procurement
AI Informed	<ul style="list-style-type: none"> Basic AI and digital literacy 	<ul style="list-style-type: none"> All levels

Source: Adapted from NASSCOM and Deloitte, *Advancing India's AI Skills, 2024*.

Broadly, the provision of digital literacy has remained primarily the government's responsibility. But as one moves up the table, through more complex and high-value AI skill sets, the roles of research and academic institutions and the private sector become more central, while the government continues to set AI priorities and policy directions and establish overarching skilling programmes and platforms.

The Ministry of Electronics and IT launched the India AI Mission in 2023. An important part of its vision is to prepare “India and its workforce ... for the AI wave” and a key objective is to “ensure the availability of skilled AI talent”.⁶ The National AI Skilling Framework (NAISF) developed under the Mission divides its target segments of potential beneficiaries into the following categories:

- **All:** Which covers those under the “AI Informed” class above
- **Many:** Which covers the class of “AI Users”, who can leverage AI tools for better productivity
- **Few:** Which refers to AI integrators, developers and architects, and experts—a group of skilled practitioners with a depth of technical expertise who develop AI products and applications

In keeping with the NAISF’s recommendations, and the emphasis on AI education by the National Education Policy (NEP) 2020, large numbers of AI courses and modules are being developed for schools and higher education institutions (HEIs) across India. Indeed, of the various AI-related interventions suggested by the NEP, the greatest progress so far has been in the area of course development. Additionally, programmes and organisations such as FutureSkills Prime, the National Programme for Technology-Enhanced Learning (NPTEL), the Centre for Development of Advanced Computing (C-DAC), and the National Institute of Electronics and Information Technology (NIELIT) as well as private edtech platforms now offer a range of courses targeting adult learners and tech professionals.

Many of India’s private HEIs are sharpening their focus on AI education. Reliance Industries’ Jio Institute, for example, has invested heavily in its AI and data science programmes for professionals who intend to become full-stack data scientists.⁷ Universal AI University—India’s first exclusively AI university, set up in 2023—aims to “serve as a research hub for developing new AI technologies, bringing economic and technological benefits to India.”⁸

Private-sector tie-ups with engineering- and tech-focused HEIs are also on the rise.⁹ For instance, Google, Microsoft, NVIDIA, IBM, and Intel have all partnered with Indian institutions to co-design AI curricula, support research initiatives, provide resources for AI R&D, or even set up AI labs and research centres. Besides, these companies offer a host of AI courses through their own learning platforms or institutes. As a result of these activities, not only are Indian students and professionals beginning to acquire cutting-edge skills, the future of work itself is extending in newer directions.

Gaps and Deficits

The rapid evolution of AI presents a unique set of challenges for skilling and education. The fast-changing skills required of the Indian workforce mean that domestic training programmes often fail to keep pace with tech transformations, leaving gaps in the preparedness of professionals. Leading institutions like the Indian Institutes of Technology (IITs) have begun to respond to this challenge, continually revamping their AI curricula with inputs from industry, but these practices need to be normalised across the HEI ecosystem.¹⁰

Beyond the modernisation of curricula, institutes are struggling to address the shortage of qualified educators capable of teaching advanced AI concepts, but high-quality teacher training programmes are not as widespread as they need to be.¹¹ Furthermore, a robust AI education demands significant investments in infrastructure such as labs, hardware, computational power, and cloud services as well as the integration of hands-on training into academic programmes. Funding for these activities, however, is scant, if at all present, rendering much of the learning theoretical and less applicable to real-world scenarios. At a more general level, the decline in STEM enrollments in Indian higher education is diminishing the pipeline of students entering AI-related disciplines.¹² There is a need to revitalise student interest in STEM and evolving fields like AI at the school level.

In spite of growing collaborations between tech firms and premier HEIs, there is widespread disconnect between the AI skills demanded by the job market and those provided by academia. For the most part, HEIs fail to align their programmes with industry needs, leading to a mismatch that leaves graduates underprepared for AI roles.¹³ The limited participation of industry stakeholders in curriculum design—when one considers the large number of computer science and engineering institutes in India—and the paucity of internships and apprenticeships hinder students' ability to gain practical exposure and professional skills.

The onus for workforce development thus falls largely on businesses who are compelled to upskill graduates. As the *AI Workplace Report* found, nearly 88 percent of Indian businesses are focusing on AI training to future-proof their workforce, as compared to 67 percent of businesses in Europe, 66 percent in the United Kingdom, and 62 percent in Australia.¹⁴

Finally, economic constraints play a role in limiting access to AI skilling programmes. The relatively high cost of certifications, courses, and other resources—especially

those offered by private edtech players—often puts them beyond the reach of students from economically weaker sections of the population. The geographical location of learners also skews AI training opportunities, with better equipped urban areas benefiting disproportionately while technologically deficient rural areas hardly contribute to the AI labour pool.

Building a World-Class AI Workforce

Global tech leaders have lauded India's efforts to apply AI across sectors.¹⁵ As the country works towards developing new applications, it could take several steps to strengthen its AI workforce, putting itself on track to become a possible AI superpower.¹⁶

- **Bridge industry-academia gaps:** First, HEIs must collaborate more actively with industry stakeholders to align their AI curricula with market requirements. There is an urgent need to establish advisory boards consisting of AI practitioners and experts from leading tech firms, who can guide curriculum design. More internships, apprenticeships, and hackathons hosted jointly by HEIs and businesses would provide students with much-needed practical experience, helping bridge the gap between academic training and job needs. Second, while tech companies tend to partner principally with top-tier public and private HEIs, more collaborations need to be established with second- and third-tier institutions if a larger, more distributed workforce is to be built.
- **Invest in institutional infrastructure and training educators:** Investing in advanced infrastructure at HEIs—such as AI labs, cloud computing facilities, and high-performance computing clusters—is essential if the quality of AI education is to be improved. Simultaneously, government-funded fellowships, exchange programmes for subject matter experts, and advanced teacher training courses could help build capacities, address the shortage of AI educators, and raise the quality of teaching.
- **Promote inclusive access to AI skilling:** In order to democratise access to AI education, larger numbers of subsidised, affordable AI courses could be made available through platforms like NPTEL, SWAYAM, and FutureSkills Prime. Additionally, private edtech platforms could be encouraged to make a proportion of their AI resources available as Open Educational Resources (OER) or open-access content, which could benefit less privileged students. Targeted initiatives to bring AI training to rural areas through mobile AI labs or digital skilling hubs

could also ensure that talent from underserved regions is allowed to participate meaningfully in the national AI workforce.

- **Enhance STEM and AI literacy in schools:** STEM education must be revitalised and an interest in AI inculcated during schoolgoing years. While NEP 2020 directs schools and school boards to introduce AI literacy and awareness modules, these should be complemented by hands-on projects, coding workshops, and AI competitions for students. Nurturing this early engagement with AI could lay a strong foundation for advanced studies and, eventually, careers in the discipline.

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III

Driving Sectoral Transformations

Reimagining Care: India's AI Prescription

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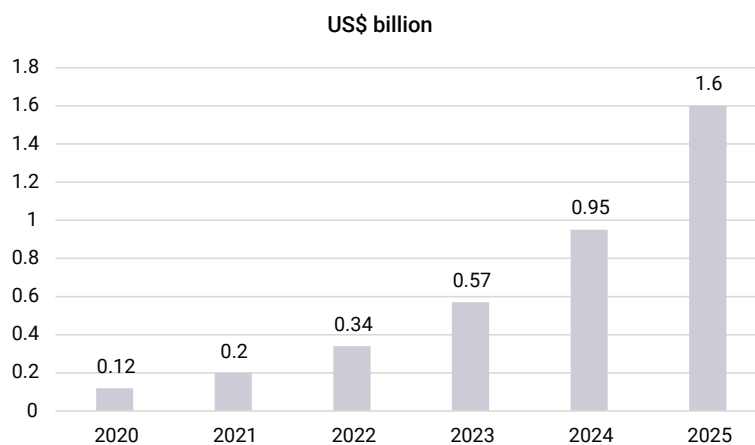
Artificial Intelligence (AI) is rapidly becoming a catalyst for technological advancement across multiple sectors, with healthcare as one of the domains with the most promise and greatest potential impact.¹ The *Governing AI for Humanity* report published by the United Nations in September 2024 emphasised the transformative potential of AI while calling attention to the need for ethical governance to ensure that its benefits are equitably distributed, particularly in sectors like healthcare, where disparities are most profound.² In India, the integration of AI in healthcare has the potential to transform medical practice, enhance patient outcomes, and ease pressures on the healthcare system, particularly amid wide urban-rural infrastructure disparities.³

This same rural-urban divide prevents the wide-ranging adoption of AI for healthcare services in India.⁴ Access to the internet, regular supply of electricity, and deployment of electronic health records remain massive challenges in many regions, hindering the flow of maximum benefits of AI to rural areas, thus limiting healthcare access.

According to the NITI Aayog's 2018 report, *National Strategy for Artificial Intelligence*, India has thus far failed to adopt AI at scale because of shortfalls in data infrastructure, data privacy regulations, investment in technology, and skilled AI professionals.⁵ The 2019 National Digital Health Blueprint has established a digital health ecosystem in India with the aim to leverage emerging technologies, including AI, Machine Learning (ML), the Internet of Things (IoT), and Big Data.⁶

With the increasing capability of AI to enhance diagnostics and provide support to remote healthcare institutions, the use of AI in the health sector in India will continue to rise, and expenditure is expected to reach US\$11.78 billion by 2025 and contribute US\$1 trillion to the economy by 2035.⁷ A report from 2018 projects that the adoption of AI in India's healthcare will result in the creation of 3 million new jobs by 2028, with increasing demand for virtual assistants and data scientists.⁸ Recognising that an ethically sound policy framework is crucial to guiding the development and application of AI technologies in healthcare in the country, the Indian Council of Medical Research (ICMR) released the National Ethical Guidelines for Application of Artificial Intelligence in Biomedical Research and Healthcare in 2023.⁹

The market size of AI in Indian healthcare is estimated to grow rapidly, from US\$120 million in 2020 to US\$160 million by 2025 (Figure 1).¹⁰ AI is emerging as a key tool for transforming many aspects of healthcare, including providing accurate diagnostics, reducing costs by optimising resource allocation, providing long-term innovative solutions, and enhancing health equity.¹¹ In 2019, the Government of India (GoI) launched 'e-Sanjeevani', a telemedicine platform that leverages AI and ML to improve doctor-patient consultation and quality of care. In 2023, GoI launched the 'Ayushman Bharat Digital Mission', with three Centres for Excellence to promote and integrate AI technologies for improving health services.¹²

Figure 1: Indian Market for AI in Healthcare (US\$ billion)

Source: NASSCOM Insights, August 2024¹³

Current AI Applications in Healthcare

Diagnostics

AI has proved to be useful in diagnostics, particularly in radiology, which relies on imaging techniques such as X-rays and MRIs to interpret and diagnose diseases.¹⁴ Ongoing monitoring of AI performance, now called 'algorithmovigilance',^a similar to pharmacovigilance^b in drug safety, is essential to ensure that AI systems maintain high diagnostic accuracy across diverse populations and environments.¹⁵ At present, AI is applied by using ML algorithms to interpret medical images, which helps to cope with the shortage of well-trained medical professionals in many regions of the country. Several organisations in India are pioneering the application of AI to healthcare settings to transform diagnostics and healthcare delivery. Table 1 summarises the key players, their AI-driven innovations, and their contributions to improving clinical outcomes. Further, AI diagnostic capabilities provide an advantage in areas with limited healthcare workers and radiologists.¹⁶

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- a Algorithmovigilance refers to the continuous monitoring and assessment of AI systems to ensure that they function accurately and fairly across diverse populations and settings. Coined by Dr. Peter Embi, president and CEO of the Regenstrief Institute, algorithmovigilance aims to identify, assess, and mitigate adverse effects, biases, and ethical concerns from AI deployment. It is akin to pharmacovigilance in the pharmaceutical industry but applied to the realm of algorithms.
- b Pharmacovigilance is the science and activities related to the detection, assessment, understanding, and prevention of adverse effects or any other medicine- or vaccine-related problems. Pharmacovigilance helps identify side effects that may emerge only when products are used by broader, more diverse populations or over longer periods, thus ensuring safer public-health outcomes.

Table 1: Key Indian Players Advancing AI in Diagnostics and Healthcare

Organisation	AI Application Focus	Key Features and Impact
Qure.ai ¹⁷	Medical Imaging Analysis	Utilises ML to analyse X-rays and CT scans for conditions like Tuberculosis and Stroke, enhancing diagnostic accuracy and efficacy.
NIRAMAI ¹⁸	Breast Cancer Detection	Uses AI-based thermal imaging for early, non-invasive, and low-cost screening of breast cancer, improving accessibility in rural and semi-urban areas with limited specialists. ¹⁹
Wadhvani AI ²⁰	Tuberculosis Diagnosis and Management	Focuses on AI solutions to improve Tuberculosis diagnosis and treatment to enhance healthcare delivery.
Aindra ²¹	Cervical Cancer Screening	Develops AI-based technology for cervical cancer screening, facilitating early detection.
SigTuple ²²	Automated Medical Data Analysis	Automates visual medical data analysis to assist pathologists, increasing diagnostic speed and reducing human error.
Artivatic.ai ²³	Personalised Healthcare Solutions	Provides personalised solutions through predictive modelling, tailoring treatments to the individual needs of patients.
HealthPlix ²⁴	AI-Powered Electronic Medical Records (EMR)	Offers an AI-powered EMR platform that supports data-driven clinical decisions, enhancing healthcare efficiency and accessibility.

Telemedicine and Remote Care

Another area where AI is showing promise is in telemedicine solutions that rely on AI to provide critical access to rural patients remotely. Platforms such as mFine use AI to enable remote consultations between a rural-based patient and an urban-centre-based doctor.²⁵ Telemedicine became even more critical during the COVID-19 pandemic, when such platforms allowed patients to consult healthcare providers while maintaining all measures for physical distancing.²⁶

Tele MANAS, a mental telehealth service by GoI, provides quality mental health care and mental health assistance via phone-based services to populations across states.²⁷ The Tele MANAS initiative has also introduced an AI-powered chatbot service in Jammu and Kashmir.²⁸ In the near future, chronic disease monitoring will also involve wearable devices that use AI to regularly monitor vital signs so that healthcare providers can monitor diseases such as diabetes and cardiovascular issues from a distance.²⁹

Administrative Efficiency

AI can also be effective from the administrative side of the healthcare perspective for Indian hospitals. The tools of generative AI are being applied for the automation of routine administrative tasks, thereby improving the efficiency of hospitals and clinics.³⁰ The Electronic Health Records (EHRs) running on AI systems enable the automatic generation of clinical documentation.³¹ Such EHRs can also allow for the generation of discharge summaries, reducing the bureaucratic burden on healthcare workers and allowing more time to focus on care for their patients.

As highlighted in the latest UN report on the subject, a global governance deficit around AI makes it difficult for individual nations to address ethical and regulatory complexities alone. Effective governance frameworks are essential to mitigate risks, such as data misuse and algorithmic bias, particularly in sectors like healthcare.³²

Regulatory and Ethical Concerns

While AI technology has the potential to transform healthcare, there are some regulatory and ethical issues preventing mass deployment. The Information Technology Act of 2000 was not prepared with AI in mind and technologies were not well developed at the time.³³

New policy documents have been drafted in India in the last decade, including the National Health Stack (2018), the Digital Information Security in Healthcare Act (DISHA) draft of 2018, the Personal Data Protection (PDP) Bill of 2019, the Ayushman Bharat Digital Mission (2021), the Health Data Management Policy (2022), and the Digital Personal Data Protection (DPDP) Act of 2023.³⁴ Many of these initiatives were undertaken by different government agencies, and a process of streamlining them is underway. For example, both the DISHA Act and the PDP Bill were withdrawn to avoid duplication, with the Digital Personal Data Protection (DPDP) Act being introduced as a comprehensive framework covering all domains, including healthcare. The DPDP

Act, 2023, is intended for general personal data protection and does not identify health data as a separate category, which raises concerns about whether it can adequately safeguard the highly sensitive nature of patient information.³⁵

The outcome of the process of centralisation of data protection under one legislation also raises concerns about whether the unique needs of healthcare data, such as patient confidentiality and consent, are adequately addressed within the broader framework. Health data requires a higher level of protection due to its deeply personal nature and the serious consequences that could emerge from its misuse—which could range from privacy violations to impacts on employment, insurance, and social status. Algorithmic bias is also emerging as a critical concern, as AI models trained on urban hospital data often fail to generalise to rural or underserved contexts, potentially exacerbating healthcare disparities.³⁶ This bias in AI systems can lead to misdiagnosis, inappropriate treatment recommendations, and a failure to recognise conditions in populations that are under-represented in the AI dataset, potentially undermining the quality of care for these communities.

AI systems also require huge data loads, which raise concerns related to data privacy and security. The more data that is used by AI systems, the more vulnerable that data will be to breaches and cyberattacks.³⁷ The lack of a robust framework is one of the biggest challenges for AI-driven healthcare systems across the world.³⁸ In India, too, given the specific challenges within the health sector, experts have recommended that dedicated legislation for health data management may be required to go beyond addressing 'breaches' alone and move towards protecting individuals from potential harm.³⁹

The Way Forward

AI in healthcare is a policy area in which regulatory structures often lag behind the rapid technological developments. AI can be part of a multi-pronged reform agenda within the health sector in India, accompanied by efforts to improve infrastructure to overcome the digital divide, so that system improvements are accessible to all segments of society. AI can indeed solve many healthcare challenges that India faces today in diagnostics and remote care. It will need to overcome huge regulatory, infrastructural, and ethical hurdles to succeed.

To enhance healthcare in India, significant investments in the digital infrastructure is needed, including cloud-based data-sharing systems and seamless interoperability between public and private providers. Expedited AI regulations and the creation of

ethics boards in hospitals will ensure the responsible use of AI and curb bias. AI literacy programmes and subsidies are essential to promote widespread AI adoption, especially in rural areas.

Getting government and private sector actors to align on the general pace and direction of technology change within the sector will be the predominant policy challenge for the next decade. India needs to build responsible AI frameworks, which will include creating a healthy platform for public-private partnerships so that AI can deliver gains for every segment of society, including the most remote parts of the country, which require technologies to help overcome physical infrastructure bottlenecks.

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Instructing Generations: AI and Education in India

Anirban Sarma

The integration of Artificial Intelligence (AI) and the deployment of new AI-based solutions have begun to transform educational technology (edtech) worldwide. The global market for AI in edtech is projected to grow from around US\$3.65 billion in 2023 to US\$92.09 billion by 2033, with a compound annual growth rate (CAGR) of over 38 percent between 2024 and 2033.¹ Generative AI, in particular, has prompted countries in highly varied geographies to incorporate AI into their national educational strategies. Key areas in which AI is being used include personalised learning, feedback and assessment, AI-powered content platforms, and teacher support in coursework design, grading, and evaluation.²

India's edtech sector grew during the COVID-19 pandemic in 2020 and 2021, but there has been a marked decline in demand and investment since 2022. With nearly 4,500 edtech startups crowding the market,³ attracting funding and acquiring new customers has become increasingly challenging. A wave of cost-cutting seemed to have marred the industry's promise in 2022–23.⁴ Challenges persist, but some signs of recovery and resurgence have emerged in early 2024. Forecasts indicate that Indian edtech, worth an estimated US\$7.5 billion in 2024, will grow at a CAGR of 25.8 percent and touch US\$29 billion by 2030, with over 100 million paid users.⁵ AI is expected to be a key driver of this growth story, and a recent pan-India survey of more than 6,000 educators showed that nearly 65 percent of them advocate using AI to improve learning experiences and personalise education.⁶

Policy and Practice: Mainstreaming AI into Education

Since releasing its National Strategy for Artificial Intelligence in 2018, India has been paying greater attention to leveraging AI to improve educational outcomes. The Strategy identifies education as one of five priority sectors for AI-related interventions in the country and recommends niche applications. These include the development of customised learning platforms, smart and interactive tutoring systems, predictive tools for identifying potential dropouts, and enabling pre-emptive teacher interventions, automated systems for posting and transferring teachers based on supply gaps, and customised professional development courses.⁷

India's National Education Policy (NEP) 2020, launched amid the COVID-19 pandemic, reinforced the idea of incorporating AI into educational planning and delivery. The NEP 2020 is seen as a game changer because of its unprecedented focus on technology-enhanced learning (TEL), and it outlines actionable steps for AI application. For instance, it suggests using AI to track student performance and growth, automating assessments through the school years to identify areas for corrective action. It also recommends strengthening Natural Language Processing (NLP) capacities for India's regional languages, with efforts to teach languages to K-12 students. Importantly, the NEP mandates the inclusion of a wide range of courses on AI, machine learning, and deep learning across schools, colleges, and universities to raise awareness about these subjects and build India's future AI talent pool.⁸

Implementing AI-related NEP recommendations is underway at both central and state levels. For example, the Indian Ministry of Education is integrating AI-driven personalised adaptive learning (PAL) with DIKSHA (Digital Infrastructure for Knowledge Sharing), a large-scale government platform for online education. A number of states and Union Territories—including Andhra Pradesh, Telangana, Chhattisgarh, and Goa—are leveraging AI tools across their public school systems to automate attendance registration, monitor student performance, take practice tests, evaluate assessments, enhance teacher proficiency and communication skills

through personalised assistants, and manage midday meal data and school sanitation.^{9,10,11} Arguably, however, the greatest progress has been made in the area of AI-focused course development, where schools and universities across the country, as well as premier technical institutions like the Indian Institutes of Technology (IITs), are vigorously promoting AI education.

The private sector continues to be the principal driver of AI innovation in India, with leading homegrown edtech brands—such as BYJU's, Physics Wallah (PW), Leverage Edu, and ODA Class—among the most creative AI deployers. These four companies dominate markets in AI-generated PAL; 'AI University Course Finders' that help students identify courses, universities, and professions based on their aptitude and academic strengths; as well as personalised tutoring and the real-time resolution of queries. Companies like PW are also leveraging AI and other emerging technologies to make quality education accessible nationwide, "reaching 98 percent of India's pin codes."¹² Additionally, since the mid-2010s, a host of purely AI-for-education startups has emerged, offering a spectrum of niche products and services.¹³

Recognising the value that edtech businesses unlock for the Indian education sector, in 2019, the government established the National Educational Alliance for Technology (NEAT)—an online platform built as a public-private partnership where edtech firms can showcase and demonstrate selected products and services. NEAT is "bridging the gap between edtech companies, academic institutions and students" and is likely to help improve learners' access to education.¹⁴

Challenges and Bottlenecks

The development and rollout of AI-driven education solutions in India confronts a diverse set of challenges. To begin with, AI tools and platforms require substantial investments in hardware, software, and training, which many educational institutions may struggle to afford without government support. Under-resourced schools in rural regions often face difficulties in setting up and accessing basic digital infrastructure. These tools are a necessity in public institutions as students from economically weaker sections may not be able to afford access to commercial AI-enabled edtech platforms.¹⁵

As efforts to mainstream AI tools continue, building teachers' capacities and ensuring their readiness to adopt new technologies has emerged as a bottleneck. A 2022 India-wide survey of teachers revealed that 30 percent were still not proficient with digital tools, only 31.4 percent were comfortable managing a Learning Management System (LMS), and less than 15 percent could manage a Virtual Lab.¹⁶ These figures are likely to be even lower in non-urban settings. As AI rollouts will require blended efforts, involving both human teachers and computer systems, large-scale training programmes are essential to better equip Indian teachers for the age of AI.

Globally, the relative paucity of data and content in languages other than English has hindered AI model training, making AI less effective for local languages. This issue is particularly challenging in India, where multiple regional languages exist and teaching materials in government schools and higher education institutions vary across states. However, there is often insufficient educational content in these languages to train AI models effectively. The primary onus for building AI tools in niche languages may fall on state governments, as private edtech players may not feel sufficiently incentivised to build platforms without the promise of scale. If universal access to education is to be achieved, tech solutions in local languages will have to be built.

Finally, ensuring the privacy, personal data protection, and security of learners on AI platforms will need to be an important consideration. Across geographies, there have been troubling cases of breaches and theft of children's data by edtech players,¹⁷ which is then used for hard-selling or mis-selling edtech products and services.¹⁸ Incidents involving the recurrent, non-consensual digital tracking of children and young learners have also come to light. While these issues are not unique to AI platforms, they tend to plague the edtech sector. Without stringent compliance and oversight mechanisms, the incidence of data misuse may increase as more TEL products and services are built.

The Way Forward

The following actions could be considered to strengthen the integration of AI into education:

- **Creating a national fund for TEL that prioritises AI solutions:** The launch of the well-funded India AI Mission in early 2024 is an important step for supporting critical sectors through AI solutions, particularly as the Mission intends to design AI services in response to problem statements sourced from central ministries, state departments, and other institutions.¹⁹ This approach will be especially valuable for education, which is a concurrent subject. These developments need to be aligned with the Union Budget's generous allocation for education in 2024-25 and its emphasis on digital learning solutions, despite the absence of a well-defined allocation for the latter. A clearer budgetary and implementation focus on AI in edtech is certainly needed. Establishing a national fund for TEL could help allocate funds for specific AI-in-education initiatives at the state and central levels, addressing technological and skilling challenges faced by under-resourced state educational systems.
- **Promoting the production of educational content in regional languages:** To develop effective AI solutions in local languages, a much larger volume of educational content in regional languages must be made available. India's open universities maintain rich and growing open repositories of course content in regional languages. A start could be made by hosting these contents on or providing access to them via a centralised platform, such

as the National Repository of Open Courses. Additionally, private edtech players could be encouraged to make part of their vernacular materials available as open educational resources to contribute to the AI development ecosystem. All these resources could prove invaluable for building more inclusive and unbiased AI systems.

- **Resolving the issue of verifiable parental consent for children using edtech platforms:** India's Digital Personal Data Protection (DPDP) Act of 2023 states that a data fiduciary (such as an edtech platform) must obtain verifiable parental consent (VPC) before processing any data related to a child using the platform; and that it cannot track children, monitor their behaviour, or target them for advertising based on collected data.²⁰ As the Rules for implementing the DPDP Act are formulated, it will be crucial to strike a balance between ensuring compliance with the idea of promoting children's safety on the one hand, and avoiding the stifling of AI development by foreclosing the possibility of using certain kinds of child-related personal data.
- **Building stronger government-industry interfaces for building and promoting edtech:** Finally, building on the possibilities afforded by the NEAT platform, businesses—working through industry associations—and the state and central governments must continue to scout for new opportunities to collaborate and to craft AI-focused partnerships that benefit teachers, learners, and institutions.

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AI in the Agriculture Sector in India: Building for the Future

Debajyoti Chakravarty

The agriculture sector in India contributes 18.2 percent¹ of gross domestic product (GDP) and provides livelihood to 42.3 percent of the population. With the country's population projected to reach 1.7 billion by the 2060s,² there is a need to enhance food security.

Agriculture in India is facing multiple challenges—unpredictable monsoons, shifting climate patterns, varying soil quality, frequent droughts and pest outbreaks—which result in declining crop yields. Emerging technologies, such as Artificial Intelligence (AI), can provide remedies by analysing large datasets, and thereby offering real-time insights into soil health, moisture levels, and crop conditions. Data-driven solutions can help farmers apply fertilisers, pesticides, and water more accurately and efficiently, minimising waste, optimising resource management, and reducing environmental harm. Machine Learning (ML) algorithms can also detect early signs of disease or pest infestations, allowing for timely, targeted interventions to prevent crop damage and predict crop yield to enable farmers to take timely and adequate contingency measures.³

The future lies in embracing the fruits of what has been called the fourth agricultural revolution^{3,4}—building enabling capacities, and engaging in productive, adaptable and sustainable AI powered farming practices.

India's Thrust for AI in Agriculture

India has undertaken certain steps to integrate AI into agriculture, keeping in mind ground realities and operating within a systematic policy framework, using international collaborations and developing domestic capacities.

The National Strategy for AI⁵ highlights agriculture as a 'focus area for intervention', explaining how, along with other related technologies, it can help improve soil and crop health and enhance efficiency and productivity at all stages of the agricultural value chain. Real-time monitoring and advisory systems for farmers and designing of 'smart' farming equipment are among the examples of AI applications emphasised in the policy. Given that Indian agriculture mainly comprises subsistence farming by small and medium farmers with small and fragmented landholdings,⁶ this acquires particular significance. Through another policy document, 'Principles for Responsible AI',⁷ the government has laid down overarching principles to guide AI application and governance in India. These in turn draw from India's constitutional principles and certain Supreme Court judgments.

a The literature on agriculture maintains that the first agricultural revolution took place many millennia ago, when humans shifted from nomadic living or the hunting/gathering stage to settled agriculture. The second was in the 17th-19th centuries when farm sizes expanded, crop rotation was introduced, and technological improvements in agricultural implements were made to raise productivity. The third revolution was the green revolution of the 20th century.

India has adopted a focused strategy to build and bolster its AI capacity. The India AI 2023 Report⁸ describes the operational framework, which envisages, among others, establishing ‘centres of excellence’ and setting up institutional structures for capacity building activities such as data collection.

Table 1 lists the key areas in which AI is already being used in agriculture in India.

Table 1: Schemes to Bolster Agriculture

Pradhan Mantri Fasal Bima Yojna ⁹	This pan-India crop insurance programme provides comprehensive coverage for farmers against crop failure. As part of its assessment mechanism, the Ministry of Agriculture and Farmers’ Welfare plans to conduct crop-specific ‘crop cutting experiments’ (CCE) in each gram panchayat to assess crop yield during a cultivation cycle. This has so far been implemented in states like Maharashtra, Madhya Pradesh, and Karnataka, on crops such as cotton, paddy, and maize. ‘SmartFarm’ ^b and ‘SmartRisk’ ^c AI solutions of CropIn Technology have brought all stakeholders—farmers, relevant government bodies, insurance firms, and financial institutions—on to a unified platform for streamlined administration and enhanced transparency, providing real-time data and monitoring.
Kisan e-Mitra ¹⁰ (AI chat bot)	‘Kisan e-mitra’, an AI-powered chatbot provides assistance in multiple languages, breaking down technological and language barriers. It is a feature of the PM-KISAN scheme, designed to subsidise farmers, who receive INR 6,000 annually in three equal instalments, paid every four months through Direct Benefit Transfer (DBT) into their bank accounts without involving intermediaries. The scheme also has a grievance redressal mechanism, allowing farmers to file complaints via the PM-KISAN portal. The PM-KISAN mobile app has a unique face authentication facility, based on an e-KYC system that enables farmers to complete their e-KYC remotely from their homes, even in remote areas, without requiring OTPs or fingerprint scans.

b SmartFarm captures the precise location and size of the farm, details of farmers and the crop details right from the pre-harvest stage. The solution also enables accountability, efficiency, and transparency in farms by geo-tagging. This ensures that the field data is accurate, enabling authorities to easily use relevant data at the appropriate time.

c SmartRisk makes use of both ground-level data and satellite imagery to identify the plots that are apt for these experiments. SmartRisk also helps in estimating crop health, yield proxy of a given crop in a district, and acreage.

Virtually Integrated System to Access Agricultural Resources ¹¹ (VISTAAR)	VISTAAR is an innovative open-source digital platform aimed at enhancing collaboration among stakeholders in India's agricultural ecosystem, with a focus on addressing challenges in the agricultural extension system. ¹² This farmer-focused digital network uses AI to deliver real-time farming solutions. It also has an AI-powered multilingual chatbot, available on platforms like Telegram, to provide farmers with precise, context-relevant advice. Another conversational chatbot connects farmers to the Kisan call centre, enabling them to access agricultural guidance, weather updates, report issues, and receive reliable responses, thereby enabling timely and informed decision-making.
National Pest Surveillance System ¹³ (NPSS)	NPSS provides farmers across the country with easy and timely access to expert support for pest identification and pest management based on pest surveillance. This service helps prevent pest epidemics and reduces crop losses by using AI and (information and communications technologies) ICTs to power large-scale, systematic pest surveillance. Smartphones are leveraged to automate the delivery of expert guidance.
Krishi 24/7 ¹⁴	Krishi 24/7 is the first AI-powered solution designed for automated monitoring and analysis of agricultural news. It provides the ministry pertinent agricultural news, generates timely alerts, and takes swift action to safeguard farmers' interests.
Digital Agriculture Mission ¹⁵	Platforms such as Agristack, the Krishi Decision Support System and Soil Profile Mapping have been set up by leveraging AI and data analytics to improve service delivery for farmers, streamline access to government schemes and crop loans, issue real-time advisories, and more. ¹⁶

Data Collection

Stating productivity and resilience in agriculture as the first among nine priority areas in the Union Budget of 2024-25, a total of INR 1.52 lakh crore has been allocated for agriculture and allied sector. Among other measures, the budget seeks to implement the Digital Public Infrastructure¹⁷ (DPI) in agriculture within three years, starting with a digital crop survey of kharif crops in 400 of India's 737 districts. Farmers and their land details will be brought into relevant registries, boosting digital databases.

Enabling a Start-up Ecosystem

Recognising the pivotal role that start-ups are playing in the fourth industrial revolution,¹⁸ India hopes to achieve the same in agriculture. It has boosted its AI-powered agriculture start-up ecosystem through initiatives such as the Innovation and Agri-entrepreneurship Development Programme, under the Rashtriya Krishi Vikas Yojana^d and the Agriculture Accelerator Fund.^{e,19} Of the 3,903 agriculture-based start-ups in the country, 1,708 were set up under this programme, launched in 2018.²⁰ AI-based solutions are also being used to enable precision agriculture, with the government collaborating with the likes of Microsoft²¹ and IBM²² to run pilot projects.²³

India has entered into a number of international collaborations to boost AI use in agriculture. Table 2 lists some of the notable collaborations.

Table 2: International Collaborations with India's Engagement

USA-India Artificial Intelligence Initiative ²⁴ (USIAI) ²⁵	Includes bilateral AI cooperation in agriculture with the US, along with other critical areas for AI research and developmental collaboration.
QUAD-led AI-ENGAGE ²⁶	A joint effort by the Quad nations—India, the US, Australia and Japan—to use cutting-edge AI research and innovation to transform agricultural approaches, increase crop yield and crop resilience, and create a space for ideas and best practice exchanges.

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- d The Innovation and Agri-entrepreneurship Development programme under the Rashtriya Krishi Vikas Yojana is being implemented by the Agriculture and Farmers Welfare department of the Government of India to promote innovation and agri-entrepreneurship by nurturing an incubation ecosystem and providing financial support. Under this initiative, five 'knowledge partners' and 24 'agribusiness incubators' have been appointed for incubation of startups and implementation of this programme. Financial support of INR 5 lakh at the idea/pre-seed stage and INR 25 lakh at the seed stage along with technical, financial and scaling assistance to launch their products, services, and business platforms, into the market is provided here.
- e Ministry of Agriculture and Farmers Welfare, Government of India set up the Agriculture Accelerator Fund worth INR 300 crore for three years commencing from 2023-24 to nurture the agriculture start-up ecosystem. The fund will help scale up startups with innovative technologies having the potential to modernise the agriculture ecosystem of India.

<p>Collaboration with Japan International Cooperation Agency (JICA)²⁷</p>	<p>Japan's JICA has extended loans worth US\$225 billion to support Indian agriculture since 1988,²⁸ especially to states such as Himachal Pradesh, Mizoram, Odisha and Rajasthan.²⁹</p> <p>Future collaboration could involve expanding this partnership to other Indian states, focusing on technical cooperation, policy development, and integration of emerging technologies such as drones, AI and the Internet of Things (IoT) into Indian agriculture.</p>
<p>Collaboration with Germany³⁰</p>	<p>The framework for Indo-German collaboration in AI has been laid down in the 'Joint Declaration of Intent' between the Ministry of Electronics and Information Technology of India and the Federal Ministry of Economic Affairs and Energy of Germany.³¹</p> <p>It covers information exchanges on best practices, energising start-up ecosystems, creating a business friendly environment, and stronger bilateral relations in ICT trade.</p>

What Lies Ahead

The integration of AI-powered tools into agricultural practices is essential for effective crop management, as it helps farmers achieve maximum yields while minimising resource use and wastage.³² There are, however, challenges, as outlined in the following points:

Scaling Limitations

- For AI models to successfully predict and deliver robust and real-time-based results, different kinds of data are needed from different sources. This is vital for India's rapidly growing AI-powered agriculture start-ups,³³ as myriad datasets presented on a single consolidated platform will make access easier, enabling scaling of AI interventions.³⁴ So far, though promising results have been obtained within pilot project settings,³⁵ challenges remain in scaling them to a level where

they are commercially viable. Awareness generation, capacity-building and regulatory interventions are also essential.

High Costs

- To be commercially viable, AI solutions need to be cost effective, which alone can bring about mass adoption by small landholders. Currently, it is only big farmers who can afford AI solutions to improve their agricultural practices. The government could consider subsidising³⁶ such access initially to encourage small and medium farmers to follow suit, thereby also narrowing the digital divide.³⁷

Lack of Infrastructural Support

- Components such as uninterrupted high computational power and reliable internet access in rural areas are critical for data transmission and real-time decision making by AI software. Absence of these can hinder deployment and scalability of AI technologies in agriculture. This challenge will have to be comprehensively and uniformly addressed if India is to effectively step into the fourth agricultural revolution.

Lack of Awareness

- Farmers have concerns about the proper functioning of the machines they use, as well as their dependence on mechanical and electronic components. They fear that if a malfunction arises during critical periods, such as harvest time, it could jeopardise part—or all—of their crop. Implementing testing sandboxes for integrated mechanical, electronic, and AI systems may help boost their confidence in these technologies.
- The successful implementation of AI applications in agriculture calls for specialised infrastructure, underscoring the importance of capacity building and inculcating digital skills among farmers. Demonstration activities and small field trials may be effective in persuading farmers of the benefits, and help ensure that full-scale deployments of AI solutions are successful.³⁸

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Smart(er) Cities: Integrating Artificial Intelligence for Inclusive Built Environments

Anusha Kesarkar Gavankar

Smart cities integrate technology, information, and innovation to improve quality of life.¹ Cities are increasingly leveraging digital public infrastructure in areas such as mobility, water, housing, waste management, energy, and governance to achieve smart city status.² However, this digital shift towards creating resilient built environments can only succeed through a people-centric approach where technology serves all equally, including the poor and marginalised. Artificial Intelligence (AI) and the Internet of Things (IoT) offer immense opportunities³ for optimising public services, enhancing citizen participation, aligning aspirations, and addressing socioeconomic challenges.

AI is transforming smart cities by improving public spaces, such as parks, through automated monitoring and maintenance systems. It can also aid in managing crowds during public events, like in Singapore's SG50 celebrations and India's Kumbh Mela,⁴ where it has helped predict crowd behaviour and thereby prevent potential crises. In cities like Surat, AI-driven safety systems have contributed to a remarkable 27-percent reduction in crime rates.⁵ Additionally, AI is becoming indispensable for cybersecurity, identifying system vulnerabilities and safeguarding critical urban infrastructure from cyberattacks.

India's 'Smart Cities' Mission

Launched in 2015 by India's Ministry of Housing and Urban Affairs (MoHUA), the Smart Cities Mission (SCM)⁶ aims to develop 100 smart cities between 2019 and 2025, with a budget of INR 980 billion (US\$12 billion).⁷ The SCM emphasises collaboration between state governments and special purpose vehicles (SPVs) to identify region-specific priorities through area-based development and participatory planning, extending its impact to neighbouring towns.

The SCM is buttressed by India's national strategy for AI, which envisions transforming these smart cities into 'intelligent cities' by gaining actionable insights from the data generated by smart cities. To this end, the MoHUA has launched an 'AI Playbook for Cities'⁸ that draws out AI's role and potential for Indian cities, apart from outlining successful AI use cases in urban areas⁹ that offer valuable resources for cities across the country.

The introduction of Centres of Excellence (CoE) in the 2023-24 budget, with an allocation of INR 9.9 billion¹⁰ (US\$116 million), further underlines urban India's focus on leveraging AI to achieve the 2047 vision of 'Viksit Bharat' that aspires to transform the nation into a fully developed country by the centenary of its independence. CoEs will focus on interdisciplinary research—in collaboration with leading educational institutions, industries, and startups—to develop innovative, practical, and scalable AI solutions that can effectively address the needs of India's cities. Some of their goals are for smart cities to reduce energy consumption by 15 percent,¹¹ cut air and water pollution by 10 percent, improve waste management by 25 percent, and reduce commuting time by 20 percent. These efforts will also lower pollutant levels in rivers and seas and enhance water and waste reclamation.

Indeed, AI is already transforming urban living in the country, improving efficiency, safety, and sustainability in cities. The 2024 Smart City Index¹² showcased successful outcomes from several cities' AI-based smart city initiatives. Bhubaneswar, for

example, has transformed its traffic management system using AI-powered cameras and sensors¹³ that track real-time traffic and reduce congestion¹⁴ while helping drivers find available parking areas through IoT devices. This has made roads safer and improved travel efficiency.¹⁵ Indore has made strides in waste management, using IoT-based monitoring and AI to optimise trash collection,¹⁶ reduce environmental impact,¹⁷ and keep the city clean.¹⁸ Surat's AI-powered safety systems, mentioned earlier, have highlighted the potential of AI in improving public safety. Bengaluru has launched the AI-driven Bengaluru Adaptive Traffic Control System (BATCS),¹⁹ which uses real-time data to optimise traffic flow, reducing delays across 165 junctions. Kerala and Karnataka have leveraged the Automated Fingerprint Identification System (AFIS) to accurately identify suspects by analysing unclear or fragmented fingerprints. Mysore's adoption of the Intelligent Transport System (ITS) has reduced fatal accidents by half, boosted bus punctuality to 90 percent, and reduced passenger wait times to under 10 minutes.²⁰

To support such innovations, India has developed digital platforms like the National Urban Digital Mission,²¹ India Urban Data Exchange,²² and the Smart Cities Open Data portal,²³ to foster public-private collaboration and address urban issues.

Despite these achievements, Urban Local Bodies (ULBs) continue to face challenges, including financial constraints,²⁴ reliance on state and Central grants, lack of institutional capacity, and gaps in technology.²⁵ These hurdles limit their ability to fund and implement smart city projects.

Not as Smart?

While AI promises transformative development, ease of governance and a better quality of life, integrating cutting-edge technology poses challenges, especially for cities in the Global South. The high costs of adopting and upgrading AI-powered technologies is one of these,²⁶ especially for cities with limited budgets. In Mexico, budget constraints have delayed intelligent public transportation systems²⁷ that could benefit low-income communities. Similarly, in Bengaluru, despite the implementation of BATCS, the city's outdated infrastructure has restricted the city's efforts²⁸ in resolving issues of traffic congestion and inadequate public transport.

The existing digital divide²⁹ is accentuated as vulnerable groups,³⁰ such as the elderly,³¹ women,³² children,³³ and persons with disabilities,³⁴ may not have access to technology or the skills needed to use it. They are then excluded from AI-driven services like e-governance, e-commerce, and telehealth.

The absence of citizen participation³⁵ and concerns about data misuse, privacy, and surveillance³⁶ also reinforce prevailing inequalities, hindering adoption. For example, despite its advanced AI-enabled systems, South Korea's Songdo³⁷ has faced criticism for prioritising efficiency over social interaction, resulting in diminished community life. For their part, Bilbao in Spain and Australia's Canberra successfully overcame resistance to change³⁸ by involving residents in decision-making and fostering open communication. Mysore's ITS,³⁹ too, which has improved bus route identification, highlights the need for public education to maximise its impact and effectiveness. This involves helping people learn how to use features like smart crossings and real-time tracking, while encouraging safe road habits and making sure that everyone can access it.

Addressing these challenges demands effective governance, citizen engagement, and scalable, inclusive solutions to ensure long-term effectiveness and equity. Moreover, effective AI initiatives rely on interoperability,⁴⁰ requiring collaboration among multiple stakeholders and technologies, as well as standardised frameworks for seamless integration. It is only by tackling such issues that the AI can foster inclusive, equitable urban environments.

Co-Creating People-Smart Cities: The Essentials

- **Promote participatory planning**

Participatory AI brings together residents, policymakers, and local organisations to ensure that the development and implementation of AI technologies reflect the diverse needs and values of all urban residents,⁴¹ especially the marginalised populations.⁴² By involving communities in decision-making,⁴³ cities can ensure transparency, reduce biases, and create AI systems that are more inclusive, effective, and responsive to local challenges.

Cities like Pune have shown how data-driven technologies,⁴⁴ such as the Digital Twins with AI simulations,^a can prioritise public health and safety,⁴⁵ especially during crises such as the COVID-19 pandemic. However, cases like Uttar Pradesh's AI-

a During the COVID-19 pandemic, Tata Consultancy Services, a global player in IT services, created a digital twin of Pune—a virtual replica of the city that combined real-time data on cases, demographics, healthcare resources, and mobility patterns. This innovative tool used advanced simulations and AI to help city administrators assess the impact of decisions like lockdowns, school reopenings, and resource distribution. By visualising potential outcomes, it supported proactive and informed decision-making, enabling more effective management of the crisis.

based security systems, with AI-based cameras in 17 cities to enhance the safety of women, the elderly, children, and persons with disabilities,⁴⁶ have highlighted the need to balance technological advancements with citizen concerns.⁴⁷ Some of the key challenges that emerge include privacy violation, misuse of data, biased algorithms that might discriminate against vulnerable groups, and a lack of informed consent from individuals whose sensitive data is collected and used by the government.

- **Bridge the digital divide**

To ensure equitable access to technology, cities must focus on digital literacy programmes and make affordable digital devices available to marginalised populations while sensitising government officials. This includes raising awareness about the difficulties of access to technology for the disadvantaged, importance of digital inclusive policies, and the ethical use of AI. India's Aarogya Setu app, launched during the COVID-19 pandemic, is an example of how AI can bridge the digital divide.⁴⁸ With features such as multilingual support with offline functions, the app ensured that even those with limited digital literacy or internet access could benefit from vital health information and contact-tracing services.

Similarly, Kenya's AI Masterplan⁴⁹ seeks to bridge the digitalisation gap by increasing internet availability, providing access to digital education, and ensuring universal mobile services. It also aims to improve AI literacy and enhance skills in AI and other STEM domains, particularly among youth, to open access into digital jobs and participation into the digital economy. Another example of inclusivity is Singapore's implementation of assistive technologies⁵⁰ for individuals with disabilities—features like tactile paving, audio signals at road crossings, and customisable digital interfaces in public transport enhance accessibility for all.

- **Empower ULBs**

By decentralising decision-making, cities will be able to tackle their unique challenges more effectively. Equipping ULBs to leverage AI can play a key role in this regard.⁵¹ ULBs need to be empowered with sufficient financial and technical resources,⁵² along with decision-making autonomy and access to innovative funding tools such as green financing, municipal bonds, and public–private partnerships.

ULBs can be critical to driving AI initiatives by collecting and managing localised data through IoT sensors that can provide real-time insights for addressing urban

challenges. The Bhopal Smart City Development Corporation's cloud-based management system⁵³ is an example of how enabling ULBs to deploy technology can improve urban governance and service delivery. Similarly, the integrated command-and-control centres established by SPVs in smart cities across India offer real-time data to local authorities, enabling faster and effective decision-making.⁵⁴ These systems, supported by IoT sensors, are becoming critical components of India's digital infrastructure.⁵⁵

- **Leverage collaborations**

Policymakers must encourage more multi-stakeholder and cross-border partnerships to share resources and strategies that address common urban challenges. One example of effective mobilisation in this regard is San José's GovAI Coalition,⁵⁶ formed in November 2023, which brings together over 800 members from 300 local governments to develop responsible AI policies and practice. Through efforts such as real-time translation of public meetings and traffic pattern prediction for better bus routes, the coalition among government agencies, industry leaders, non-profits, philanthropies, and the public has demonstrated how a collaborative approach to deploying AI can enhance public services and ensure inclusive development.

Likewise, Recife's Porto Digital in Brazil⁵⁷ is a collective that uses AI to improve public services, including traffic management, security, and healthcare, by collaborating with local universities and tech companies. Jaipur has developed AI tools through collaborations too. For its Jaipur Smart City Phase-II Project, the city has partnered with private player Sterlite Tech.⁵⁸ The association involves setting up interactive kiosks for gathering real-time information to enhance citizen engagement and administrative efficiency, including environmental sensors that provide valuable data.

- **Foster innovative financing**

Governments will need new financing strategies, including innovative partnerships and procurement methods, to make smart cities a reality. AI-driven financial models can help balance long-term investments with social, economic, and environmental benefits. Moreover, cities in the Global South must prioritise a collaborative approach⁵⁹ to financing and ensuring transparent governance to guarantee the successful and equitable implementation of AI solutions.

Singapore's 'Smart Nation' initiative is a case study in utilising innovative financing to deploy AI in urban planning.⁶⁰ Mechanisms like government grants and public-

private partnerships, and revenue models like green bonds, fund AI-driven solutions for various concerns in the country—optimising land use, predicting housing needs, and improving transport networks. Barcelona utilises the EU’s Horizon 2020 funding for research and innovation,⁶¹ public-private partnerships, and revenue-sharing models to support AI applications⁶² in optimising traffic, waste management, and public transportation. Further, open-source AI platforms like Sentilo⁶³ generate revenue by offering data-driven urban planning services to other cities. For instance, Sentilo helps in collecting and managing data from sensors across the city, enabling planners to make better decisions for improving urban services and infrastructure.

Conclusion

Creating people-smart cities is not just about introducing new technology but also about making sure that these innovations work for the people who live in the city. To build cities that are truly inclusive, it is essential to account for the needs of the community and work together to find solutions that benefit all.

Examples from India and elsewhere show that if AI-based solutions are designed for citizens, they can make cities a better place for everyone. With every technological advancement, planners must prioritise public engagement to ensure that urban spaces remain fair, sustainable, and equitable. Ultimately, the success of people-smart cities depends on balancing new technology with creating built environments where everyone can enjoy a better quality of life.

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IV

Security and Strategy

National Security: India's Critical AI Moment

Sameer Patil

Advancements in Artificial Intelligence (AI) have implications for national security establishments worldwide, complicating their threat landscape while also providing them with the tools to counter these novel threats. Three examples illustrate how advancements in AI are introducing new threats: the emergence of deepfake-enabled disinformation, AI-driven cyberattacks, and the use of autonomous systems by violent non-state actors. These developments have made it imperative for states to assess both the opportunities and risks associated with AI.

The expansion of computing power and growth of Large Language Models in the past few years has resulted in a number of applications, from facial recognition technology (FRT), to threat and anomaly detection and autonomous systems, to predictive intelligence, that nations can utilise to buttress their defence systems.¹ For law enforcement agencies with limited time and resources, AI potentially offers the tools to rapidly sift through various kinds of data, predict patterns, generate avenues of action, and develop operational capabilities to pursue those actions.² This can enable agencies to respond more effectively to national security threats and public safety challenges.

This article examines the opportunities offered by AI for India's national security establishment, with a focus on law enforcement and crime, as distinct from the application of AI for military purposes. It examines the current use of AI-enabled applications by various agencies and the challenges that thereby arise. It argues that even as Indian security agencies at the central and state levels harness AI to augment their capabilities, they must tackle critical accountability and ethics questions to ensure its fair, responsible, and optimal use. For this, additional research and development must be conducted to identify specific use cases and the challenges that may arise in real-world applications. This should be combined with a central regulation or directive that can offer guiding principles on using AI for national security.

AI for Law Enforcement

Recognising the strides in the AI domain, India began exploring AI for defence some seven years ago. In 2018, the Ministry of Defence (MoD) set up a multistakeholder task force to implement AI in national defence.³ The high-level Defence AI Council and a Defence AI Project Agency were thereafter created.⁴ The MoD viewed the development of AI capabilities as a key dimension of *Atmanirbhar Bharat*. Consequently, it encouraged the domestic start-up and innovation ecosystem to develop applications that the military can deploy. These applications include autonomous systems, cybersecurity solutions, human behavioural analysis, intelligent monitoring systems, and speech/voice analysis systems.⁵ Besides their relevance for the military, many of these applications are useful for law enforcement and public safety.⁶

However, a similar national security-focused approach to AI, which analyses its use for law enforcement agencies, is missing in India. Even the flagship National Strategy for AI of the NITI Aayog in June 2018 mentions the security applications of AI in general terms, such as through crowd management and intelligent safety systems.⁷ Home Minister Amit Shah has repeatedly urged security agencies to increase the

use of AI and machine learning. In September 2024, speaking at the first foundation day of the Indian Cyber Crime Coordination Centre, he asked the Centre to use AI to identify the modus operandi of criminals to find new ways to tackle cybercrime.⁸ On another occasion, he mentioned that one of the primary challenges for the Ministry of Home Affairs was the creation of software using AI and making it “legal”.⁹

In light of this, police departments across India have begun extensively using locally developed, commercially available AI-enabled applications for preventive and predictive policing.¹⁰ Examples include the use of AI by the Karnataka Police for historical data analysis and multidimensional incident analysis. Additionally, it has used AI to automate tasks, such as vehicle licence-plate recognition. Similarly, Bengaluru Police, as part of the Safe City Project, has used FRT to flag individuals with a history of crimes, identify suspicious behaviour, and earmark vulnerable areas for enhanced police patrolling.¹¹ In Maharashtra, the state government has collaborated with the Indian Institute of Management Nagpur and a Chennai-based startup to create a separate entity, named Maharashtra Research and Vigilance for Enhanced Law Enforcement (MARVEL), which aims to enhance the state police force's intelligence and crime prediction capabilities using AI.¹² Some state police forces have also used AI-based solutions Trinetra and Crime GPT, developed by an Indian start-up for crime detection and investigation. These solutions reportedly have a repository of over 900,000 criminal records from Uttar Pradesh (UP).¹³ Kerala Police, too, has used AI to build a centralised data repository of people involved in criminal activities.¹⁴

Besides the above uses, police forces are regularly deploying drones and facial recognition cameras for crowd management. For example, during the New Delhi G20 Summit in September 2023, Delhi Police used FRT to identify potential suspects from the crowds gathered at the summit venue.¹⁵ Similarly, for the Mahakumbh Mela scheduled to start from mid-January, UP Police will deploy FRT-enabled CCTV cameras to monitor the crowds.¹⁶ In other instances, police have used FRT to trace missing children.¹⁷

Beyond the police, agencies like the Reserve Bank of India (RBI) have explored AI for security. RBI has developed an AI-based tool called MuleHunter.ai to detect money mule accounts more efficiently.¹⁸ In November 2024, the government also announced the creation of an AI Data Bank that will include satellite, drone, and Internet of Things devices data.¹⁹ This data can be utilised for several functions, including surveillance and cybersecurity.

Emerging Gaps

While security agencies' use of AI flourishes, it also raises important questions regarding their practices. Excessive dependence on AI, combined with a limited understanding of its potential and perils, can lead to misguided decision-making and reduced human oversight and make national security establishments vulnerable to manipulation. AI is not infallible; trained on insufficient or inaccurate data, it can perpetuate biases and misperceptions that could have harmful consequences if deployed for policing and criminal investigations. Moreover, AI-based applications have other concerns, such as the "black box problem" and hallucinations that go beyond the national security domain but have grave implications for national security.²⁰

Further, it is difficult to assess the efficacy of one AI system over another due to the lack of standardised benchmarks and mechanisms. Like the deliberations about the applications of AI in other domains in India, including military/defence, such deliberations about the use of AI for national security are not taking place publicly—barring the debate about the use of FRT—this has triggered privacy concerns.^{21,22} The absence of proportional guardrails for surveillance in India and the chequered history of Indian agencies engaging in unlawful monitoring casts an additional shadow on this issue.²³

At a more fundamental level, the absence of a central directive or regulation on using AI for national security purposes and one that aligns with India's commitment to Responsible and Explainable AI represents a stark policy gap. Such a directive will help keep AI trustworthy, including, for instance, undertaking pre- and post-deployment testing of frontier AI models and risk assessments and mandating that AI developers check for AI models that could be used maliciously. However, its absence creates an implementation gap regarding misuse/abuse, harms, and accountability. There is also the issue of private companies and tech start-ups being the primary drivers of AI innovation and development, which can complicate regulatory efforts.

Seizing the Moment

AI presents opportunities for ramping up India's national security. The national security establishment can build on its current use of AI to ensure that these technologies are applied in a fair, responsible, and optimal manner. Towards this, India should consider taking the following steps:

- Introduce a central directive/regulation that focuses on using AI for national security purposes and lays down guiding principles.
- Conduct and support independent research that evaluates the applications and challenges of AI within the field of national security by other countries, generating actionable insights for India.
- Identify specific use cases and challenges for the Indian context.
- Create concurrent guidelines for cybersecurity and the development/usage of Responsible and Explainable AI.
- Explore public-private partnerships like MARVEL to evaluate the potential for start-ups and tech companies to provide AI-enabled solutions to law enforcement agencies.
- Train and engage in capacity building for law enforcement officials to understand the opportunities offered by using AI and its limitations.

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Military AI in India: Building Technological Deterrence Amid Global Competition

Amoha Basrur

Artificial Intelligence (AI) used in military applications can enhance a country's tactical and strategic capabilities. It improves data analysis, predictive maintenance, and operational efficiency. By enabling quicker situational awareness and reducing response times, AI can change battlefield conditions while also reducing human risk.

Warfare today operates in a multi-domain environment where battles in cyberspace, outer space, and over information are as crucial as traditional combat operations.¹ The emergence of grey zones^a has also increased reliance on tools of unconventional warfare such as cyberattacks and disinformation campaigns.² Apart from its use as a force multiplier in battlefields, AI is a powerful tool for dealing with these non-conventional threats. The global market for military-related AI was valued at US\$7.95 billion in 2023 and is expected to grow at a compound annual growth rate (CAGR) of 11.8 percent till 2032.³

The use of AI in the military, however, is not just a technological upgrade. AI has reshaped the defence paradigm by shifting the reliance for not just operations but also decision-making away from humans. Contemporary conflicts have accelerated the development of AI for military applications, fuelled the race for dominance in the sector,⁴ and raised crucial questions about the impact of this novel technology.⁵

In the Indian context, a growing wariness of China's rising power and renewed tension at its northeastern borders since 2017 have led to consistently increasing defence budgets⁶ and a spate of reforms.⁷ Modernisation is a clear priority for the Indian military and AI integration is an important aspect of this transformation.⁸ All three services have taken steps to adopt AI across the spectrum of their operations.

India still has a long way to go before it fully realises its military AI ambitions. Nevertheless, AI is undoubtedly going to play a key role in its broader strategic goal of ensuring technological deterrence and operational readiness.⁹

The Military-Related AI Landscape

With the intent of prioritising military AI, India created the Defence AI Council and the Defence AI Projects Agency in 2019.¹⁰ The Department of Defence Production has earmarked INR 100 crore per year for AI projects for the armed forces¹¹ and introduced the Scheme for Innovations for Defence Excellence, whose focus is AI.¹² The sector has been gradually gaining momentum, and in 2022, the Ministry of Defence (MoD) unveiled 75 AI products.^{b,13}

a 'Grey zones' refer to the space in which combatants compete to gain advantage without crossing the threshold into armed conflict.

b These include AI Platform Automation, Autonomous/ Unmanned/ Robotics systems, Block Chain-based Automation, Command, Control, Communication, Computer & Intelligence, Surveillance & Reconnaissance, Cyber Security, Human Behavioural Analysis, Intelligent Monitoring Systems, Lethal Autonomous Weapon Systems, Logistics and Supply Chain Management, Operational Data Analytics, Manufacturing and Maintenance, Simulators/Test Equipment, and Natural Language Processing.

Despite the structural and funding reforms, India still has a mixed defence AI organisation without any central decision-making body. Design, development, deployment, proliferation, and control of defence AI, the 16 defence public sector undertakings, and the Defence Research and Development Organisation (DRDO) with its sub-centres are all under the Ministry of Defence (MoD), albeit with different departments. However, external agencies such as industry, start-ups, academia, and civil society have a limited role in the ecosystem and a unidirectional relationship with the government.¹⁴ This fragmentation in decision-making and lack of integration between the civil and military spheres is an impediment as it leaves room for duplication of effort and limits the resource-sharing necessary for rapid innovation. India must develop a more agile system if it is to keep pace with the technological advancements of other global military powers.

China, for example, has been making massive investments in robotics, swarming drones, and other applications of AI.¹⁵ Concerned that the Chinese advances in autonomy and AI-enabled weapons systems could impact the global military balance, the US military nearly tripled its AI spending from 2022 to 2023.¹⁶ Both countries have been investing heavily in autonomous vehicles and Intelligence, Surveillance, and Reconnaissance applications of AI.¹⁷ India, meanwhile, has an AI budget less than 0.002 percent of its overall defence budget, which does not reflect the level of prioritisation of AI that it claims to have initiated.¹⁸

Apart from funding constraints, India lacks high-quality, domain-specific data required to train AI models. The military's data management practices have created silos of data that are often not machine-readable. Breaking these silos is essential to creating a unified and coherent data stream for both training and analysis. Interoperability across different branches of the military is another critical requirement to ensure seamless communication for AI-enabled efforts.¹⁹

India also needs to develop its infrastructure architecture for AI in terms of both capacity and security. India currently has less than 2 percent of the world's compute infrastructure which significantly hinders its AI potential.²⁰ Conditions are ripe in the country for a boom in data centres,²¹ but while building this infrastructure, security must be a priority, especially for sensitive applications like military AI. India reported 593 cyberattacks in the first half of 2024,²² including attacks on three state-owned aerospace and defence companies.²³ The cyber security threat landscape grows more complex with AI-assisted attacks, but the same technology also provides the solutions.²⁴ AI-driven cyber security tools are capable of autonomously detecting and neutralising threats and protecting critical infrastructure. India needs to accelerate

the uptake of AI-enhanced cyber defence to safeguard its mission to become a digital leader.

Challenges of Military AI

AI has facilitated advanced surveillance, real-time data analysis, predictive threat assessments, and enabled autonomous systems such as drones and unmanned vehicles to increase operational reach and efficiency. In non-conventional domains like cyberspace and outer space, it has redefined the landscape by serving as an effective tool for both offence and defence. Indeed, AI-driven military innovation has gone beyond weapons development. It has become central to maintaining technological superiority, influencing national strategies, and defining global power dynamics.

India's focus on AI is not only about enhancing internal security but also maintaining its status as a regional power. Though the focus was previously on civilian applications, India now aims to use AI to counterbalance the influence of other regional powers like China,²⁵ which have significantly advanced their military AI technologies. The need for such development has also pushed India to deepen defence collaboration with allies such as the US,²⁶ Israel,²⁷ and France.²⁸ The importance of cutting-edge technology such as AI calls for a balancing act by India. It must manage its long-standing ties with Russia, whom the West perceives as an 'enemy', while also safeguarding its strategic autonomy and access to Western technology.

Two main issues with the use of military AI are the ethical and strategic concerns they raise. Ethical issues include questions about responsibility, transparency, and whether AI should be allowed to make autonomous life-or-death decisions. Strategic risks cover questions about the possibility that AI will increase the likelihood of war, escalate ongoing conflicts, and proliferate to reach malicious actors.²⁹ These are ongoing and open-ended discussions, but India will have to establish its stand on them. Despite having a clear focus on 'Responsible AI' in its civilian AI landscape, India did not sign the Call to Action blueprint to include Responsible AI considerations in military ecosystems at the Responsible AI in the Military (REAIM) Conference in the Netherlands in 2023³⁰ nor the Blueprint for Action at REAIM in the Republic of Korea in 2024.³¹ As the use of military AI proliferates, countries will have to balance their technological and security ambitions with ethical standards.

The Way Forward

India needs to adopt a multi-pronged approach that effectively and ethically integrates AI into its defence operations. Some suggestions are outlined in the following points.

1. Integrated Strategy for Military AI

The fragmented ecosystem will need cohesive direction from the level of the Chief of Defence Staff and the Headquarters Integrated Defence Staff.³² Formulating a dedicated Military AI Strategy would help create new organisational structures or processes required to focus spending, determine objectives on the basis of threats, scale applications, tailor workforce requirements, and identify avenues for collaboration outside the government.

2. Infrastructure and Talent Development

Along with secure and interoperable AI infrastructure, a vibrant ecosystem needs data from all sources in the military to be stored and managed effectively. Proper data governance protocols and cyber security measures are also critical to maintain data integrity, standardise data, protect sensitive information, and prevent unauthorised access. On the human resource side, limited funding has led to a shortage of talent to staff laboratories and research institutes. There needs to be sufficient incentivising for India's AI talent to join the defence AI architecture instead of the private sector.³³ Talent development is the key to creating a cycle of innovation, monitoring, performance measurement, and evaluation.

3. Ethical Considerations

Responsible AI must remain as central in military uses as they are in civilian applications. Establishing India's ethical framework for military AI requires close collaboration between policymakers, military personnel, technologists, and academia to understand the unique nexus of issues at play. Transparency in AI development, from training data to models, can assist in identifying biases and ensuring responsible deployment in line with security priorities and imperatives.

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CBRN Disasters and Incidents: The Need for AI Risk Assessment Models

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Chemical, Biological, Radiological, and Nuclear (CBRN) threats and incidents are often described as “low probability but high impact”: there is limited probability of use due to strict global governance mechanisms, but the consequences can be catastrophic if they are deployed, whether in warfare or otherwise. The use of CBRN weapons by non-state actors or an attack on a CBRN facility resulting in a leakage, has the potential to harm individuals, ecosystems, and the environment. This necessitates discussions around CBRN threat outcomes.

Whether a disaster is caused by an attack or negligence, integrating Artificial Intelligence (AI) into incident management is important and demands further discussion and proper implementation. Effective oversight in all CBRN areas involves three key aspects: developing CBRN materials; managing their stockpiling, databasing, and transportation; and establishing robust reporting systems to respond to incidents.

AI Integration in Chemical and Biological Incident Management

The Biological Weapons Convention (BWC) of 1972 and the Chemical Weapons Convention (CWC) of 1993 prohibit the stockpiling, trade, and development of dangerous biological and toxic agents in signatory countries.^{a,1,2} Due to these conventions, and the universal disdain, the use of such agents is rare; yet, they are not unseen.³ The limited use of biological agents or toxins in warfare, combined with the risk of leaks due to negligence or mishandling of material that may remain unreported, is a threat factor.

The existing regulations and policies around biotechnology and synthetic toxins draw from the BWC and CWC. Key policies include the 'Rules for the Manufacture, Use, Import, Export, and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells, 1989' (1989 Rules) and the 'Guidelines and Handbook for Institutional Biosafety Committees (IBSCs), 2011'.^{4,5} These emphasise the role of individual staff members in reporting suspicious activity, potential leaks, and infections.^{6,7} Further, environmental policies on water, air, and soil management address the detection of non-reported leaks or threats.⁸ However, these methods rely on individual reporting and testing environmental damages post-leak, which can delay disaster response.

Integrating AI into biological and chemical safety can enhance incident response time and strengthen security measures.⁹ Globally, efforts are underway to include AI in these domains.^b Thus far, India lacks an explicit policy overseeing the integration of technology, security, and safety in biological and chemical development.¹⁰ In 2024, India launched its BioE3 (Biotechnology for Economy, Environment and Employment) policy as the first step in this area.¹¹ While the policy emphasises research, economic growth, and employment, it does not address applications of biotechnology,

a The BWC opened for signatures in 1972 and came into force in 1975. The convention currently has 187 state signatories. The CWC opened for signatures in 1992 and came into force in 1997. The convention currently has 193 state signatories.

b The United States has indicated this desire in their executive order by the white house to address the integration of AI in synthetic biology. See: <https://www.whitehouse.gov/briefing-room/presidential-actions/2023/10/30/executive-order-on-the-safe-secure-and-trustworthy-development-and-use-of-artificial-intelligence/>

especially in detection and biosafety. The integration of AI as a detection method to enhance biosafety, security, and reduce toxic impact remains absent from India's formal governance framework.

The inclusion of AI in toxicology detection is already underway. A 2018 study observed that AI systems produced toxicology results with an accuracy of 87 percent, surpassing the 81 percent accuracy of traditional animal testing.¹² This highlighted AI's potential in predictive analysis, attribution accuracy, time efficiency, and reducing human error.¹³ The same AI-based models for toxicology attribution can be adapted for chemical agent attribution. By leveraging extensive and diverse datasets, AI can conduct probabilistic risk assessments, identifying potential hazards with unprecedented precision. As these models are enhanced, integrating them into domestic policies will address gaps in detection methods and improve safety measures.

AI Integration in Radiological and Nuclear Incident Management

AI can play an important role in enhancing nuclear security and preparedness. By processing data from radiation detection systems, AI can enhance the detection and identification of nuclear and radioactive material.¹⁴ Its application in analysing data from physical detection systems can enhance intrusion detection mechanisms. AI can also play a significant role in radiation protection; its integration into safety standards-related software can aid in protecting workers with occupational exposure in medicine, mining, agriculture, and nuclear power.¹⁵

The International Atomic Energy Agency (IAEA) implements its safeguards by assessing states' declared nuclear material and nuclear-related activities while verifying the absence of undeclared ones through inspections at nuclear sites and facilities. These safeguards rely on processing and analysing vast datasets collected from satellite imagery, environmental sampling, gamma-ray spectroscopy, and video surveillance.¹⁶

Machine learning (ML) models have already been employed to detect anomalies in large datasets, verify spent fuel, and analyse surveillance recordings.¹⁷ Delegating repetitive and routine analysis of large datasets to AI can reduce the workload on inspectors and analysts, thereby enhancing the efficiency and effectiveness of safeguards implementation.

The application of AI in cybersecurity systems can offer round-the-clock monitoring against cyber threats, reducing reliance on human intervention and allowing nuclear security professionals to focus more on strategic tasks. ML algorithms can be utilised in nuclear facilities to defend against cyberattacks by identifying anomalous data or activity within its network.¹⁸ Consequently, AI can supplement the workforce and establish resources that can make early detection and response in cybersecurity realistically achievable.

AI and Large Language Models (LLMs) can be used as decision-support tools during radiation emergencies. For instance, in case of a leak of radioactive material from a nuclear reactor, plant operators could use chatbots or smart assistants to assess plant parameters.¹⁹ LLMs can also monitor plant status and generate reports highlighting critical parameters that need attention.

First responder teams could also utilise LLMs to plan their response actions, optimise their resources, and develop action reports. Once their reliability reaches a certain threshold, LLMs could potentially be utilised by citizens in the area to address their concerns regarding the situation.²⁰

AI models can also assist in detecting lost radioactive sources. Licenses and first responder teams can use LLM-based chatbots to aid in identifying possible search areas by inputting²¹ information such as the source type, quantity, and last known location. This enables the elimination of improbable locations, streamlining the search process. LLMs can also assess the extent of the hazard, possible dispersal areas, efficient monitoring protocols, and resource allocation.²²

In the Indian context, while catastrophes like the Chernobyl (1986) or Fukushima (2011) incidents have not occurred, the possibility of such an event cannot be dismissed altogether. India's nuclear security measures have been robust so far, but AI can play a pivotal role in strengthening them further. The 2019 cyberattack on the Kudankulam nuclear reactor highlights the importance of a robust nuclear cybersecurity infrastructure,²³ while the Mayapuri incident in 2010 also serves as a stark reminder of the importance of detecting orphan and lost radioactive sources.²⁴ Consequently, AI applications, such as enhanced cybersecurity, radiation detection, and incident response tools, can aid in enhancing India's nuclear security and incident management architecture. This incorporation of AI necessitates active collaboration and engagement from agencies such as the Nuclear Power Corporation of India Limited (NPCIL) and the National Disaster Management Agency (NDMA).

To be sure, the application of AI to radiological and nuclear security poses certain challenges. Most AI models function as “black boxes”, meaning that there is a fundamental lack of understanding when it comes to their inner workings.²⁵ This makes it particularly difficult to extrapolate what decision an AI model will make in a given situation—this is a key concern when it comes to an issue as sensitive as nuclear security, where decision-making is of utmost importance. Additionally, the datasets used to train an AI model are as important as the model itself, and it is essential that these are free of manipulation and biases to ensure reliable output. While AI offers cost-effective and time-saving advantages, human oversight will continue to be crucial.

Key Recommendations for an Incident Management Framework

Each CBRN area requires a nodal agency to address its specific threat areas. These nodal agencies must oversee their critical infrastructure and supply chains while maintaining coordination with national security and disaster management bodies. Such interactions will help address and update horizontal applications, safety protocols, and security measures. A framework for these agencies should include the following key elements:

Planned integration from ground zero

- AI should be integrated into planning across the full spectrum—prevention, detection, and response—targeting weapons of mass destruction, negligence, or natural disaster outcomes.

AI model development

- Nodal agencies prioritise clean data collection and models trained on historical data, engaging with stakeholders across the pilot phase to assess potential threats and outcomes effectively. Using interpretable models alongside historical data can enhance security without compromising cybersecurity.²⁶
- Nodal agencies should map and analyse terrorist networks to predict and interrupt potential attacks on factories or critical infrastructure. They should monitor and screen commercial orders for materials and equipment that could potentially be utilised to execute such attacks in civilian areas or grey zones.^c

c Grey zones, usually refers to regions or parts of supply chains that lie between clear demarcations of peace and conflict. This can include international waters, border regions, but also parts of supply chains in critical infrastructure that are not explicitly protected, such as transport.

Real-Time monitoring and analysis

- AI models should be employed in systems for detecting radiation, chemical leaks, or infection and integrated into safety standards software. Nodal agencies like the Nuclear Power Corporation of India (NPCIL) in the nuclear domain and the National Disaster Management Authority (NDMA) can play a pioneering role in this regard. AI should be integrated into cybersecurity systems at nuclear facilities to enable constant monitoring and surveillance, providing essential support to human operators.
- Beyond verified and reliable datasets, such a model cannot exclude human oversight. Such oversight will be necessary to determine the appropriate implementation levels in AI-driven scenario analysis tools to evaluate the impact of different risk factors. For instance, the response to a Biosafety Level-2 (BSL-2) laboratory leak cannot be equated with that required for a highly adaptive virus or a chemical attack on a water body.

Domain-specific AI models

- Specialised AI models and LLMs should be developed for radiation emergencies to enhance crisis response capabilities. The National Disaster Management Authority (NDMA) can be equipped with these tools. The development of an app employing LLMs or chatbots for civilians could also be extremely useful in case of a CBRN emergency.

Integration of AI in a regulatory framework

- Integrating AI incident management models into existing regulations alone cannot fully address threats across all toxin-related areas. While CBRN threats are categorised as weapons of mass destruction, they also encompass naturally occurring disasters and negligence that may impact critical infrastructure, requiring a more nuanced approach. This entails embedding AI incident management into longstanding regulations, with regular updates in short-term policies. These updates should be informed by feedback mechanisms involving stakeholders, on-ground experts, and civilians in vulnerable areas. Policies should also include training modules with the National Disaster Management Authority (NDMA) and private sector organisations, fostering robust public-private partnerships.²⁷

This approach underscores the necessity of a proactive rather than a reactive approach in CBRN risk assessment. As technological advancements accelerate, AI can potentially transform risk assessment practices. By leveraging AI's capabilities and fostering a culture of transparency and collaboration, the field can improve its methodologies. The aim is to nurture safer, more sustainable practices in critical material development, safety, and security.

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The Future of India's Geospatial Industry: GeoAI Foundational Models and GeoAI LLMs

Chaitanya Giri

Modern geospatial (earth imaging or remote sensing) satellites are generating exabytes of data daily.¹ The data is diversified across infrared, near-infrared, optical, and short-wavelength infrared wavelengths and also includes images captured by radar and electro-optical technologies.² The supply side is technologically robust owing to the continuous innovation at space agencies and space technology companies. However, on the demand side, new use cases are urging the generation of a deeper sense of voluminous and rich geospatial images.

The convergence of geospatial data analysis with Artificial Intelligence (AI) provides breakthrough solutions, such as predictive analyses of cyclonic storms and weather extremes;³ assessing the appropriate crop for a soil type and predicting its sowing and harvest;⁴ determining the vulnerability of forest fires;⁵ predicting air quality index by factoring in weather and climate variables;⁶ determining urban sprawls and managing built-up infrastructure;⁷ determining anomalous adversarial movements and countering their surveillance and reconnaissance platforms in military domains.⁸ Machine learning,⁹ deep learning, dimensionality reduction, random forests, object detection, object tracking, and creating and using massive machine learning data libraries are all tools of Geospatial Analytics Artificial Intelligence (geoAI).¹⁰

The global market of geospatial analytics is based on demands generated from two sets of end users: the end users who prefer 'pattern recognition' are from sectors such as agriculture, meteorology, land-use and land-cover management, insurance and banking, construction and engineering, natural resource management, and mining, which are in need of rich geospatial data that offers accurate, high-quality, and high-resolution images that allow for finer pattern recognition. The end users who prefer predictive analytics are from sectors such as transportation, logistics, meteorology, homeland security, and the military, which require quicker situational awareness, accurate location intelligence, and forecast outcomes.

The upcoming iterations of the Department of Space's 2020 space sector reforms and the National Geospatial Policy 2022, helmed by the Ministry of Science and Technology, must make space for geoAI.¹¹ A multi-stakeholder strategy is necessary for it to be meticulously strategised and implemented. GeoAI can become a major contributor to the downstream space sector, which includes the geospatial industry, which is the biggest value creator in the global space economy. Such strategising is even more necessary if the Indian space economy intends to achieve its set target of capturing 8 percent of the global space economy by 2030.¹² In such a context, what should be the next steps for India's geoAI?

The Indian Space Research Organisation (ISRO) has been generating geospatial imagery since 1979 via its remote-sensing satellites.¹³ The 2022 National Geospatial Policy made the public availability of ISRO's archival geospatial datasets possible through the Bhuvan-Bhoonidhi portal.¹⁴ However, despite this data being available, Indian commercial geospatial companies seldom use ISRO datasets; instead, they prefer to use datasets from the European Space Agency's Sentinel satellites or images that are commercially disbursed from American geospatial companies, Maxar and Planet. These globally selling private imagery providers have worked on

an aspect that is beyond availability—i.e., accessibility—by uploading commercial data on cloud platforms such as Azure, Google Cloud, Amazon Web Services, or even the Esri Geospatial Cloud.

The Bhuvan-Bhoonidhi portal does not offer the flexibility and web-service-based architecture of cloud-uploaded data for the purposes of geoAI. The image resolutions offered by Bhuvan-Bhoonidhi are lower than those of Maxar; additionally, the former requires manual image downloads. Furthermore, the application programming interface of Sentinel and other American geospatial datasets are tuned so that exclusive Artificial Intelligence Foundational Models (AI-FM)¹⁵ can use them seamlessly and with interactive visualisation, which ISRO images lack.

With the rise of AI Large Language Models (LLMs), a lot of information that was previously unfit for geospatialising can now be geospatialised at pinpoint locations on a map along with the fine-tuning of prompts. The convergence of GeoAI-FMs with GeoAI-LLMs will add unprecedented richness to datasets and the information that can be derived from them by end users.¹⁶

India has a treasure trove of legacy geospatial datasets gathered over several years, based on which commercial and academic interest groups must come together to form GeoAI-FMs and GeoAI-LLMs. Collaboration between ISRO, academia, and industry at the commercial and non-commercial levels is necessary to convert these legacy unused and untapped datasets to create GeoAI-FMs and GeoAI-LLMs for greater social, economic, scientific, environmental and national security applications in India.

ISRO has made some basic AI forays, such as the ISRO-IIIT Hyderabad-led AI for Space Immersion Programme¹⁷ or the ISRO-NITI Aayog-led ATAL New India Challenges.¹⁸ It is a welcome step that the Indian government intends to release the geospatial data repository for private end users.

China can offer some lessons. It does not upload its geospatial datasets on commercial cloud platforms of Western origin but uses the indigenous China Open Data Cube Framework.¹⁹ At the Geospatial Intelligence Software Technology Conference held in Beijing in June 2024, SuperMap, a leading Chinese geospatial company, joined hands with Huawei to create large GeoAI models and geospatial agents and integrate Kunpeng (AI hardware products) and Ascend (AI processors) with SuperMap into an all-in-one machine.²⁰

With regard to must-do data accessibility, ISRO will need to decide whether to store its publicly released data on a commercial cloud of Indian or overseas origin. In 2023, ISRO and IN-SPACe signed a memorandum of agreement with AWS to support space-tech innovation through cloud computing.²¹ However, given AI sovereignty concerns, both ISRO and IN-SPACe need to consider hosting legacy geospatial datasets on indigenous clouds that are either built by a commercial player or by an ISRO-exclusive geospatial cloud.

On the geoAI front, ISRO, IN-SPACe, and Indian geospatial academic R&D laboratories should collaborate on indigenous open-source GeoAI-FMs using ISRO's legacy geospatial datasets as well as datasets gathered from overseas data providers. In parallel, IN-SPACe, Indian commercial geospatial companies, and academic R&D laboratories could work together on both commercial and semi-open-source GeoAI-LLMs.

Indigenous geospatial data clouds, indigenous GeoAI-FM, and indigenous GeoAI-LLM are vital constituents of the India Open GeoAI Data Cube Framework. The Framework will extend beyond the data cloud-FM-LLM software realms. Hardware capacities such as AI processors and other relevant cloud storage must also be meticulously planned.

In the early 2000s and 2010s, ISRO claimed to possess the largest number of remote-sensing satellites of any national agency. However, the data generated by Indian satellites then and now remains commercially untapped. India is a crucial information technology hub of the world and could be among the early advantage seekers of GeoAI. However, this requires ISRO, IN-SPACe, the Indian IT sector, and geospatial companies to collaborate. A multi-stakeholder approach is necessary. The sooner New Delhi realises the significance of GeoAI and creates a conducive environment for its organic progress into the commercial, military, and civilian realms, the better it is for comprehensive national interests.

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