Confederation of Indian Industry

A THOUGHT LEADERSHIP REPORT ON ROBOTICS, DRONES & AUTOMATION FOR INDIA

Accelerating the Journey to a Future-Ready Nation

December 2025

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FOREWORD

Mr Chandrajit Banerjee

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India is at an important juncture in its technological journey. Rapid progress in robotics, automation, and unmanned systems is reshaping global value chains and creating new opportunities for industry. To emerge as a leading innovation-driven economy, India must adopt these frontier technologies at scale, build strong capabilities, and ensure that businesses of all sizes across sectors benefit from their impact.

CII has long recognised this shift and continues to support the integration of advanced technologies across the economy. By working closely with industry, government, startups, and academia, CII is helping build a strong technology ecosystem. This includes enabling supportive policies, nurturing innovation partnerships, developing skills, and advancing mission-driven national initiatives that promote technology-led growth.

Robotics, automation, and drones are now central to this transformation. Their applications are growing across manufacturing, infrastructure, mining, food and pharmaceuticals, logistics, agriculture, disaster management, and national security. Industry is now viewing automation not just as a tool to reduce costs but as a strategic capability that enhances productivity, quality, resilience, and global competitiveness.

This thought leadership report provides a comprehensive perspective on India's current capabilities and emerging opportunities in robotics, automation, and drone technologies. It outlines India's strengths and gaps, and outlines actionable recommendations to advance innovation, improve standards, scale manufacturing, build talent, and expand adoption

These insights aim to guide stakeholders in shaping a cohesive national strategy that supports India's transition towards a future-ready, innovation-led economy. They reflect CII's commitment to helping India build leadership in next-generation intelligent systems and ensure that the benefits of technological advancement reach every sector and community. CII remains dedicated to working with all partners to translate this vision into measurable outcomes in the years ahead.

FOREWORD

Mr Sameer Gandhi

Chairman, CII National Committee on Robotics, Drones & Automation and Managing Director, OMRON Automation Pvt Ltd

Robotics, drones, and automation are redefining the way industries operate and societies function—driving efficiency, precision, and sustainability across sectors. These technologies are no longer futuristic concepts but key enablers of national growth, economic resilience, global competitiveness as well as national security. As India moves toward the vision of Viksit Bharat, leveraging these emerging technologies will be central to transforming manufacturing, agriculture, logistics, healthcare, and defence.

As Chair of CII National Committee on Robotics, Drones & Automation, it gives me great pleasure to present this report developed by the CII National Committee on Robotics, Drones, and Automation. Over the past few decades, CII has been at the forefront of advancing India's technology landscape—enabling innovation, shaping policy frameworks, and building industry-academia linkages. In continuation of this journey, the Robotics Committee has worked to harness the transformative potential of robotics, drones, and automation in realizing the vision of Viksit Bharat.

This report is the result of extensive deliberations across our four sub-groups—Industrial Robotics & Automation, IT & IoT Applications in Robotics, Non-Defence Drone Applications, and Defence, Aerospace & Security Drones. It captures current trends, challenges, and actionable recommendations both for deployment and local development from the industry's perspective.

The rapid evolution of these technologies presents a unique opportunity for India to strengthen its global competitiveness, enhance productivity, and create new avenues for growth. I believe this report will serve as a valuable resource for policymakers, industry leaders, and innovators to collaboratively build a robust, future-ready ecosystem for robotics and automation in India. I place on record my thanks to all the committee members for contributing to this report and a special thanks to the four sub-group leaders.

Acknowledgments

The CII National Committee on Robotics, Drones, and Automation extends its sincere appreciation to all members, partners, and contributors who have played a vital role in the preparation of this report. The development of this report has been a truly collaborative effort, reflecting the insights, expertise, and commitment of industry leaders, technology experts, startups, academia, and policymakers who share a common vision for advancing India's robotics and automation ecosystem.

We express our special thanks to the leads and members of the four sub-groups—Industrial Robotics & Automation, IT & IoT Applications in Robotics, Non-Defence Drone Applications, and Defence, Aerospace & Security Drones—for their valuable time and guidance in shaping the discussions and recommendations presented here.

This report is a reflection of our collective endeavour to accelerate India's progress toward technological self-reliance and to strengthen its global standing in the fields of robotics, drones, and automation. We hope it serves as a meaningful contribution toward realizing the vision of Viksit Bharat.

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Executive Summary

This report presents a comprehensive analysis of Industrial Robotics & Automation, IT/IoT Applications in Robotics, Non-Defence Drone Applications and Defence Aerospace & Security Drones, outlining global trends, India's current position, indigenous capabilities, ecosystem gaps, and strategic pathways for national leadership. As industries worldwide undergo rapid digital transformation, these technologies are redefining production systems, supply chain resilience, security frameworks, and competitiveness. For India, they represent one of the most significant opportunities to accelerate economic growth, strengthen technological sovereignty, and enhance industrial productivity in the coming decade.

Recognizing the critical importance of these emerging technologies, CII constituted an exclusive Committee on Robotics and Automation, bringing together industry leaders, technology experts, academia, and policymakers. Under this committee, four dedicated sub-groups were formed, each developing one of the four chapters of this report, ensuring deep domain expertise and focused analysis across Robotics, Automation, IoT/IoRT, and Drone Systems.

Globally, robotics adoption is expanding across manufacturing, logistics, healthcare, agriculture, mobility, and public services. Countries across the U.S., Europe, Japan, China, and South Korea are deploying advanced systems—AI-enabled robots, collaborative robots (cobots), autonomous mobile robots (AMRs), digital twins, and next-generation humanoids—to enhance precision, speed, and adaptability. Asia continues to dominate robot installations, with China alone accounting for over half of global deployments. The rise of Physical AI and Robots-as-a-Service (RaaS) is further democratizing access, particularly for small and medium enterprises (SMEs).

India's robotics landscape has shown strong progress, with the industrial robot operational stock reaching 52,570 units in 2024. Yet robot density—at 8–10 robots per 10,000 workers—remains far below global averages, indicating vast untapped potential. Adoption is currently led by automotive, electronics, pharmaceuticals, and plastics sectors, with SMEs increasingly exploring cobots for flexible automation. Indigenous innovation is emerging through companies like Systemantics, ASIMOV, Omnipresent, and TAL, though challenges persist in component dependency, R&D investment, and scaling hardware innovation.

The report underscores the transformative role of IoRT, where robotics converges with IoT, AI, and cloud systems to enable autonomous decision-making, predictive diagnostics, and real-time factory optimization. Given India's global leadership in IT services and software engineering, IoRT represents a powerful differentiator, enabling intelligent robotic platforms that prioritize data, analytics, and interoperability.

Parallelly, the drone sector is experiencing rapid momentum under Atmanirbhar Bharat, with DRDO, HAL, BEL, ISRO, and a vibrant startup ecosystem developing surveillance, agriculture, logistics, mapping, and combat UAVs. Drones are becoming integral to national security, disaster response, infrastructure monitoring, and precision farming.

To fully capitalize on these opportunities, the report highlights the need to overcome barriers such as high automation costs, supply chain fragmentation, skill shortages, regulatory bottlenecks, and limited R&D commercialization. It calls for coordinated national efforts across policy, standards, manufacturing, industry–academia collaboration, and indigenous IP creation.

With focused implementation, India can position itself as a global hub for robotics, IoRT-driven intelligent automation, and advanced drone systems by 2030.

Chapter 1:
Industrial Robotics and Automation

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1 Background and strategic importance for India

Robotics adoption is accelerating globally due to skilled labor shortages, rising operational complexity, and the push for resilience in manufacturing, logistics, and healthcare. The COVID-19 pandemic significantly amplified the need for automation, remote operability, and human-safe systems.

Key macro drivers include:

- Persistent skilled labor shortages in manufacturing, warehousing, and care environments
- Shift toward decentralized, resilient supply chains and autonomous operations
- Heightened safety and hygiene requirements in clinical and healthcare settings
- Demand for smart manufacturing modernization—WMS/MES/QMS integration, digital twins
- Emergence of Robotics-as-a-Service (RaaS), Cognitive Robotics and Cobots as viable business models
- Achieve & maintain Process Stability with multiplied productivity – for delivering consistent quality which can then be used to optimize processes and increased productivity
- Move towards I5.0 - For human-in-the-loop, sustainability and resilient operations
- Rise of Physical AI: AI being pervasive will become more ubiquitous in adoption. When AI reasons and takes decisions, converting the decisions to any related physical tasks will be very important
- Competitiveness: Critical for Make in India, PLI outcomes, and export-led growth
- Cross-sector impact: Automotive, electronics, precision engineering, pharma, food, logistics, textiles, MSMEs
- Tech scope: Industrial robots (articulated, SCARA, delta, Cartesian), cobots, AMRs/AGVs, machine vision, PLC/SCADA, IIoT/edge, AI for quality /predictive maintenance, digital twins, additive manufacturing, safety systems.
- National goals alignment: SDGs, Manufacturing share of GDP, export diversification, supply-chain resilience, net-zero via resource efficiency, defense and space self-reliance.

While it is extremely important to be aware of misuse of robotics and or the stochastic nature of AI, they shouldn't be looked at as deterrents to the advancement of these technologies. Such negativities must be tackled with adequate and well thought of regulations and its governance without stifling innovation or research or experimentation. Today we see varied regulations across the globe, some highly regulated markets like EU to a not so controlled market like China (for Chinese technologies) to non-uniform regulations in each state of US. One possible reason could be that the technologies are advancing so fast that regulators are either not able to cope with the pace and or do not have a full understanding of the deep technology and its potential harm.

2 Global trends

Global Trends in Robotics & Automation: Focus on US, Europe, and Asia

Executive Overview

Robotics and automation are transforming industries worldwide, with rapid deployment driven by technological innovation, economic necessity, and evolving business models. The United States, Europe, and Asia are at the forefront, each shaping and responding to global trends in distinctive ways.

1. Integration of Artificial Intelligence (AI)

Global Perspective

- AI is revolutionizing robotics by enabling perception, decision-making, and self-optimization.
- Analytical AI allows robots to analyze sensor data and adapt to variability (e.g., vision-equipped robots learning tasks).
- Physical AI uses simulation environments for virtual training and improvement.
- Ambitious projects aim for a “ChatGPT moment” in robotics—generative AI enabling robots to program and improve themselves.

United States

- The US leads in AI-driven robotics R&D, with Silicon Valley and major universities pioneering advances in machine learning, computer vision, and digital twins.
- American companies are integrating AI into industrial robots for manufacturing, logistics, and healthcare, driving autonomy and efficiency.

Europe

- Europe emphasizes ethical AI and human-centric robotics, with strong regulatory frameworks.
- European firms focus on collaborative robots (cobots) and AI-powered automation in automotive, electronics, and healthcare sectors.

Asia

- Asia, especially China, is rapidly adopting AI in robotics, with massive investments in smart factories and digital twins.
- Japan and South Korea are global leaders in robotics innovation, integrating AI for precision manufacturing and service robots.

2. New Robot Forms: Humanoids, Mobile, and Collaborative Robots

Global Perspective

- Humanoid robots are being prototyped for general-purpose labor, but specialized robots remain more economically viable.
- Mobile robots (AMRs) and collaborative robots (cobots) are seeing faster uptake, especially in warehouses and assembly lines.

United States

- US startups and tech giants are developing humanoid robots for logistics and manufacturing.
- Mobile robots are widely used in e-commerce fulfillment centers (e.g., Amazon's Kiva robots).

Europe

- Europe is a leader in collaborative robotics, with companies like Universal Robots and ABB pioneering cobots for manufacturing and healthcare.
- Mobile robots are increasingly used in European logistics and automotive sectors.

Asia

- Asia dominates in mobile robot deployment, especially in China's vast manufacturing and logistics operations.
- Japan's robotics industry is renowned for humanoid robots and service robots in healthcare and hospitality.

3. Sustainability and Energy Efficiency

Global Perspective

- Robotics are leveraged for green production, waste reduction, and precision manufacturing.
- Efforts to make robots more energy-efficient include lighter materials, power-saving modes, and bio-inspired designs.

United States

- US manufacturers are adopting robotics to improve sustainability, especially solar panels and battery production.
- Energy-efficient robots are prioritized in the automotive and electronics sectors.

Europe

- Europe leads sustainable robotics, with strict environmental standards and a focus on circular economy principles.
- European companies innovate energy-saving robot designs and green manufacturing processes.

Asia

- Asian manufacturers, particularly in China and South Korea, are investing in energy-efficient robotics to meet global environmental goals.
- Robotics is central to Asia's push for sustainable, high-volume production.

4. Expansion into New Sectors & Business Models

Global Perspective

- Robotics is expanding beyond automotive and electronics into construction, healthcare, retail, agriculture, and laboratories.
- Robots-as-a-Service (RaaS) models allow firms to rent robots, lowering barriers for small and mid-sized enterprises.

United States

- US companies are pioneering RaaS and low-cost automation, democratizing access for SMEs.
- Robotics adoption is growing in healthcare (surgical robots), agriculture (agribots), and retail (automated warehouses).

Europe

- Europe is expanding robotics into healthcare, agriculture, and public services, with strong support for SME adoption.
- European startups offer subscription-based robotics solutions for small businesses.

Asia

- Asia is rapidly deploying robots in new sectors, especially in agriculture (precision farming in Japan and China) and healthcare (medical robots in South Korea).
- RaaS models are gaining traction in China and India, enabling broader adoption.

5. Addressing Labor Shortages and Productivity

Global Perspective

- Robots are increasingly used to fill workforce gaps, especially dull, dirty, dangerous, and delicate tasks.
- Innovations in ease-of-use and collaborative safety features make deployment simpler.

United States

- US industries use robots to address skilled labor shortages in manufacturing, logistics, and agriculture.
- Automation is key to maintaining productivity and competitiveness.

Europe

- Europe faces demographic challenges and uses robotics to supplement aging workforces, especially in manufacturing and healthcare.
- Collaborative robots are deployed to enhance productivity and safety.

Asia

- Asia's aging populations (Japan, South Korea) drive robotics adoption to maintain industrial output.

- China uses robots to boost productivity and offset rising labor costs.

6. Regional Adoption Metrics

- Asia: Leads global adoption, with China accounting for 54% of new installations in 2024 (295,000 units). Japan, South Korea, and China host the majority of the world's robots. South Korea has the highest robot adoption per capita due to government support, a focus on high-tech manufacturing, and demographic pressures like a low birth rate and aging population. These factors have driven a national strategy to use automation to maintain economic competitiveness, address labor shortages, and boost productivity in sectors like electronics and automotive manufacturing. A big push from the Government and prominent industries like Samsung, Hyundai etc has steered the per capita robot implementation in South Korea to the highest in the world.
- United States: Installed ~34,200 robots in 2024, with strong growth in manufacturing, logistics, and healthcare.
- Europe: Germany (~27,000 units), along with France, Italy, and the Nordics, are major adopters, focusing on high robot density and advanced automation.
- Robot Density: South Korea exceeds 900 robots per 10,000 manufacturing workers; US and

Country/Region	Robot Density (robots per 10,000 manufacturing workers)
South Korea	1,102
Singapore	770
China	770
Germany (EU avg.)	219
North America	197
Japan	~390
Global Average	162
India (overall)	~8 to 10
India (Automotive)	148

- Robot density per 10,000 manufacturing workers varies significantly across the globe, indicating different levels of automation maturity and industrial robot adoption. South Korea leads globally with exceptionally high robot density, reflecting its highly automated manufacturing sector followed by China, Singapore, Japan & western countries.
- India's overall robot density is much lower (~8 to 10), with the automotive sector showing higher density (~148) indicating concentrated adoption within specific industries. The substantial gap between India and leading industrialized nations shows large growth potential in Indian automation and robotics adoption.

7. Advanced Trends and Technology Platforms

- Physical AI & Simulation: Platforms like NVIDIA Omniverse enable robots to train in virtual environments, accelerating prototyping and adaptation.
- Post-pandemic Resilience: COVID-19 accelerated automation for supply chain resilience, especially in US, European, and Asian logistics.

- Healthcare & Consumer Robotics: Medical robots (e.g., da Vinci platform) and consumer robots (e.g., Roomba) are mainstream in US, Europe, and Asia.

8. Key Challenges

- Upskilling & Training: Need for hands-on, project-based learning in robotics and AI.
- SME Access: Barriers remain for small enterprises, especially in rural and less-developed regions.
- Regulatory & Security: Data privacy, compliance, and integration with legacy systems are ongoing concerns.
- Talent Disparity: Deep-tech talent is concentrated in major hubs; retention and upskilling are challenging globally.

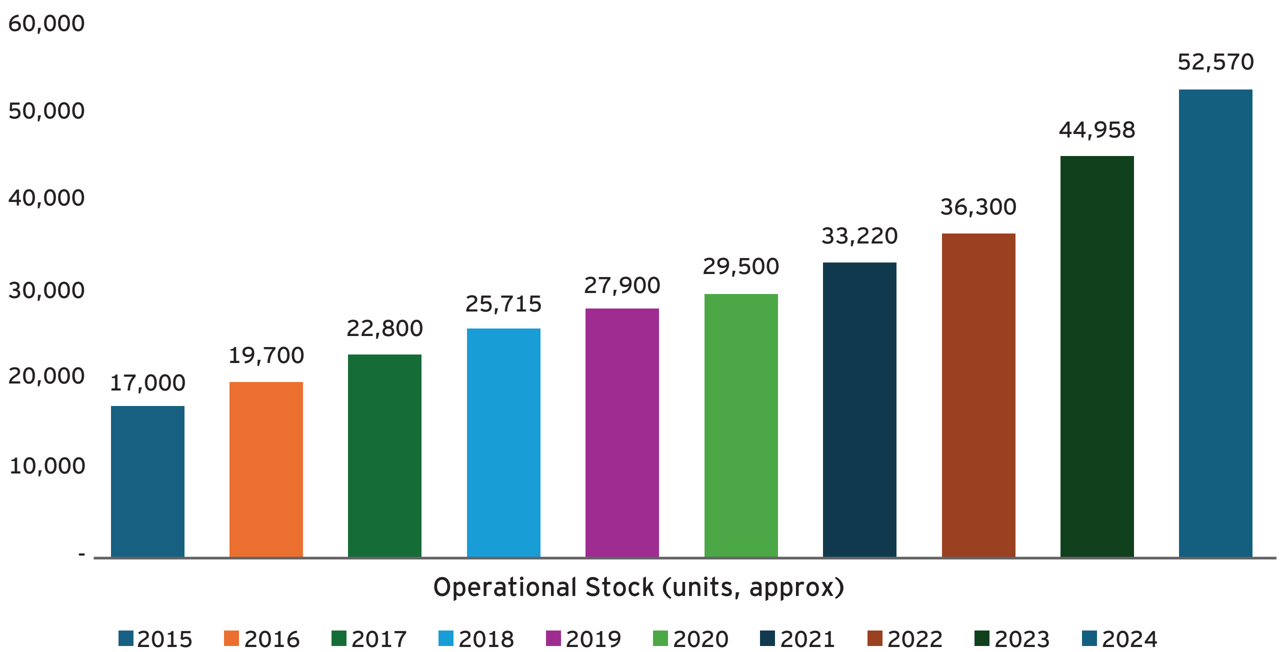
3 Indian scenario

In India, industrial robots are majorly used in automotive industry. The operational stock of industrial robots has grown rapidly in the past decade with an average annual growth rate of 14%. In 2024, India is having about 52,570 units installed, placing India 10th globally in terms of industrial robot stock.

3.1.1 Major Uses of Industrial Robots in India

- Automotive Industry: The largest sector using robots, accounting for 42-45% of installations. Robots are extensively used for welding, assembly, material handling, and painting in both car manufacturing and parts suppliers.
- Rubber and Plastics Industry: Second-largest general industry using robots, with over 400 units installed in 2024, supporting tasks like material handling and assembly.
- Metal Industry: Stable robot usage with operations like welding, machining, and material handling.
- Electronics and Electrical: Growing adoption due to precision and speed requirements, robots handle assembly, screw tightening, parts insertion, and inspection of electronic components.
- Pharmaceuticals and Consumer Goods: Increasing deployment for packaging, inspection, and repetitive tasks to improve quality and throughput.
- Collaborative Robots (Cobots): Rapidly gaining ground in SMEs, assisting with flexible tasks and working safely alongside humans.

3.1.2 Yearly Operational Stock Data (2015–2024):



3.2 Indigenously developed Industrial Robots

India is currently lagging in the development of its own industrial robots, resulting in a heavy reliance on imported industrial robots by domestic industries. This dependence on imports significantly adds to the overall cost of automation solutions and consequently leads to higher budget requirements for

Indian manufacturers. The high cost of imported robotic hardware, coupled with limited indigenous research and development, poses a challenge to the widespread adoption of industrial automation. Addressing these issues through enhanced investment in local innovation, skilled workforce development, and strengthening the domestic robotics ecosystem is essential for India to achieve self-reliance and cost-efficient industrial automation solutions in the future. Two case studies of the indigenously developed products in the country are:

3.2.1 TAL Bravo

TATA Automation Limited Manufacturing Solutions (a Tata Motors subsidiary) created the TAL Brabo, India's first indigenously developed articulated industrial robot. It represents a milestone for Indian robotics. It was designed and built in Pune, aiming specifically to serve India's MSME sector by making industrial automation affordable and accessible.

The robot was conceptualized and designed in-house by TAL and Tata Elxsi, with critical components (motors and drives) initially sourced via a collaboration with RTA Motion Control Systems, Italy, but most other parts are indigenously made.

Brabo has been validated in over 50 customer workflows across industries like automotive, engineering, plastics, logistics, and education, and can help boost productivity by 15–30% with a payback period of about 15–18 months.

Major Achievements for TAL Brabo

- First indigenous articulated industrial robot in India—significant step for "Make in India" and domestic manufacturing self-reliance.
- Compliance with European health and safety standards, allowing export to Europe.
- Four patents registered for core technologies within Brabo.
  - The patents cover critical aspects of the robot's articulated arm design, including mechanisms for rotary joints, drive assemblies, and unique structural innovations tailored for the MSME sector and Indian manufacturing conditions.
  - These patents protect advances in compactness, simplicity, ease of installation, and reliability—addressing specific challenges of industrial automation for small and medium enterprises.
  - TAL has also applied for additional intellectual property certifications, focusing on European health, safety, and environmental compliance, enabling export of Brabo to Europe.
  - In addition to mechanical innovations, Brabo's patents reportedly include embedded programmable logic controller (PLC) integration and efficient low-cost power transmission technology.
- Successful integration into multiple industries, showing flexibility and rapid ROI for MSMEs.

Concerns and Challenges

- Partial Import of Critical Components: The initial need to import motors and drives means the robot was not 100% indigenized at launch, posing supply chain and cost challenges.
- Market Acceptance: While innovative, adoption among MSMEs can be slow due to awareness, skill gaps, and high initial investment sensitivity.
- Competition and R&D: Global giants remain dominant in advanced robotics, meaning continuous innovation is needed for TAL and others to maintain competitiveness.
- Service and Support: Ensuring robust after-sales support and upskilling customers for robot programming and maintenance are ongoing challenges for widespread adoption.

Key Reasons for Limited Success

- Partial Localization: Although branded as 'Made in India', critical components like motors and drives were sourced from Italian partner RTA, which limited full indigenization and, in some cases, raised costs and supply dependencies compared to global competitors with established procurement and manufacturing networks.
- Competition: International brands such as ABB, KUKA, Yaskawa, and Fanuc remained dominant – offering a wider, more mature product range, higher payload capacities, and more advanced features, making it difficult for TAL Brabo to compete beyond entry-level and MSME segments.
- Skill and Awareness Gap: MSMEs, the primary target market, often lacked awareness or expertise to integrate and operate industrial robots, slowing adoption rates despite government pushes for automation.
- Slow Market Penetration: TAL Brabo received positive interest, but actual production and sales volumes remained relatively modest, with only a few hundred units delivered over several years compared to the thousands expected.
- Service Ecosystem: Building an extensive service, support, and integration network takes time and expertise – potential buyers sometimes face hesitation due to concerns about after-sales support, training, and reliability.
- Technological Limitations: Brabo's initial models had lower payload capacities (2kg, 10kg) and were suited for pick-and-place, MIG welding, and assembly, limiting applicability for heavier or more complex manufacturing needs, where established international robots had a tech advantage.
- Perceived Value: Despite cost advantages (30–40% cheaper than imports), some buyers preferred established global brands for proven reliability and comprehensive automation solutions, especially for large-scale manufacturing.

TAL Brabo marked an important technological milestone for India's robotics sector with indigenized design, patents, and entry into European markets, but broader market forces, ecosystem maturity, tech limitations, and buyer conservatism tempered its commercial impact and expansion.

3.2.2 Systemantics: Industrial Robot/Cobot Development

Another significant indigenous industrial robot development project in India was undertaken by Systemantics India Pvt Ltd in Bengaluru. This project focused on the design, development, and manufacturing of industrial robots, with Technology Development Board (TDB) support. Their flagship product, the ASYSTR series, represents a notable milestone for Indian robotics.

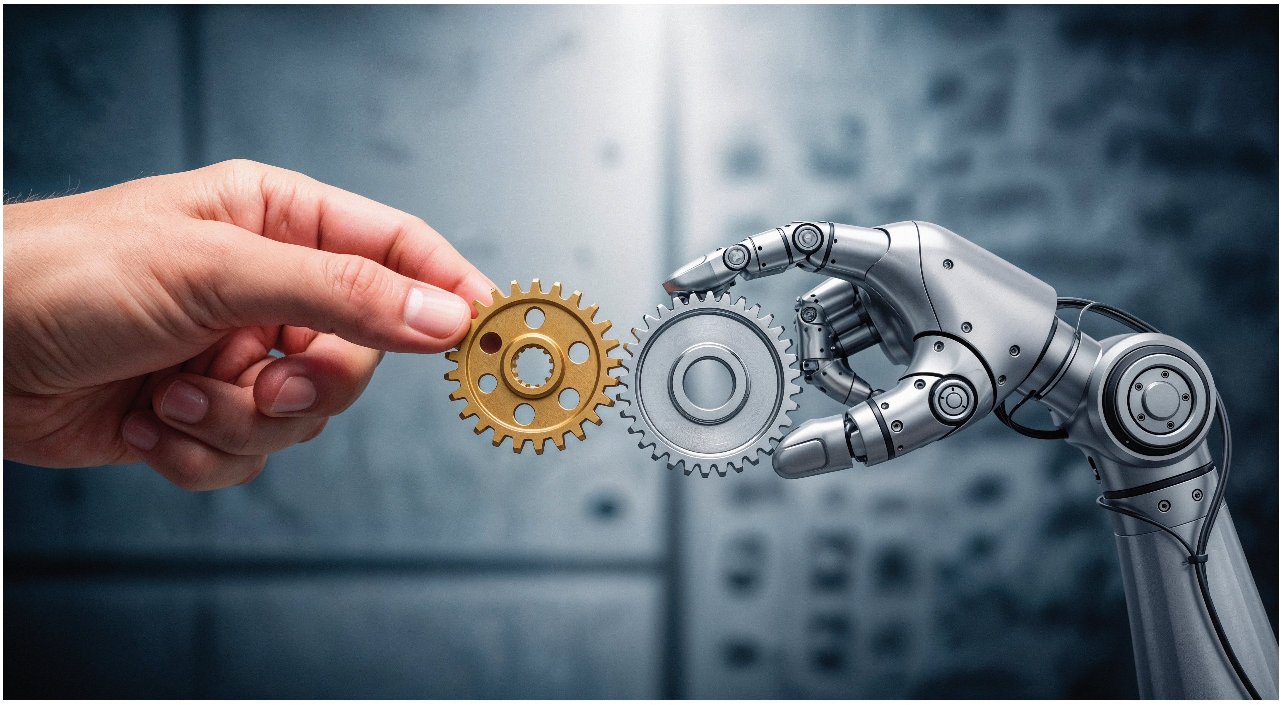
- Project Details: Systemantics developed the ASYSTR industrial robotic arm series—including the ASYSTR 400 (4-axis parallel mechanism) and ASYSTR 600 (6-axis serial arm). The project aimed to offer flexible factory automation via indigenous innovation, commercialized from in-house R&D and prototyping with TDB funding.
- Technology Innovations: Their unique hybrid design combines the working volume of a serial arm with the speed and low power consumption of parallel link mechanisms, delivering cost, simplicity, and performance improvements tailored for India's manufacturing sector.
- Outcomes: Systemantics successfully produced and commercialized these robots, adding features and manufacturing infrastructure for scale. Their robot arms have been adopted for assembly, material handling, and similar tasks, targeting SMEs and larger factories.
- Recognition: Systemantics is widely recognized as a leading Indian industrial robotics and collaborative robot (cobot) company, with more than two decades of expertise and implementation in manufacturing and process automation.

Comparative Disadvantages Versus Global Players

Aspect	Indian Industrial Robotics	Global Players (e.g., Fanuc, ABB, KUKA)
Component Sourcing	Heavy reliance on imports, costly	Integrated global supply chains, local plants
Technology & R&D	Lower investment, fewer innovations	Significant proprietary tech, AI integration
Robot Density (2021)	7 per 10,000 workers	141 per 10,000 workers (global average)
Product Range	Limited payload, niche segments	Wide product range, advanced payloads
Talent & Expertise	Shortage of specialized AI/ robotics skill	Strong talent pool and training infrastructure
Cost & Affordability	Higher relative cost, less price competitive	Economies of scale, cost-effective solutions
Support & Infrastructure	Less mature, fragmented support networks	Well-established global service networks

3.3 Conclusion

While India's industrial robotics sector is growing rapidly and benefiting from government initiatives like "Make in India" and Production Linked Incentive (PLI) schemes, it continues to face significant challenges in technology, supply chain, talent, and ecosystem development relative to global leaders. Addressing these limitations through enhanced R&D, building local supply chains, skill development, and ecosystem maturity will be critical for India to become truly competitive internationally.



4 Gap areas

Here are the key gap areas hindering the widespread adoption of robotics and automation in Indian manufacturing/automation today:

a. High Upfront Costs

- Capital-intensive nature of robotics deters many MSMEs.
- Long ROI cycles make automation less attractive for cost-sensitive sectors.

b. Skill Shortages

- Lack of trained engineers and technicians to design, operate, and maintain robotic systems.
- Existing technical institutions (ITIs, polytechnics) are not adequately equipped to deliver industry-relevant robotics education.

c. Low Awareness & Cultural Resistance

- Many manufacturers, especially in Tier 2 and Tier 3 cities, are unaware of the benefits of automation.
- Labor resistance due to fear of job displacement and lack of trust in machines.

d. Fragmented Ecosystem

- Heavy reliance on imported robotics components and systems.
- Limited presence of domestic robotics OEMs and integrators.

e. Infrastructure Deficiencies

- Inadequate digital infrastructure, such as reliable internet, cloud access, and power supply, especially in rural industrial zones.
- Lack of standardized protocols for interoperability between machines and systems.

f. Limited R&D and Innovation

- Insufficient investment in robotics R&D and indigenous innovation.
- Weak industry-academia collaboration for developing next-gen automation solutions.

g. Policy and Regulatory Gaps

- Absence of clear national robotics policy or automation standards.
- Limited incentives for SMEs to adopt automation beyond large-scale PLI schemes.

5 Recommendations

Recommendations in two categories – deployment and local development – short term (1–3 years), medium term (3–5 years), and long term (5–10 years)

To accelerate robotics and automation in Indian manufacturing, a phased strategy across immediate, mid-term, and long-term horizons is essential. Here's a structured recommendation based on recent insights from industry reports and government initiatives:

Category 1: Deployment (Adoption by Industry)

- **Short Term (1–3 years)**
  - **Policy & Incentives for Fast Adoption**
    - Leverage PLI and SAMARTH Udyog Bharat 4.0 to subsidize automation and robotics deployment.
    - Fast-track approvals for automation projects, especially for MSMEs.
  - **Quick Wins in High-Potential Sectors**
    - Prioritize automation in automotive, electronics, pharma, textiles.
    - Promote rapid rollout of cobots, AGVs, and low-cost automation.
  - **Awareness for Faster Uptake**
    - National campaigns and workshops on the ROI of automation.
    - Sector-focused showcases of successful deployments.
- **Medium Term (3–5 years)**
  - **Create Regional Automation Hubs**
    - Shared automation facilities for MSMEs to reduce cost barriers.
    - Demonstration lines, rental robots, and common testing facilities.
  - **Integrated Smart Manufacturing**
    - Promote adoption of AI, ML, IoT, predictive maintenance, and digital twins.
    - Support process simulation tools for planning and optimization.
  - **Financing Support**
    - Low-interest loans for automation investments.
    - Insurance products to offset technology adoption risks.
- **Long Term (5–10 years)**
  - **Automation for Global Competitiveness**
    - Align Indian manufacturing lines with global Industry 4.0 standards.
    - Drive automation-led competitiveness in EV, semiconductors, aerospace.
- **Shift to Knowledge-Intensive Manufacturing**
  - Gradual transition from manual operations to smart, automated production systems.

Category 2: Local Development (Ecosystem, R&D, Talent & IP)

- **Short Term (1–3 years)**
  - **Establish an Automation Council of India**
    - Modeled on QCI, with mandate to set standards, train industry, and harmonize practices with global norms.
  - **National COEs & Academia–Industry Integration**
    - Centres for industrial automation to build use cases and demonstrate solutions.
    - Strengthen industry–academia collaboration for R&D, internships, and hands-on training.
  - Skilling & Workforce Preparation
    - Large-scale skilling programs in AI, IoT, robotics through ITIs and engineering colleges.
- **Medium Term (3–5 years)**
  - **Robotics & Automation Innovation Clusters**
    - Develop local R&D ecosystems through public–private partnerships.
    - Incubate robotics startups and facilitate technology transfer.
  - **Advanced Technology Development**
    - Support indigenous development of AI-driven manufacturing solutions.
    - Build capabilities in digital twins, intelligent controls, and industrial software.
  - **Risk-Tolerant R&D Funding**
    - Create capital pools for high-risk, deep-tech robotics R&D.
- **Long Term (5–10 years)**
  - **Building Indian IP & Deep-Tech Platforms**
    - Invest in next-generation robotics, sensors, automation software, and indigenous platforms.
  - **Make India a Global Smart Manufacturing Hub**
    - Build local capability in advanced manufacturing technologies to export solutions, not just deploy them.
  - **Future-Ready Workforce**
    - Continuous learning systems to keep talent aligned with evolving robotics and automation technologies.

CASE STUDIES

Case Study 1

Client Profile: **A multi-national FMCG company from USA**

Core Business Areas:

- Food & Beverage– Manufacture, marketing, and distribution of beverages and convenient foods.
- Snacks and Beverages
- Nutrition – Products under Quaker, Naked Juice, and other health-focused brands.
- Sustainability & Innovation – Initiatives like regenerative agriculture, circular packaging.

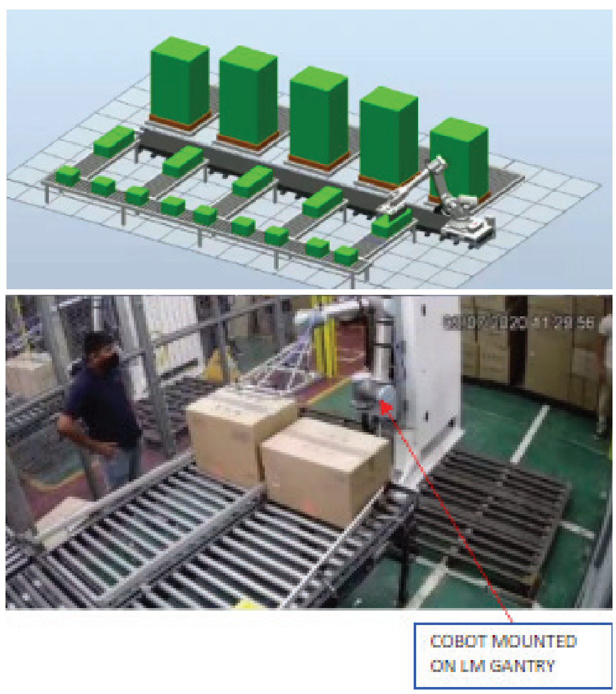
Products & Services

- Convenient Foods: Chips, cereals, granola bars, oatmeal, rice cakes, and side dishes.
- Beverages: Carbonated soft drinks, ready-to-drink tea and coffee, juices, dairy products, and sparkling water makers.
- Distribution & Bottling: Direct operations and licensed bottlers across global markets.
- Retail & B2B Channels: Grocery stores, food service, e-commerce, convenience stores, and independent bottlers.

Problem statement

Several operators were working on material handling, which was causing in higher cycle time. Current line was with Multi-Product, Multi-variant Line and Multiple pallet configuration. Project requirement was to study the Current process & provide solutions for End-of-Line Robotic Palletizing to improve reliability, quality and human safety.

LTTS solution highlights



LTTS has worked to provide below task

- Plant layout fitment Analysis
- FMEA & Simulation
- Design & development
- Solution Integration
- Testing & FAT

Tools/Software used- Delmia V5 and Catia V5

Values delivered

- Reduced cost-

Reduction in 5 Operator requirements.

- Productivity improvement -

Productivity improved with High throughput rates.

Easy programming to upgrade for future changes.

Case Study 2

Client Profile: A versatile leading auto tier-1 manufacturing company from Europe that builds complete BIW line set up

Core Business Areas:

- High tech – Precision engineering, mechatronics, and systems for semiconductors and electronics.
- Mobility – Automotive components, buses (e.g., Citea, MidCity), and car assembly.
- Energy – Sustainable energy systems including hydrogen technologies.
- Infratech – Infrastructure solutions like heating, cooling, and air-technical systems.
- Food tech – Machinery for food processing and packaging.

Products & Services

- Manufacturing: Metalworking, plastics processing, surface treatment.
- Systems: Mechatronic systems, chassis modules, cigar-making machines.
- Contract Manufacturing: For automotive and high-tech sectors.

Problem statement

Customer wanted to establish a new Cabin in white (CIW) line which can accommodate 8 product configurations.

Green field project to support in Robotics simulation studies and tool design.

LTTS solution highlights

LTTS has worked to provide below task

- Process planning, Layout finalization and Weld distribution
- Application worked- Material Handling, Spot welding, Sealing, MIG welding, Stud welding
- Tool Design and Validation (200+ Tools)
- Robot selection based on payload, reach, application
- Operator and Robot Safety validation
- Cycle time verification and offline programming (OLP) for 60+ robots
- Documentation for operator training (working & safety)

Tools/Software used- Process Simulate and Catia V5

Values delivered

- Reduced cost- ~20%

Tool Commonality to accommodate multi-variant. Reduction in Operator requirement.

- Space optimized ~15% -

Optimized space & flexibility for future volume expansion.

- Safety –

Worked on Ergonomics, Operator and Robot Safety validation.

Case Study 3

Tata Motors – Robotic Welding Excellence

Tata Motors has transformed its vehicle body assembly through the deployment of advanced robotic welding systems. These robots, equipped with real-time seam tracking and automated positioning capabilities, ensure superior precision and speed in the body-in-white process. As a result, the company achieved a 35% reduction in production cycle time, 99.8% weld consistency, and 60% improvement in workplace safety. The success underscores Tata Motors' commitment to aligning with global quality standards while simultaneously advancing workforce reskilling to operate and maintain high-end automation systems.

Case Study 4

Mahindra & Mahindra – Human–Robot Collaboration

Mahindra & Mahindra partnered with Universal Robots to integrate collaborative robots (cobots) into its engine assembly operations. These cobots work alongside human operators without physical barriers, performing repetitive and precision-intensive tasks such as torque application, part insertion, and quality inspection. This initiative not only improved productivity by 15% but also significantly reduced ergonomic strain among workers. The deployment showcases how intelligent human-robot collaboration can enhance safety and flexibility in Indian manufacturing while maintaining the human element central to production.

Case Study 5

Bharat Forge – IoT-Enabled Smart Forging

Bharat Forge has pioneered the integration of Internet of Things (IoT) sensors with robotic forging systems, enabling the transition from traditional manufacturing to a smart, data-driven ecosystem. These systems continuously monitor variables such as temperature, pressure, and force, while predictive maintenance algorithms minimize downtime. The result was a 28% reduction in unplanned downtime, 22% energy savings, and 40% faster defect detection rates. This case reflects how heavy engineering industries in India are embracing intelligent automation to enhance reliability, sustainability, and cost efficiency.

Case Study 6

ISRO & HAL – Precision Aerospace Automation

In the aerospace sector, ISRO and Hindustan Aeronautics Limited (HAL) have implemented robotic systems for composite fabrication and precision drilling. Automated robots now lay carbon fiber composites with micron-level accuracy and drill thousands of holes in aircraft and satellite structures with near-zero deviation. This automation has led to a 90% reduction in drilling errors and the production of lightweight, high-strength components vital for space missions. Such advancements highlight how robotics ensures both structural excellence and repeatability in India's most technologically demanding sectors.

Case Study 7

Client Profile: A leading Indian Pharmaceutical company

Challenge

- Achieving GMP-EU compliance with strict validation and audits
- Designing a controlled cleanroom with precise HVAC and air filtration
- Integrating IT and OT systems for seamless automation
- Optimizing energy efficiency while maintaining compliance

Solution

- Building Management System (BMS), Environmental Monitoring System (EMS)
- ISA-95-compliant automation for seamless IT-OT integration
- HVAC automation to maintain cleanroom conditions
- Smart energy management for optimized resource use
- Technologies/ solutions implemented include:
  - Optimize Productivity with Smarter, More Efficient Control Systems: with PLC (programmable logic controller) and PAC (programmable automation controller)
  - Enhance energy efficiency and operational performance with Variable Frequency Drives (VFD): VFD for AHU (Air Handling Units)
  - Plant-wide network connectivity systems enabling real-time control and information

Result

- 45% reduction in energy consumption
- Enhanced compliance and data integrity
- Improved process control and efficiency
- Scalable and future-ready facility

Case Study 8

JCB India Private Limited – Automation of manufacturing plants

JCB India, a leader in construction and earthmoving equipment manufacturing, has been on a continuous journey to enhance productivity, quality, and operator safety across its manufacturing plants.

As part of its automation, digital transformation and Industry 4.0 roadmap, JCB gradually invested in various state of art automation system. These systems designed specifically for heavy fabrication applications. This initiative represents a strategic step towards low-cost automation (LCA) — leveraging in-house engineering and local integrator expertise to achieve world-class weld quality at optimized capital expenditure.

Objective

Heavy fabrication components such as various booms, chassis and other structures require precise and consistent welding to ensure long-term durability and safety.

Excess dependency of Manual welding poses challenges like skill manpower availability, Inconsistency in welding, safety risks & output variance. These challenges prompted the need for a sustainable, scalable, and locally supported robotic solution.

Solution

JCB collaborated with local system integrators to design and deploy multiple tailor-made robotic welding stations on various product lines.

Each system includes:

- Robots with latest Industry 4.0 features
- Custom fixturing for minimal changeover time
- Peripheral infeed & outfeed system
- Locally built positioners
- Offline programming tools.

In-house operator training made the solution self-reliant and cost-effective, reinforcing the company's Make-in-India commitment.

The installation of various system was executed in phases, validating them on various crucial requirements:

- Weld penetration
- Fixture 3C (Capability, Capacity & Consistency)
- Safety compliance.

Robots were connected to Digital performance Management dashboards for various KPI tracking that include OEE tracking and predictive maintenance.

This integration aligned with JCB's digital manufacturing standards, ensuring traceability and consistency. Also, they are pivotal for its digital transformation Roadmap

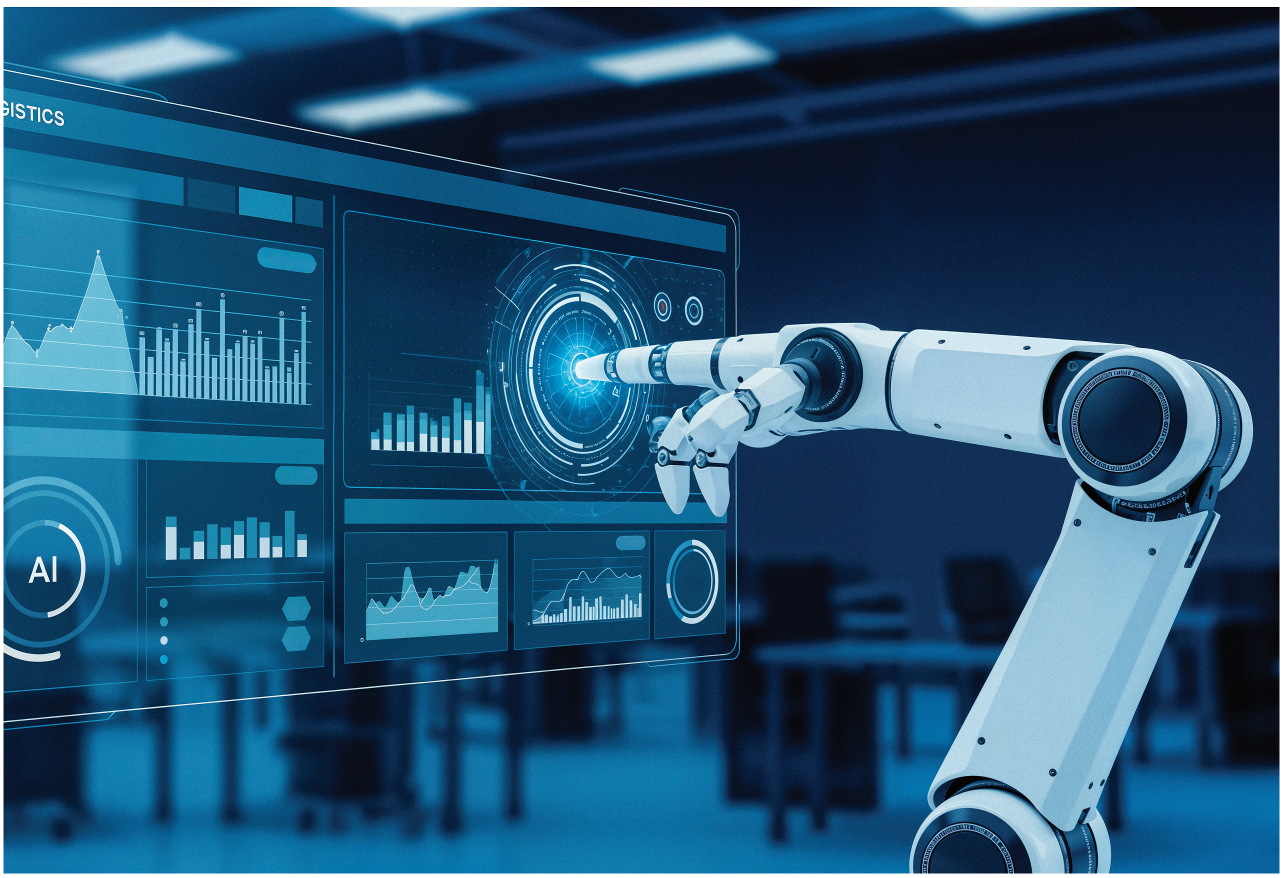
Results/Benefits

Parameter	After Robotic Integration
Skill welder dependencies	Reduced drastically .
Consistency in Welding	Improved
Cycle Time	Reduced
Rework Rate	Major reduction
CAPEX	30- 35% saving compare to imported system.

Case Study 9

Other Indigenous Innovation in Robotics - Indian Startups and MSMEs

Startups such as Asimov Robotics (Kerala) and Systemantics (Bengaluru) are redefining accessibility in automation by designing affordable, modular robotic systems tailored for Indian SMEs. Asimov develops service robots and educational cobots, while Systemantics focuses on vision-guided robots for electronics and component assembly. Their products operate at 40% lower cost than imported alternatives, bridging the affordability gap. These innovators are also fostering local employment and building India's intellectual property base, ensuring that automation growth remains inclusive and domestically rooted.



Chapter 2:

IT/IoT Application in Robotics & Automation

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1 Background and strategic importance for India

The convergence of Information Technology (IT) and the Internet of Things (IoT) in robotics - commonly known as the Internet of Robotic Things (IoRT). This is transforming industrial ecosystems by enabling robotic systems to operate with enhanced intelligence, autonomy, and connectivity.

Indian Robotics IT/IoT Eco System

India is positioning itself as a global manufacturing hub1, especially under initiatives like Make in India 2.02, SAMARTH Udyog Bharat 4.03, and Digital India4.

Considering India's optimistic vision of becoming the leader in Robotics & Automation by 2030, IoRT plays the key role as the backbone of Industrial Manufacturing ecosystem. India has several strategic advantages in the development and deployment of IT and IoT applications, making it a global hub for innovation and implementation.

India is a global leader in IT services and a fast-rising player in IoT, especially in industrial applications. Although India lags behind the U.S. and China in IoT market size, its strong talent pool, cost efficiency, and proactive government support position it for long-term leadership. As per NASSCOM India's Total tech industry5 revenue expected to hit $283 billion, with $224 billion from exports, giving an employment to 5.8 million tech employees, with net hiring of 126,000 in FY25.

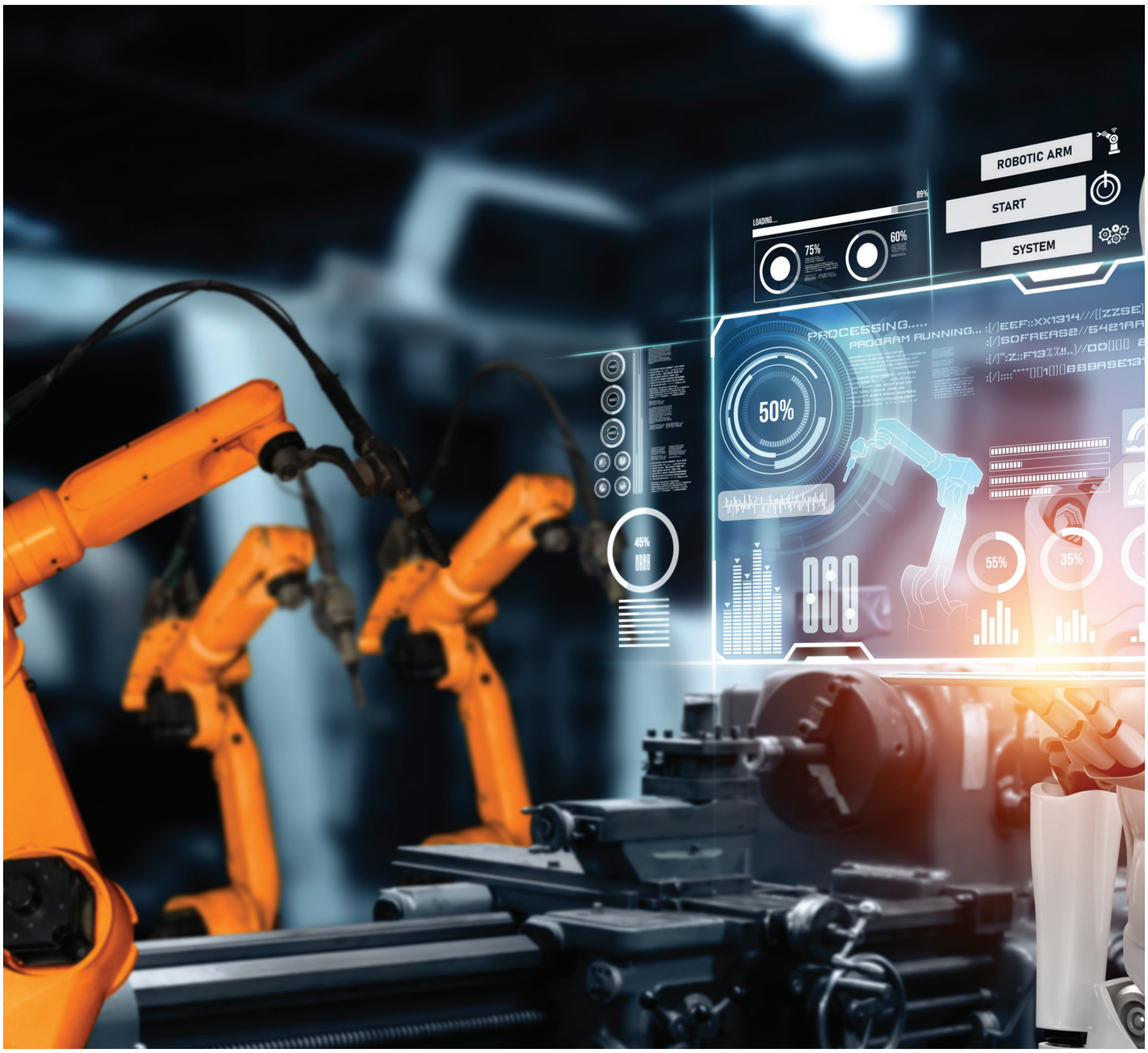
While most robots may appear similar in form, the true differentiation lies in the outcomes they deliver. This reflects the maturity of the robotics industry, where hardware has largely converged, and the real value now stems from software, IoT integration, deployment strategies, and system reliability.

Global Regulatory & Advisory Bodies

The table below lists key global regulatory and advisory bodies along with their relevance to IT/IoT and Robotics.

Name	Primary Focus / Role	Relevance to IT, IoT, Robotics
IEEE Robotics and Automation Society (IEEE RAS)	A society under IEEE dedicated to robotics & automation; has advisory committees, technical committees, standardization activities.	Very high — robotics, automation, and robotics+IoT integration are key topics. RAS/SCSA (Standing Committees for Standards Activities) works on standardization for robotics & automation. https://sagroups.ieee.org/
OneM2M	Standardization of common platform for IoT (M2M = machine to machine) globally.	Helps ensure interoperability, messaging, platform standards which are very relevant when robots are interacting over networks, or using IoT platforms
Open Connectivity Foundation (OCF)	Standards & certification for device interoperability in IoT.	Robotics often contains many devices / sensors / actuators that need interoperability

Name	Primary Focus / Role	Relevance to IT, IoT, Robotics
Industry IoT Consortium (IIC)	An industry forum for accelerating adoption of Industrial IoT; works with other SDOs, open-source groups, etc.	Robotics in industrial settings (IIoT + Robotics) is a big area; advisory work, liaison, standardization etc.
International Federation of Robotics (IFR)	NGO promoting development, use, research and international cooperation in robotics (industrial & service robots)	Provides global perspective, statistics, policy advice, trends etc. Useful for robotics policy, regulation, and standardization awareness.
Smart Industry Readiness Index (SIRI)	SIRI framework is a comprehensive framework designed to help manufacturers assess and enhance their digital transformation journey towards Industry 4.0.	Aligning SIRI framework to the Robotics context means aligning its three pillars -Process, Technology, Organization, with robotics adoption and integration in manufacturing or industrial environments.



2 Layered Architecture of IT/IoT based Robotic Systems

IT/IoT application in Robotics can be broadly categorized in below 5 layers.

1. **Sensor & Data Acquisition**: It captures real-world data for robotic perception and environment monitoring. For example: Motion/IMU (accelerometer, gyroscope), Cameras, LiDAR, Radar, Temperature/Humidity sensors, RFID, Barcode scanners etc. And for Data acquisition some of the technology that can be used are embedded boards like ARM, ESP32, Jetson, Raspberry Pi etc.
2. **Connectivity & Networking**: Connectivity and networking should ensure reliable, low-latency communication between devices, robots, and cloud systems to support seamless data exchange and real-time responsiveness. Some of the technologies used here are Wi-Fi 6/6E, Bluetooth LE, Zigbee, Z-Wave, UWB, 4G LTE-M, NB-IoT, 5G URLLC, LoRaWAN, Sigfox, OPC-UA, Modbus, PROFINET, Ether CAT, Time-Sensitive Networking (TSN).
3. **IoT Platforms and Cloud Infrastructure**: Middleware & IoT platform is essential for managing device operations, messaging protocols, interoperability, and orchestrating system-wide functions. The cloud infrastructure should support scalable storage, advanced analytics, and efficient orchestration of vast volumes of IoT and robotic data.
4. **Data Analytics & Intelligence**: Data Analytics and Intelligence transform raw data into meaningful insights and enable autonomous decision-making. These capabilities are applied in areas such as predictive maintenance, anomaly detection, and path planning. Technologies driving this include AI/ML (for predictive insights and anomaly detection), Computer Vision (for SLAM and object recognition), Edge AI platforms (like TensorFlow Lite, TinyML, NVIDIA Jetson),Physical AI and visualization tools (such as Grafana, Power BI, and Tableau).
5. **Security & Privacy**: Security and privacy are critical for safeguarding devices, data, and communications from cyber threats. Key technologies supporting this include Public Key Infrastructure (PKI), X.509 certificates, Trusted Platform Module (TPM) chips, TLS/SSL and DTLS protocols, secure boot mechanisms, over-the-air (OTA) updates, and Zero-Trust network architectures.

3 Maturity Level for IT/IoT Architecture Layers in Robotics

Below table outlines a maturity scoring parameters for all the five layers in robotics, based on their technological readiness, adoption, and innovation depth.

1. Sensor & Data Acquisition

Score	Level of Maturity	Parameters & Criteria
5	Established	Technologies are at Horizon Level - Deployment / Market category where product has been at Commercialization & operational use.
4	Advanced	Focuses on fundamental research at early Technology Readiness Levels (TRL 1–3), typically conducted within academic or research institutions.
3	Developing -Advanced	Technology is available and understood; capable of incremental innovation and research i.e. enhancing existing technologies rather than creating new paradigms.
2	Developing	High-precision products are built using existing technologies; engineering-focused.
1	Emerging	Largely depends on imports or manufacturing know-how is available.

2. Connectivity & Networking

Score	Level of Maturity	Parameters & Criteria
5	Established	AI-powered Software-Defined Networks (SDNs) enabling dynamic network reconfiguration, optimized resource allocation, and enhanced security protocols.
4	Advanced	Software-Defined Networks (SDNs) & Network Virtualization.
3	Developing – Advanced	Standards driven, multi-protocol support devices and networks.
2	Developing	Connectivity reinforced with tight security controls.
1	Emerging	Basic connectivity - sensor/actuators to storage (Ex: Zigbee, MQTT, TCPIP, Wi-Fi, LoRa WAN, Bluetooth, etc)

3. Platform & Cloud Infrastructure

Score	Level of Maturity	Parameters & Criteria
5	Established	Fully decentralized eco-system: Continuous improvement is embedded, leveraging AI and automation for self-healing systems. Organizations at this level lead in IOT ecosystems, achieving sub-millisecond latencies and 99.999% uptime.
4	Advanced	Dominant Edge computing with Fog orchestration: Infrastructure is dynamically managed using data-driven metrics. IOT data is processed at the edge with low-latency orchestration (e.g., Kubernetes). Security employs zero-trust models with automated threat hunting. Performance is tuned via quantitative feedback loops (e.g., SLA monitoring); ideal for data-intensive industries like manufacturing.
3	Developing – Advanced	Balanced computing between edge, on Prem, Fog & Cloud. Standardized policies and tools are implemented organization wide. Data flows efficiently through automated pipelines (e.g., ETL tools), with hybrid storage (on-premises and cloud). Edge computing enables near-real-time processing, and analytics integrate machine learning for insights. IOT ecosystems are governed by defined architectures (e.g., microservices), with role-based security and compliance checks. Scalability is proactive via auto-scaling groups. Governance includes KPIs for data quality.
2	Developing	Basic processes are established and repeatable for core functions. Data ingestion is semiautomated via simple APIs or middleware, with centralized storage (e.g., relational databases). Processing uses scripted tools for routine tasks, but real-time analytics are limited. IOT integration follows basic protocols (e.g., MQTT), and security includes perimeter controls. Scalability is project-specific, with some monitoring. This level reduces errors but still relies on individual expertise; suitable for early commercial deployments.
1	Emerging	Fully cloud dependent / no optimization. Infrastructure is fragmented and reactive. Data handling is manual or improvised, with no standardized processes. IOT devices connect sporadically, leading to siloed data storage (e.g., local files or basic spreadsheets). Processing is batch-oriented and inefficient, often causing bottlenecks during peak loads. Security is inconsistent, and scalability is limited to ad-hoc scaling (e.g., manual server additions). Metrics are absent, resulting in frequent downtime and data loss. Typical for pilot projects.

4. Data Analytics & Intelligence

Score	Level of Maturity	Parameters & Criteria
5	Established	AI driven Autonomous decisions
4	Advanced	Prescriptive AI where humans confirm AI recommendations
3	Developing – Advanced	Data Analytics and/or AI driven insights to support operators - Digital Twins
2	Developing	AI used for predictive maintenance
1	Emerging	Exploratory Data visualization and AI use cases

5. Security & Privacy

Score	Level of Maturity	Parameters & Criteria
5	Established	Continuous improvement is embedded, with agile adaptation to emerging threats and regulations. IOT platforms leverage advanced techniques like zero-trust architectures, homomorphic encryption for privacy, and blockchain for supply chain integrity.
4	Advanced	Security and privacy are proactively monitored with metrics and analytics. IOT solutions use real-time threat intelligence, AI-driven anomaly detection, and privacy impact assessments (PIAs) tied to KPIs (e.g., mean time to detect/remediate). Ecosystem-wide controls ensure end-to-end protection, with data lineage tracking for privacy. Maturity indicators: Data-driven decisions; breach rates below industry benchmarks.
3	Developing -Advanced	Processes are documented and consistently applied across the IOT platform. Security includes automated device provisioning, secure boot, and regular vulnerability scanning. Privacy features like data minimization, anonymization, and consent mechanisms are embedded in designs. Governance includes defined roles, training, and third-party risk assessments. Maturity indicators: Predictable compliance; integrated security in development.
2	Developing	Fundamental security and privacy measures are implemented reactively for critical assets. Basic device hardening (e.g., firewalls, password policies) and data encryption are in place, but coverage is uneven across the IOT ecosystem. Incident response exists but is manual. Privacy compliance is limited to legal requirements without proactive user controls. Maturity indicators: Reduced low-hanging fruit risks; some audit trails.

Score	Level of Maturity	Parameters & Criteria
1	Emerging	Security and privacy practices are reactive and inconsistent. Threats are addressed only after incidents occur, with no formal policies or standardized tools. IOT devices may lack basic protections like default credential changes or encryption, leading to high vulnerability to common attacks (e.g., Mirai botnets). Privacy is an afterthought, with minimal data handling controls. Maturity indicators: Frequent breaches; no centralized oversight.

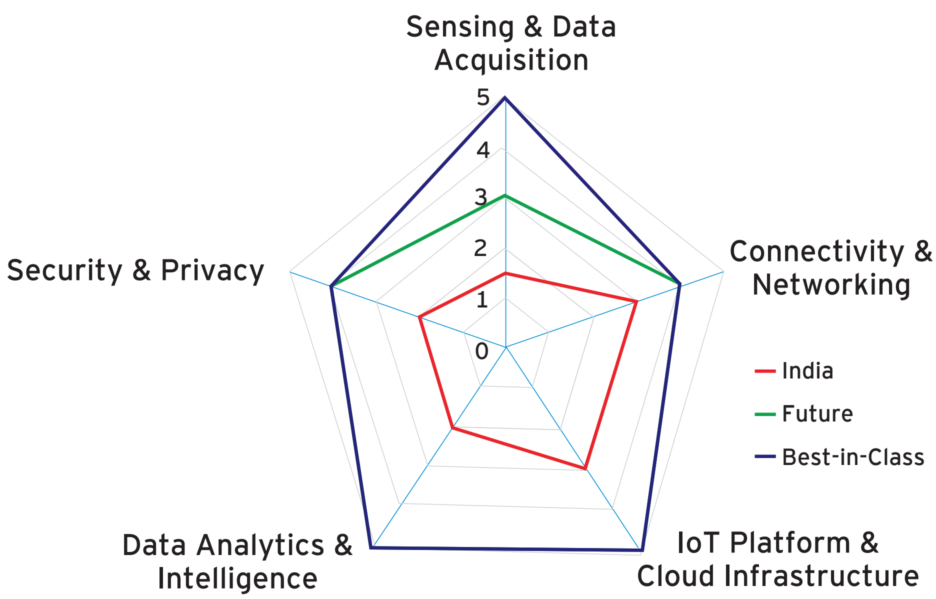
IT/IoT Maturity Assessment for Autonomous Operations

Robotics IT/IoT maturity assessment for autonomous operations evaluates how ready an organization is to adopt self-governing, self-adaptive, and intelligent automation across its IT and IoT ecosystem.

The table and graph below present India's IT/IoT Robotics & Automation maturity assessment index, its projected future maturity targets in 5 years, and the current global best-in-class benchmarks.

Category	India Maturity	Future Maturity (5 years)	Best-in Class / Global Maturity
Sensing & Data Acquisition	1.5	3	5
Connectivity & Networking	3	4	4
IoT Platform & Cloud Infrastructure	3	5	5
Data Analytics & Intelligence	2	5	5
Security & Privacy	2	4	4

Note: The ratings presented are derived from the above parameter index and the expertise of industry professionals. It is recommended that the maturity assessment parameters and index be validated through comprehensive market survey reports and global benchmarking studies.



4 Gap & Recommendation for all layers in IT/IoT Application in Robotics & Automation

4.1 Sensing & Data Acquisition:

The global robotic sensors market6 was valued at $1.82 billion in 2024 and is projected to reach $3.63 billion by 2033, growing at a CAGR of ~8.1%. Rising adoption of industrial robots and collaborative robots (Cobots) for manufacturing, logistics, and healthcare has been the key drivers. Force/Torque sensors dominate (25–28% share) and Asia-Pacific holds ~50% share where China is leading the market.

Gap in Sensing & Data Acquisition

- **Heavy Dependence on Imported Sensors**: Most advanced robotic sensors (e.g., LiDAR, force/torque sensors, vision systems) are imported, leading to high costs and supply chain vulnerabilities. Domestic manufacturing of high-precision sensors is still in its infancy, limiting scalability and affordability.
- **Limited Indigenous R&D in Sensor Technology**: India lacks robust research and development ecosystems focused on sensor innovation for robotics. There's minimal collaboration between academia, industry, and government labs to develop custom sensors for Indian use cases (e.g., agriculture, healthcare, low-cost automation).
- **Lack of Skilled talent in Sensor Technology**: India's rapid growth in the IT sector has inadvertently reduced student interest in core science disciplines such as mechanical engineering, electrical engineering, physics, chemistry, applied materials etc. The significant pay disparity between experienced IT professionals and core research engineers is further encouraging young talent to pursue careers in IT over foundational science and engineering fields.
- **Inadequate Testing and Validation Infrastructure**: There are few national-level testbeds or labs for validating sensor performance in real-world robotic applications. This slows down innovation and commercialization of indigenous sensor technologies.
- **Cost Barriers for SMEs and Startups**: High-end sensors are expensive, making them inaccessible to small manufacturers and robotics startups. There's a need for low-cost, modular sensor kits tailored to Indian conditions and budgets.
- **Limited Use of AI for Sensor Data Interpretation**: While AI adoption is growing, many robotic systems still lack advanced perception capabilities due to poor sensor data quality or limited processing infrastructure. AI-powered sensor fusion and edge analytics are underutilized in India.
- **Fragmented Data Acquisition Systems**: Robotic systems often operate in silos with non-standardized data formats, making integration and real-time decision-making difficult. There's a need for interoperable platforms that can unify sensor data from multiple sources (vision, tactile, environmental).

Recommendation for Sensing & Data Acquisition

Short Term (0 - 3 years)

- **Promote Local Assembly & Calibration Units**: Extend PLI Scheme to encourage startups and MSMEs to set up sensor assembly and calibration facilities using imported components. This reduces costs and builds local expertise in sensor integration and testing.

- **Integrate Sensor Education into Engineering Curriculum**: Extend Government fund support for Tier-2 and Tier-3 colleges to Introduce specialized courses and degree programs in sensor design, embedded systems, and data acquisition. Utilize the fund to develop laboratories and infrastructure. Encourage exchange programs and collaborations with international institutions specializing in Sensor Engineering for Tier-2 and Tier-3 colleges.
- **Incentivize Academia-Industry Collaboration**: Launch government funded pilot projects between engineering institutes and sensor manufacturers to develop application-specific sensors (e.g., for agriculture, healthcare, manufacturing).

Mid Term (3 - 5 years)

- **Develop Open-Source Sensor Libraries and Toolkits**: All government-funded research institutes and technical universities should be required to develop and maintain open-source sensor libraries and toolkits. These resources should include Sensor design templates, schematics, firmware, and integration guides. Calibration algorithms and Integration modules for IoT applications. Ensure compliance with global standards for interoperability and security.
- **Foster Global Collaborations and Technology Transfers**: Partner with countries strong in sensor tech (e.g., Japan, Germany, South Korea) for joint R&D, licensing, and training. Leverage diplomatic and trade channels to bring advanced sensor technologies to India under co-development models.
    - Under the ministry of Commerce and Industry, establish Technology-Transfer Framework guideline highlighting guidelines on IP sharing, Licensing model and compliance with Indian standards.
    - Tax Benefits and funds for SMEs entering into Technology transfer agreement with foreign companies.

Long Term (5 -10 years)

- **Build a National Sensor Data Infrastructure**: Using Open-Source Sensor Libraries and toolkit, develop a centralized platform for collecting, storing, and sharing sensor data across sectors which can be used for data. Enable open access to anonymized datasets for startups, researchers, and developers to build innovative solutions.
- **Create a Sensor Standards & Certification Authority**: Establish a regulatory body to define technical standards, testing protocols, and certification for sensors. This will ensure quality, interoperability, and global competitiveness of Indian-made sensors.

4.2 Connectivity & Networking

The convergence of robotics, IoT, AI, and next-generation networks (5G/6G) will redefine robotics & automation connectivity paradigms. Standardization efforts like TSN, OPC will drive interoperability, while AI-enhanced communication will enable self-healing, adaptive robotic and automation networks. These advancements promise transformative impacts across manufacturing, logistics, healthcare, and smart cities.

Gap in Connectivity & Networking

Inadequate High-Speed and Low-Latency Networks: Robotics and IoT systems require real-time data exchange, but many regions in India still lack reliable high-speed internet and low-latency 5G infrastructure. This limits the deployment of autonomous systems and remote-controlled robots, especially in rural and industrial zones.

Lack of awareness on BIS IoT Reference Architecture (IS 18004): The lack of awareness can lead to inconsistent adoption of standardized practices, hinder interoperability across IoT ecosystems, and slow down the development of secure and scalable solutions. Without adequate understanding and implementation of this framework, organizations may struggle to align with national and global standards, impacting overall maturity and compliance.

Recommendations

Short Term (0 - 3 years)

- **Promote Use of Standardized Communication Protocols**: Encourage adoption of open and interoperable protocols like OPC-UA, MQTT, CoAP, and ROS for robotics and IoT systems. BIS should establish standardized communication protocols to enable seamless industry-wide adoption.

Mid Term (3 - 5 years)

- **Invest in Indigenous Networking Hardware R&D**:

  Extend PLI Scheme to support long-term R&D in networking chips, routers, gateways, and communication modules through public-private partnerships. Reduce dependence on imported networking components and build secure, scalable Indian alternatives.

Long Term (5 - 10 years)

- Create a National IoT Sandbox Environment: Incentivize colleges and research institutes to set up testbeds or sandboxes where startups and researchers can test their robotics and IoT solutions under real-world network conditions. These can also be hosted in tech parks or innovation hubs in universities.

4.3 IoT Platforms and Cloud Infrastructure

Rapid adoption of collaborative robots and AI-integrated IoT are driving India's IoT market. Cloud Robotics in India is also one of the emerging segments with strong potential in healthcare and logistics.

Gap in IoT Platforms and Cloud Infrastructure

- **Limited Indigenous IoT Platforms**: Most IoT platforms used in robotics are global players (Amazon AWS IoT, Microsoft Azure IoT, Google Cloud IoT). Lack of Indian platforms tailored for Indian industrial and agricultural robotics applications.
- **High Cost & dependency on global IoT providers**: Heavy reliance on AWS, Azure, and Google Cloud increases operational costs and raises data sovereignty concerns. They are not suitable for cost sensitive market like India.
- **Lack of Specialized Robotics Cloud Services**: Current cloud offerings are generic, not optimized for robotic workloads like sensor fusion, motion planning, and AI-driven control. Minimal support for IoRT (Internet of Robotic Things) platforms.

Recommendation

Short Term (0 - 3 years)

Incentivize Indian companies to build Green Data Centres: Formulate policies to incentivize Indian companies to establish green data centres by promoting the development of indigenous, energy-efficient cloud infrastructure powered by renewable energy. Such measures should include fiscal benefits, regulatory support, and long-term sustainability targets to align with national climate and digital transformation goals

Mid Term (3 – 5 years)

Launch Indigenous Cloud Robotics Platform: Incentivize Indian companies to build Open-Source Indigenous Cloud Robotics Platform similar to AWS RoboMaker or NVIDIA Isaac Cloud, tailored for Indian SMEs, with Data localization and compliance framework suitable for Indian SME sector. This facilitates seamless integration of heterogeneous devices, reducing vendor lock-in and enabling scalable robotics solutions for diverse industrial environments.

Long Term (5 – 10 years)

Global Positioning & Export Capability: Position India as a provider of affordable robotics cloud solutions for emerging global markets. Drive global standards for cloud robotics interoperability.

4.4 Data Analytics & Intelligence

India's robotics sector is rapidly evolving, leveraging data analytics and AI to bridge the gap with global leaders. While global players dominate with advanced cloud robotics and predictive intelligence, India is focusing on cost-effective, localized solutions for SMEs.

Gap in Data Analytics & Intelligence

- **Lack of Indigenous Robotics Foundation Model (RFM)**: RFM represent a transformative approach to enabling robots to perform complex tasks across diverse environments. These models are large-scale AI systems, often leveraging techniques like transformers, imitation learning, and vision-language-action (VLA) frameworks. Unlike traditional task-specific models, foundation models are pretrained on vast datasets, allowing for superior generalization and adaptability. RFM enhance various aspects of robot autonomy, including perception, decision-making, and control. For instance, large language models (LLMs) can generate code or provide reasoning, while vision-language models enable open-vocabulary recognition. These models also support multimodal inputs, such as combining visual data with natural language commands, making them versatile for real-world applications. Major global players are NVIDIA's GROOT - general purpose foundation model for humanoid robots. Tesla's BOT etc. India lacks Indigenous Robotics Foundation Model focusing on its specific requirement.
- **Data Availability & Quality**: Robotics deployments lack standardized data collection protocols, leading to inconsistent datasets for AI training. Fragmented Data Eco system and insufficient proprietary datasets affect customizing AI models for specific robotics applications.
- **Analytics Infrastructure Gaps**: India lacks specialized high-performance computing and cloud infrastructure for robotics analytics, despite initiatives like AIRAWAT.
- **Skills & Talent Shortage**: Most of the businesses lack skilled talent to develop and deploy AI-driven robotics analytics.
- **Ethical & Regulatory Gaps**: Absence of clear standards for AI in robotics raises concerns about bias, transparency, and accountability.
- **Cost & ROI Challenges**: AI-enabled robotics analytics platforms require significant investment, making ROI uncertain for SMEs. Without robust data pipelines, analytics platforms, and AI governance, India risks lagging in intelligent robotics adoption. These gaps affect predictive maintenance, real-time decision-making, and autonomous operations in manufacturing, healthcare, and logistics.

Recommendations

Short Term (0 - 3 years)

- **Standardize Data Collection**: Develop national guidelines for robotics data formats to ensure interoperability across platforms and vendors. For example: OPC-UA (Open Platform Communications Unified Architecture) for industrial automation, ROS 2 (Robot Operating System) for modular robotics.
- **Skill Development**: Introduce AI + Robotics Analytics certification/Engineering programs via IITs/NITs and reputed institutions.

Mid-Term (2 - 5 Years)

- **Hybrid Edge-Cloud Architecture for Robotics & Automation**: Edge Computing enables low-latency decision-making for real-time automation, robotic control, safety, and autonomy. Cloud Computing provides scalable resources for heavy analytics, AI model training, and centralized data storage. Deploy Distributed Intelligence Framework where Edge Layer for immediate sensor data processing and safety-critical tasks. Cloud Layer for advanced analytics, predictive maintenance, and fleet optimization.
  - Promote Government funded training for small and medium scale Industries on industry 4.0 adoption and edge to cloud strategy.
  - Mandate or incentivize global advisory firms to provide Industrie 4.0 and Robotics automation adoption consultation to improve the operational efficiency for SME sector in India

Long-Term (5 - 10 Years)

a) Advanced AI for Robotics: Extend PLI scheme in AI hub for neuromorphic computing, self-learning robotics analytics, and autonomous orchestration.

4.5 Cyber Security & Privacy

As robotics systems become increasingly connected, cybersecurity and data privacy have emerged as critical challenges. Protecting sensitive operational and user data is essential to prevent breaches and ensure compliance with emerging standards. Building robust cybersecurity ecosystems will be key to scaling safe and trusted robotics adoption across industries.

GAP in Robotics Cyber Security & Privacy

- **Lack of Cybersecurity Policies for Robotics & AI**: India's primary cybersecurity framework (e.g., NCSP 2013) lacks provisions for emerging technologies like robotics and AI.
- **Vulnerable Infrastructure**: Robotics & Automation systems often rely on cloud-based and IoT infrastructure, which are prone to cyberattacks such as ransomware, phishing, and data breaches. And critical sectors like manufacturing and healthcare using robotics are increasingly targeted.
- **Lack of Skilled Cybersecurity Workforce**: There's a shortage of professionals trained in securing robotic systems, especially in industrial and autonomous applications. Current Technical and educational institutions are not equipped to produce cybersecurity-aware robotics or automation engineers due to lack of required infrastructure.
- **Dependence on Foreign Technologies**: Many robotics components and cybersecurity solutions are imported, raising concerns about supply chain vulnerabilities and backdoors.
- **Data Privacy concern for Robotics Applications**: Robotics systems particularly in healthcare and surveillance lack adequate data protection measures, despite handling highly sensitive personal information.

- **Lack of Clear Guidelines for Data Governance in Robotics**: There are no specific privacy standards for robotics, especially in public-facing or autonomous systems. Ethical concerns around surveillance, facial recognition, and biometric data collection remain unresolved.
- **Low Public Awareness and Trust**: Citizens and businesses often lack awareness of how robotic systems handle data, leading to mistrust and resistance to adoption.

Recommendations

Short term (0 – 3 years)

- **BIS Adoption**:
  - Fast track BIS adoption/cross reference of IS/ISO 10218:2025 (Parts 1 & 2) in factory safety regulations. It requires cyber risk assessments that impact functional safety. This standard is critical for manufacturers, integrators, and safety engineers to ensure compliance, reduce risk, and enable safe deployment of robotics in industrial environments.
- **Gap Assessment**:
  - Fund project to perform gap assessments to IEC 62443 and IS/ISO 10218:2025 across robot controllers, PLCs, HMIs, networks and update threat models.
  - Skill Development & Training
  - Introduce IEC 62443 and IS/ISO 10218:2015 standards into the engineering curriculum to enhance knowledge of industrial cybersecurity and robotics safety
  - Mandate training for plant teams and integrators on safety, security and incident reporting & response. Embed robotics cyber safety modules in universities/ITIs (DPIA for robotics, asset zoning, co validation)
- **Operationalize DPDPA Rules for Robotics**:
  - Notify and operationalize DPDPA (Digital Personal Data Protection Act) rules for robotics use cases (industrial, medical, service). This shall include consent, data minimization, breach notification, cross border flows and define "significant data fiduciary" obligations for HRI (Human Robotics Interaction) telemetry.
- **Incident Reporting**:
  - Mandate incident reporting and sectoral CSIRTs for robotized OT. It extends CERT In Cyber Crisis Management Plan to robot cells and mobile robots.

Mid-term (3 - 5 years)

- **Robotics Security Conformity**: Launch a robotics security conformity lane under NCIIPC–QCI CAF mapped to IEC 62443 + IS/ISO 10218:2025 + DPDPA.

Long term (5 - 10 years)

  - **Establish Robotics NCRF**: Develop National Robotics Cybersecurity Baseline Profile derived from IEC 62443 + IS/ISO 10218:2025 + DPDPA + ISO 31700 and make it as mandatory requirement in public procurement.
  - **Promote Local Sourcing**: Incentivize indigenous secure controllers, privacy preserving perception stacks etc. to reduce supply chain risk.
  - **Map Compliances to Licenses**: Tie factory safety licenses to IS/ISO 10218 compliance with cyber in safety checks.

Note: The gaps and recommendations concerning cybersecurity and data privacy have been formulated based on the expertise of industry professionals. It is advised that these recommendations be further validated by certified cybersecurity experts to ensure accuracy and robustness.

5 Case Studies of IT/IoT application in Robotics

5.1 Cobot increases the daily production for Small Scale Industries

Executive Summary:

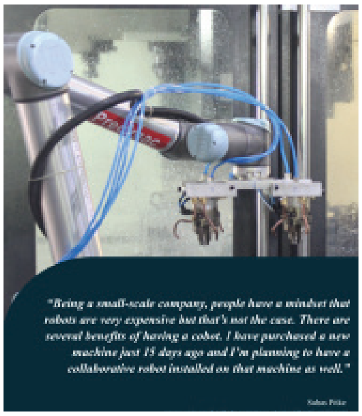
Shruti Engineers is a Micro Small and Medium Enterprise (MSME), based out of Pune. The 10-man company manufactures assembly components for automotive lines. Before installing a Cabot, their production was limited to 300 machine parts per day, and they had strict SLA(Service Level Agreement) with their customer as any delay in supplying their material to the automotive factory would result in line stoppage incurring production loss.

Shruthi Engineers realized the need for automation and installed the Cobots from Teradyne Robotics - UR10 to be used in CNC and Machine Tending tasks along with their existing workforce.

Key Challenges

- The workforce at Shruthi Engineers primarily comes from backgrounds with limited formal education and has minimal exposure to automation.
- Missing delivery deadlines could lead to significant revenue loss and damage customer relationships.
- Additionally, occasional human errors have impacted the quality of delivered products.

Solution



Shruthi Engineers implemented their first collaborative robot, the UR10. Being a cobot, it was safe for human operators to work alongside, making adoption easier. The programming interface of this Cobot was highly intuitive, simplifying its use for the team. With the cobot integrated into the existing workforce, daily production increased from 300 to 400 parts. This automation also minimized human errors, improved product quality, and ensured timely delivery to customers.

Quote from owner of Shruthi Engineers – Suhas Pitke

Key Takeaways

- Affordable collaborative robots (cobots) are ideal for small-scale industries as they are safe and designed to work alongside human operators.
- Ease of commissioning and operation is a key driver for adoption. A simple, intuitive interface, preferably available in local languages, greatly enhances user experience and acceptance.

- Value-based pricing can make Cobots accessible even to SMEs, enabling wider adoption across the sector.
- Cobots can be integrated into existing layouts without additional fencing, making them space-efficient and cost-effective.

Conclusion

Success in India's small-scale manufacturing sector requires more than product delivery, it demands a customer-centric approach. By understanding local pain points, providing robust support through in-country service and repair facilities, and adapting global technologies to meet cost and regulatory needs, companies can offer practical, affordable solutions. This strategy drives adoption, builds trust, and supports sustainable growth in India's Industry 4.0 journey.

5.2 Warehouse Robotics Automation for one of the largest FMCG Player

Executive Summary:

One of the largest FMCG player planned to establish its 4th production plant in India, which would be its largest and fully automated captive warehouse. They wanted to shift from manual to automated processes to address their storage and throughput requirements and wanted a solution for managing the end-to-end process from inbound of inventory to storage and later outbound to different distributors.

Addverb, an Indian Robotics company came up with a unique solution that helped them make the most of their limited space and with the unique solution provided by Addverb, the manual process could also be automated.

Key Requirement

- Shift from manual to automated processes
- Improve their storage and throughput capacity in the limited space
- Build a process that enabled direct dispatch to the distributor
- Solution shall include large number of storage bins and pick faces for case picking and provision of manual case picking for mixed pallet formation.

Solution

The solution provided by Addverb is one of the most unique solutions as it utilises the Mother-Child shuttle system not only for storage and retrieval but also for Rainbow-Pallet formation at the base of the same dense racking.

Low-Bay Storage systems consisted of G+4 levels, with 3,500 pallet storage positions. At the 'G' level, a single mother shuttle transferred to 6 single-deep mother-child shuttle systems for order sorting and mixed pallet formation. 4 multi-deep Mother-Child shuttle systems were deployed on upper 4 levels, comprising a total of 11 mother shuttles, 10 child shuttles, and supporting systems.

The high bay area and low bay area were interconnected via mezzanine. 2 Crane-based ASRS were installed for the high bay area for slow moving SKUs. The double and triple deep ASRS cranes can access high bay area of up to 30m, with 6200 pallet positions.

Key Take Away

- Achieved system throughput of 300 pallets/hour
- Developed a maintenance and troubleshooting system by directly integrating SAP EWM, WMS & PLC, eliminating middleware
- Improved accuracy and throughput at the warehouse's last touchpoint by using unified system for order sortation and storage

Conclusion

Indian robotics companies are reducing dependency on foreign automation solutions and embodying the vision of 'Make in India to Made for the World' by manufacturing locally and exporting globally. They are shaping the nation's robotics narrative through AI-integrated automation, fostering human-robot collaboration, and building global confidence in Indian engineering.

5.3 Robotic Surgery in Healthcare Sector in India

Executive Summary:

Robotic surgery is transforming the landscape of modern healthcare by enhancing precision, minimizing invasiveness, and improving patient recovery outcomes. Globally and in India, robotic-assisted procedures are gaining momentum due to their superior accuracy, reduced blood loss, shorter surgical times, and faster rehabilitation.

In India, the surgical robotics market, valued at approximately USD 851 million in 2023, is projected to grow to nearly USD 4 billion by 2031, making it one of the fastest-growing markets in the Asia-Pacific region. This growth is driven by rising healthcare infrastructure, skilled surgical talent, and indigenous innovation.

Key Challenges in Robotics Surgery Adoption in India

High capital & running costs: Buying a Robotic surgery system and paying annual service is very expensive, purchase prices run into crores of rupees and service/CMC + disposables add significantly to per-case cost. This makes robots hard to justify for smaller hospitals.

Uneven access / concentration in big cities: Robotic suites are concentrated in Tier-1 hospitals; patients in smaller towns often can't access them. This widens urban-rural inequity in advanced surgical care.

Training, credentialing and workforce gaps: There's no standard, widely-adopted national curriculum for robotic surgery training; many trainees lack structured exposure and credentialing pathways. That slows safe scale-up.

Cost-effectiveness & evidence in some specialties: For many procedures the clinical benefit vs conventional laparoscopy is still being defined; hospitals must justify expense by procedure volumes and outcomes.

Regulatory, procurement and supply-chain issues: Long procurement cycles, import rules, and dependency on foreign spare parts can delay installation and repairs. Emergence of domestic systems helps but supply chains remain maturing.

Tele-surgery, connectivity & data/privacy concerns: If remote proctoring or telesurgery expands, reliable low-latency networks and patient data protections become essential.

Solution: Evolution of Robotics Surgery in India & success stories

India's robotic surgery journey began in 2006, when AIIMS New Delhi installed the da Vinci Surgical System, marking the country's first robotic-assisted operation. Since then, adoption has accelerated across major hospitals and specialty centers, supported by both global and indigenous systems. Today, over 75 robotic systems are operational across the country.

Indian players in Robotics Surgery Ecosystem

- **MISSO** is an indigenously developed robotic surgical system by Meril Life Sciences, an Indian medical device company headquartered in Vapi, Gujarat. It is entirely made in India and designed to make robotic knee replacement surgeries more accessible and affordable, especially for smaller hospitals and Tier II/III cities. MISSO now extends to multi-arm configurations for gynecological, gallbladder, and other minimally invasive procedures.
- **SS Innovations International**, creator of the SSI Mantra system for cardiac and thoracic surgeries. SS Innovations is leading the way in making surgical robotics more accessible. It's robotic system is the first of its kind in India-cost-effective, versatile, and capable of transforming surgical practices. With applications across various specialties, including cardiac surgery, SS Innovations is committed to providing cutting-edge solutions to underserved populations that lack access to less invasive surgical technologies.
- **Makers Hive Innovations** - Focused on prosthetics and wearable robotic exoskeletons. The KalArm®-India's first fully functional Bionic Hand, with 18 pre-defined grips and bespoke aesthetics. Designed and developed in Hyderabad, India, KalArm® is a 3D-printed, EMG sensors embedded, lightweight, and affordable bionic hand, targeted at both National and Global markets of persons with Upper-limb Below-Elbow Amputations, that can give India an edge to become globally competitive in the Prosthetics Industry.

Conclusion

Indian enterprises are driving the country's rise as a hub for cost-effective, high-performance robotic platforms, strengthened by strategic collaborations with global technology leaders

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Chapter 3:

Defence Aerospace & Security Drones

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1 Background and strategic importance for India

Drones have emerged as one of the most transformative technologies shaping the future of national defence, aerospace innovation, and homeland security. For India facing complex geopolitical challenges and emerging asymmetric threats, drones are indispensable as force multipliers and strategic enablers. Drones have evolved from passive reconnaissance platforms to highly autonomous systems capable of intelligence gathering, logistics, and precision strikes. Globally, major defence powers are investing heavily in network-centric warfare and autonomous systems. India's ecosystem, through DRDO, HAL, BEL, ISRO, private players, startups etc, is advancing under Atmanirbhar Bharat and Drone Rules 2021 to strengthen its strategic UAV capabilities.

Key Strategic Domains

1. **National Security and Border Management**

- Persistent 24×7 surveillance in hostile and inaccessible terrains.
- Enhanced Intelligence, Surveillance, and Reconnaissance (ISR) capabilities.
- Support for counter-insurgency and anti-terror operations.

2. **Aerospace and Technological Leadership**

- Advancement in AI-based navigation, autonomous flight systems, and secure communication.
- Innovation in lightweight materials and propulsion technologies.
- Integration with space-based assets for extended operational reach.

3. **Force Multiplication and Tactical Superiority**

- Deployment of armed UAVs to reduce soldier risk.
- Swarm drone coordination for saturation attacks and area denial.
- Real-time battlefield intelligence and precision targeting.

4. **Strategic Intelligence and Multi-Domain Awareness**

- Real-time threat detection and situational analysis.
- Integration with cyber, space, and electronic warfare domains.
- Support for decision-making in high-stakes scenarios.

5. **Cybersecurity and Counter-Drone Measures**

- Indigenous development of detection, jamming, and electronic warfare (EW) systems.
- Protection against hostile drone incursions and cyber threats.
- Regulatory frameworks for safe and secure drone operations.

6. **Industrial and Economic Impact**

- Growth of drone startups and MSMEs under Atmanirbhar Bharat.
- Employment generation in manufacturing, R&D, and services.
- Export-led defence diplomacy and strategic partnerships.

In summary, Drones are redefining the future of warfare, surveillance, and aerospace innovation. India must continue to invest in indigenous capabilities, foster innovation, and build strategic partnerships to secure its national interests and emerge as a global leader in UAV technology.

2 Global trends

Global defence drone applications have evolved significantly, transforming from niche ISR (Intelligence, Surveillance & Reconnaissance) tools to multi-role combat systems. The market is projected to grow from USD 40.53 billion in 2024 to USD 87.63 billion by 2030, at a CAGR of 13.9%. Key application sectors include ISR, precision strike, logistics, electronic warfare, and swarm attacks. Technology enablers such as AI, autonomy, miniaturized sensors, and secure datalinks are driving innovation, while countermeasures like jamming, spoofing, and hard-kill systems are rapidly advancing in response to emerging threats.

Recent conflicts, such as the intense drone battles in Ukraine, the strategic actions in India's 'Operation Sindoor,' the asymmetric drone use in the Israel-Gaza conflict, and the disruption of global shipping by Houthi rebels, highlight a new reality: military success is increasingly dependent on a nation's ability to dominate this unmanned domain. These trends are forcing a wholesale re-evaluation of drone development and application towards security, surveillance and military doctrine. Utilization of drone technology has even been extended to internal threats and movement monitoring of personnel.

1. What's changed since earlier generations of military UAS.

- From niche ISR to multi-role combat systems. Drones now perform persistent surveillance, real-time targeting (sensor-to-shooter loops), precision strike (armed MALE and loitering munitions), logistics, EW/SIGINT, and swarm/mass-attack missions.
- Commoditization + local production. Components and modular designs allows scale up quickly — Ukraine and other conflicts show local industry and small firms producing huge numbers of FPV and loitering drones.
- Autonomy and AI are operationalizing swarms. Onboard autonomy, AI perception and cooperative behaviors are increasingly fielded to reduce operator load and enable coordinated attacks.

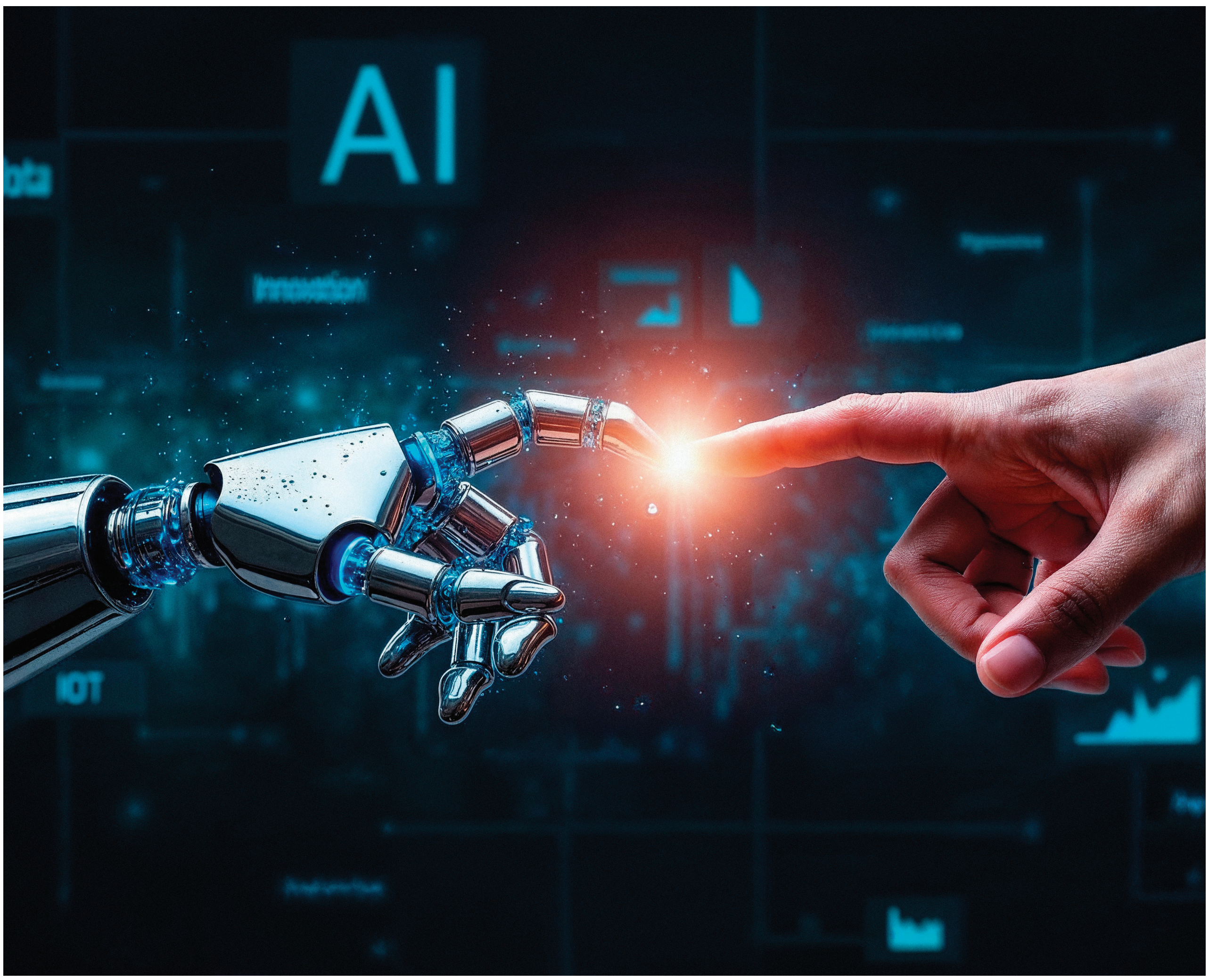
2. Core Defence Application Sectors.

- Intelligence, Surveillance & Reconnaissance: Persistent wide-area and tactical ISR (from squad level microdrones to MALE and HALE platforms) for target acquisition, BDA and command-level situational awareness.
- Strike and precision engagement: Armed MALE/UCAVs and loitering munitions (kamikaze drones) enable precision engagement with lower risk to pilots; loitering munitions fuse ISR and strike.
- Logistics and battlefield resupply: Tactical resupply (ammunition, medevac, ship-to-shore transfers) reduces convoy risk and improves responsiveness
- Electronic Warfare, SIGINT and communications relay: Drones act as mobile EW(Electronic Warfare) pods, jammers, GPS-spoofers or intercept signals(SIGINT) collectors or act as airborne communication relays to extend command-and-control networks and defeat adversary comms.
- Swarms and massed attacks: Large numbers of small UAS (cheaper and expendable) are used to saturate defences, create strategic effects or overwhelm sensors.
- Maritime and coastal roles: Maritime patrol, anti-ship targeting, and ship-resupply use UAS adapted to long endurance and naval mission profiles — raising novel anti-ship threats.

3. The Defence Drone Ecosystem

A robust ecosystem for defence drones comprises several critical layers beyond just the aircraft themselves.

- **Platform Manufacturers**: This includes companies that design and build drones of all sizes, from micro-drones to large MALE and HALE fixed-wing systems. A strategic priority for many nations is fostering indigenous platform development
- **Raw materials**: This includes availability of Rear earth materials and highly engineered lightweight defence grade materials (like carbon fiber) to push the performance boundaries
- **Subsystems and Components**: This is the foundational layer, including propulsion systems (engines, motors), flight controllers, navigation systems (GNSS/INS), and encrypted, anti-jamming data links
- **Payloads**: These are the mission-specific tools the drone carries, such as high-resolution ISR sensors (EO/IR, radar), laser based payload, strike payloads (loitering munitions, warheads), or electronic warfare (EW) modules
- **Software and Autonomy**: This includes the software for mission planning, autopilot functions, and real-time data analytics. It is also where emerging capabilities like swarm coordination, data relay and remote tactical decision and AI-enabled target recognition reside
- **Counter-Drone Systems (C-UAS)**: A critical defensive layer of the ecosystem, C-UAS involves detection systems (radar, RF), soft-kill measures (jamming), and hard-kill interceptors (missiles, lasers)



3 Indian scenario

India has seen rapid advances in defence, aerospace, and security drones by 2025, driven by indigenous innovation, major public-private collaborations, and intensified military focus on unmanned systems for border security and strategic dominance. India's top indigenous defence drones include the HAL CATS Warrior, Rudrastra Hybrid VTOL UAV, MBC2 Swarm Drones, Nagastra-1 loitering munition, ideaForge's Switch ISR and the Saksham Counter-UAS Grid. These platforms reflect the country's push for cutting-edge autonomous, combat, surveillance, and counter-drone capabilities through innovation and public-private collaboration.

HAL CATS Warrior UCAV

- The CATS Warrior is an autonomous, stealthy unmanned combat aerial vehicle (UCAV) developed by HAL, slated to become India's frontline drone for deep-strike, surveillance, jamming, and "loyal wingman" missions alongside fighter jets. It features AI-driven autonomy, can operate in swarms controlled by a mothership aircraft, and is optimized for both land and naval operations having subsonic/high-subsonic speed, stealth design, and carrier compatibility.

Rudrastra Hybrid VTOL UAV

- Developed by Solar Defence and Aerospace, Rudrastra is a tactical drone with a 170 km range, real-time reconnaissance, vertical take-off/landing, and high-speed engagement ability – suited for India's diverse terrain and hilly borders.

MBC2 Swarm Drones

- Created by NewSpace Research, these lightweight, AI-powered drones are engineered for autonomous infantry operations, rapidly seeking and neutralizing enemy combatants and functioning in swarms for area saturation and denial missions.

Nagastra-1 Loitering Munition

- Nagastra-1 is an indigenously developed loitering munition capable of precision strikes deep behind enemy lines, validated during real operational scenarios to disrupt hostile infrastructure and assets.

Indigenous Counter-Drone Platforms

- Developed by Indian Army in collaboration with Bharat Electronic Limited (BEL) The Saksham (Situational Awareness for Kinetic Soft and Hard Kill Assets Management) Counter-UAS Grid is a state-of-the-art anti-drone system for detection and neutralization of hostile UAVs, featuring real-time tracking, electronic countermeasures, and integration with air-defence networks—already operational with the Indian armed forces.

Advanced Training and Simulation

- IG Drones has delivered India's first indigenous defence drone simulator, which enables high-fidelity, realistic training for military and paramilitary forces in complex combat drone operations and tactics.

There are multiple drone systems in various stages of development and continuously growing. However, these home-grown systems provide India with a scalable, modular, and future-ready drone ecosystem across strike, surveillance, denial, and defence roles, sharply reducing dependence on imported technologies and enabling flexible use in various combat and security scenarios.

Indigenized Drones & Global Collaboration

Major domestic-private sector partnerships—such as TASL, Kalyani, Adani, ideaForge, New space etc. have boosted indigenization, showcased at Aero India 2025, including joint efforts in AI-driven UAVs and energy-efficient drone platforms. While India emphasizes "Make in India" technologies, strategic imports like Israeli Heron/Harop and the American MQ-9B Predator drones have filled crucial gaps, especially for ISR and precision strike missions.

MQ-9B Predator Drones (USA)

- India signed a major deal with the United States to acquire 31 MQ-9B drones—comprising 15 SeaGuardians for the Navy, 8 SkyGuardians for the Air Force, and 8 for the Army.
- These armed drones can perform long-range surveillance, precision strikes, and maritime patrol, with many units planned for local assembly in India as part of technology transfer agreements.
- India already operated two leased SeaGuardian variants for naval surveillance, which have proven strategic in monitoring the Indian Ocean.
- Israeli Heron Drones
- • India continues to expand its fleet of Israeli Heron drones, which are extensively used by all three services (Army, Navy, Air Force) and intelligence agencies.
- • The latest procurement round includes upgraded Heron Mark 2 drones featuring advanced satellite communication, longer endurance, and plans to arm them with Spike anti-tank guided missiles for combat missions.
- • Herons have seen effective use in recent border operations, such as Operation Sindoor, and are focused on surveillance of the Chinese and Pakistani borders.
- Other Foreign Systems
- • India has also deployed and upgraded earlier Israeli Searcher and Harop drones. Efforts remain ongoing to upgrade and weaponize its existing imported drone fleet as a complement to expanding indigenous programs.
- • These acquisitions are strengthening India's operational reach, precision strike capability, and maritime domain awareness, while facilitating future tech transfer, maintenance, and assembly within India.

National Security and Operational Use

• India's Border Security Force opened a "Drone Warfare School" in 2025 to professionally train commandos in drone operations for surveillance, patrol, bomb delivery, and anti-drone actions.

• The Indian armed forces used hundreds of indigenous and imported drones for both offensive and defensive operations during recent skirmishes with Pakistan in 2025; integrated systems intercepted more than 600 hostile drones in just one major operation.

• Indigenous systems played a key role in "Exercise Cold Start" and Operation Sindoor, where swarming, kamikaze, and counter-drone technologies were validated for real-world application.

Counter-Drone Technologies

- India unveiled a major vehicle-mounted counter-drone system co-developed by Adani Defence & Aerospace and DRDO, combining lasers, guns, jammers, advanced radars, and sensors on a single mobile platform for rapid response, showcased during Aero India 2025.
- These solutions are optimized for agility, real-time tracking, and neutralization up to a 10 km radius—critical for securing both tactical borders and strategic facilities.

Key Players and Industry Ecosystem

- Indian private sector leaders like ideaForge, Asteria Aerospace, Bharat forge and NewSpace Research are recognized for surveillance, mapping, and combat drones adopted by defence, police, and industry.
- Expansion is driven by government incentives, international collaboration, and a national push not just for military, but for dual-use civil-security drone technologies.

In supply chain, India's drone ecosystem is growing under Make in India, PLI for drones, and defence Acquisition Procedure (DAP). Indigenous programs like Rustom-II (TAPAS), SWiFT UCAV, and swarm drones are progressing, but critical components (avionics, sensors, propulsion, batteries, rear earth materials, defence grade fibers) still depend on imports (mainly from China, Israel, and the US). Private players (ideaForge, NewSpace etc) are scaling, but supply chain depth needs considerable strengthening for high-end defence-grade drones.

India's ambitious push in defence and security drones – through both native innovation and selective partnerships – has substantially improved its military readiness and tech self-reliance.

4 Gap areas

Drones are evolving field and multiple technologies are getting introduced. While work is happening in various areas, in our view following gaps needs to bridged sooner than later.

Integration & Interoperability

- **Gap**: Multiple vendors and technologies exist, but lack of a unified architecture makes it hard to integrate mission critical equipment.
- **Need**: Open digital backbones and modular systems that allow plug-and-play integration across platforms.

Small Drone (sUAS) Capability

- **Gap**: Militaries lag in small, expendable drones for reconnaissance and strike at squad/battalion level.
- **Need**: Rapid adoption of commercial off-the-shelf drones, FPV drones, and loitering munitions for tactical flexibility.

Indigenous Armed Drone Capability

- **Gap**: India still relies heavily on imports (e.g., Israeli Heron, Searcher) for ISR and lacks fully operational indigenous armed UAVs.
- **Need**: Accelerate projects like Rustom-II (TAPAS) and Ghatak UCAV for combat roles.

High-Altitude & Harsh Terrain Operations

- **Gap**: Current drones face endurance and performance issues in Ladakh, Arunachal Pradesh, and other high-altitude regions.
- **Need**: Design high-altitude capable UAVs with better propulsion and cold-weather resilience.

Swarm Drone Warfare

- **Gap**: India has demonstrated swarm drone tech (100-drone demo in 2023) but lacks large-scale operational deployment.
- **Need**: Scale up swarm-enabled offensive and defensive systems for battlefield dominance.

Electronic Warfare & Cybersecurity

- **Gap**: Vulnerability to GPS jamming, signal spoofing, and cyberattacks on drone control systems.
- **Need**: Hardened anti-jamming tech, encrypted communication, and resilient navigation systems (e.g., vision-based).

Logistics & Sustainment

- **Gap**: Supply chain stress for drone production and maintenance.
- **Need**: Scalable component supply chain, manufacturing, repair ecosystems, and cost-effective expendable drones

AI & Autonomy

- **Gap**: Limited deployment of AI-driven autonomy for real-time threat detection, swarm coordination, and predictive analytics.
- **Need**: AI-enabled autonomous navigation, target recognition, and decision support to reduce human workload.

Critical components development capability and production base

- **Gap**: Huge dependency of import for critical components like battery, motor, ECS, flight controller etc.
- **Need**: Scalable component development and manufacturing of above product in India

Regulatory & Training Gaps

- **Gap**: Lack of standardized protocols for drone deployment in defence and civil security; shortage of trained operators.
- **Need**: Unified regulatory framework, standardization of specifications, specialized training programs, and simulation-based skill development.

Unified procurement/ development system:

- **Gap**: Lack of a standardized procurement system from command to capital level resulting into varied system requirement
- **Need**: An unified procurement specification system at capital level to standardize system requirement

Apart from above, there is gap in manpower capabilities as well.

Skilled Drone Operators

- **Gap**: Shortage of certified operators for defence-grade UAVs, especially for beyond-visual-line-of-sight (BVLOS) and high-altitude missions. This limits operational readiness for border surveillance and combat scenarios.
- **Need**: Enhance DGCA-approved training programs and create standardized military UAV certifications.

Maintenance & Repair Technicians

- **Gap**: Lack of trained personnel for maintenance, repair, and overhaul (MRO) of advanced UAV systems. Thus increased downtime and reliance on OEMs
- **Need**: Create vocational programs focused on UAV hardware servicing. Create drone repair eco-system in partnership mode with OEMs

AI & Autonomy Specialists

- **Gap**: Shortage of engineers skilled in AI, computer vision, and autonomous navigation for drones. This slows development of autonomous ISR systems and swarm capabilities.
- **Need**: Improve integration of AI/ML in defence tech curricula; and create pull in these areas against migration to IT/finance sectors.

Data Analysts & Mission Planners

- **Gap**: Insufficient experts in geospatial analytics, real-time video intelligence, and mission planning. This underutilizes of ISR data for actionable intelligence.
- **Need**: Create specialized defence analytics programs in universities.

Cybersecurity & EW Specialists

- **Gap**: Few professionals trained in anti-jamming, secure communication, and cyber defence for UAV systems. Which leads high vulnerability to electronic warfare and hacking.
- **Need**: Tailor cybersecurity training for UAV systems.

Regulatory & Airspace Management Experts

- **Gap**: Limited expertise in Unmanned Traffic Management (UTM) and compliance with evolving drone laws. Which is leading to slows integration of drones into defence and civil airspace.
- **Need**: Create regulatory ecosystem with specialized courses

5 Recommendations

India's strategic aim of capability self-reliance (Atmanirbhar Bharat) and growing global demand for aerospace/ defence components create a time-window to convert procurement needs into a domestic capability base.

Typically drones are developed as platform approach and customized for application needs. The recommendations below are combination of (A) deployment — getting proven systems into field quickly and (B) local development — building a sustained domestic design/manufacturing base. They are tailored across three time horizons for defence, aerospace and security drones. Based on above gap area, a high level three steps in terms of time is recommended.

1. Foundation & Rapid Capability Building (0–12 months)

Focus: Quick wins, operational readiness, and ecosystem setup.

- **Integration & Interoperability**
  - Develop open architecture standards for defence drones.
  - Launch pilot programs for plug-and-play integration with existing C2 systems.
- **Small Drone Capability**
  - Procure COTS FPV drones for squad-level ISR and strike.
  - Begin indigenous FPV drone production (e.g. IG Drones FPV Striker).
- **Regulatory & Training**
  - One-Stop Clearance Cell: Single-window approvals for offsets, FDI, export permits, certifications. Create DGCA + MoD unified protocols for defence UAV operations. Streamline approvals with conditional clearances for low-risk areas.
  - Create CoE for Shared tooling & test-labs: Fund common-use jigs, CNC centres, certification labs (having both performance and operation requirement) accessible to entire ecosystem
  - Expand simulation-based training centers for operators and mission planners.
- **Manpower Development**
  - Skill acceleration programmes: Launch national skilling initiatives with certification for drone operators, avionics, aerostructure assembly tied to employer hiring commitments.
  - Launch AI/ML-focused defence tech courses in IITs and defence academies.
  - Start vocational programs for MRO technicians.

2. Indigenous Development & Scaling (0–24 months)

Focus: Build indigenous capability and strengthen resilience.

- **Strategic Indigenous Platforms**:
  - Transition to fully Indian-designed next-gen systems.
  - Export Push: Use government-to-government channels and defence diplomacy to promote Indian platforms globally.

- **High-Altitude Operations**
  - Develop prototype UAVs optimized for Ladakh/Arunachal conditions.
  - Integrate cold-weather propulsion systems and battery tech.
- **Swarm Drone Warfare**
  - Scale swarm drone systems for offensive and defensive roles.
  - Conduct brigade-level swarm exercises.
- **Critical Components**
  - Ensure supply of critical raw materials as rear earth material, high strength carbon fiber materials, material processing units
  - Target Tier-1 supplier status for select components to Set up domestic production lines for motors, batteries, flight controllers, ESC etc. through Focused Make-I/Make-II funding windows. Provide grants/seed funding for prototyping projects for high-impact subsystems (Battery, motors, camera, radars, etc) to reduce time from concept to production
  - Incentivize private sector partnerships for component R&D. Offer vouchers/subsidies to cover defence-standard certification costs (EMI/EMC, MIL-STD, RTCA DO-178/DO-254 equivalents for avionics) so smaller firms can qualify

3. Advanced Autonomy & Strategic Readiness (0–36 months)

Focus: AI-driven autonomy, electronic warfare resilience, and full-scale deployment.

- **Technological push**
  - An aerospace grade indigenized technological development for critical components, e.g. engines, high density power sources without REM etc.
- **AI & Autonomy**
  - Deploy AI-enabled autonomous navigation and target recognition.
  - Implement predictive analytics for mission planning and maintenance.
- **Electronic Warfare & Cybersecurity**
  - Field anti-jamming and encrypted communication systems.
  - Integrate vision-based navigation for GPS-denied environments.
- **Logistics & Sustainment**
- Establish national drone MRO hubs for defence and civil sectors.
- Scale expendable drone production for tactical flexibility.
- **Regulatory & Airspace Management**
  - Implement Unmanned Traffic Management (UTM) for defence and civil integration.
  - Create specialized courses for regulatory experts.

Cross-Cutting Initiatives (All Phases)

- Industry-Academia Collaboration: CoEs for AI, autonomy, and EW.
- Funding & Incentives: PLI for drone manufacturing, drone components and incentivize R&D activities.
- Skill Development: Continuous upskilling for operators, technicians, and analysts.

These proposals could be built on CII's ongoing industry engagement and national localization efforts.

Guiding principles (applies across all categories)

- Dual-track approach: Fast-track the deployment of mature, certified systems (to meet near-term operational gaps) while simultaneously investing in domestic R&D and localization for long-term sovereign capability. For example, CII's "Defence Industrial Sector Vision 2047" localization that "What we now need is acceleration—of funding, partnerships, and trust" to make India a global leader in defence manufacturing.
- Platform-agnostic localization: Encourage open architecture, modular systems (swappable subsystems, open communication protocol etc) so that locally-produced subsystems can be inserted and upgraded easily.
- SME & supply-chain depth: Prioritise enterprise and supplier-development (tier-2/tier-3 firms) with access to finance, test-facilities, workforce skilling, to absorb global OEM work and move up the value chain.

Conclusion & call to action

Defence, aerospace and security drone is a very growing field and progress is happening at very rapid pace. It is a very important area for India in current scenarios.

A detailed study of global trend and India trend has been listed along with gap areas and need. A brief recommendation has also been made.

By adopting a two-track policy of rapid deployments and sustained local development, India can both close its near-term capability gaps and build a credible long-term industrial base. The Government should engage immediately with industry (via CII and sectoral councils) to compile a short-list of "Operational Urgency" gaps, establish the clearance cell, and commit seed-funding for CoEs. Industry stands ready: CII recommends forming a steering group (government + industry + academia) with quarterly reviews on progress for each time-horizon (1–3, 3–5, 5–10 years). With time-bound action, India can convert its strategic demand into a durable manufacturing and export capability.

Abbreviations

ISR	:	Intelligence, Surveillance & Reconnaissance
MALE	:	Medium-Altitude Long-Endurance
HALE	:	High-Altitude Long-Endurance
UCAV	:	Unmanned Combat Aerial Vehicle
UAV	:	Unmanned Aerial Vehicles
EW	:	Electronic Warfare
SIGINT	:	Signals Intelligence
VTOL	:	Vertical Take-Off and Landing
EO	:	Electro-Optical
BDA	:	Battle Damage Assessment
BVLOS	:	Beyond Visual Line of Sight
UTM	:	Unmanned Traffic Management

Chapter 4:

Non-Defence DronesApplications

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1 Background and strategic importance for India

Introduction

India's non-defense Unmanned Aerial Systems (UAS) sector is transitioning from a nascent, highly regulated industry to a major global growth engine. Driven by the liberalizing Drone Rules, 2021 and the Production Linked Incentive (PLI) Scheme, the market is projected to reach approximately $2.5 - $4.8 billion by 2030, exhibiting a CAGR of over 20%. The strategic importance of this sector extends beyond economic growth; it is a critical enabler for national security (through dual-use technology), good governance (SVAMITVA, Drone Didi), and technological sovereignty ("Global Drone Hub by 2030"). The core challenge remains reducing over 80% import dependency on critical components like advanced sensors and flight controllers, which necessitates a coordinated national push in R&D and indigenous manufacturing. In the recent years Unmanned Aerial Vehicle (UAV) or drones are being adopted in defense (military) and non-defense areas, and India is no exception to it. Civilian drones have found their application in several areas, which include (but not limited to) agriculture, land-surveying, monitoring infrastructural projects, disaster management, wildlife management, hobby & professional photography and so on. UAV offers economic, technological, demographic and social significance to any country, and thus India plans to become Drone-Hub by 2030.

This document is organized into five chapters:

- Background and strategic importance for India
- Global trends
- Indian scenario
- Gap areas
- Recommendations for deployment and local development (short, medium, and long term).

1. Background and Strategic Imperative for India

1.1. Introduction to Non-Defense Drones

Non-Defense Drones, or Commercial/Civilian Unmanned Aerial Systems (UAS), are defined as aerial vehicles used for purposes other than military operations. They range from small rotary-wing platforms used for photography and videography to large, fixed-wing systems for long-range mapping and cargo delivery. The transition of this technology from a military tool to a commercial asset mark one of the most significant shifts in modern aerial technology.

The Indian government formally adopted a liberalized stance with the notification of the Drone Rules, 2021, viewing the technology not as a threat to be managed, but as a catalyst for national development and a critical component of the digital economy.

1.2. The Global Context of the Drone Revolution

The global commercial drone market is driven by three primary forces:

- **Sensor Miniaturization**: High-resolution cameras, LiDAR, and thermal sensors are now compact and affordable.
- **Advanced Computing**: AI/ML integration enables autonomous navigation, real-time data processing, and object identification.

- **Regulatory Evolution**: Countries are moving toward policies that safely allow complex operations like Beyond Visual Line of Sight (BVLOS).

The strategic goal for India is to participate in and capture a significant share of this global market, which is currently dominated by East Asian manufacturers.

1.3. Strategic Importance: The Indian Imperative

The deployment and indigenous development of non-defense drones are critical for India's national strategy across four dimensions: Economic Growth, Governance, Technological Sovereignty, and National Security.

1.3.1. Economic Multiplier and Market Potential

The drone sector is a direct contributor to the national goal of a $5 trillion economy. It acts as an economic multiplier by increasing efficiency in traditional sectors.

- **Market Size & Growth**: The Indian drone market was valued at approximately $1.2 to $1.7 billion in 2024. Projections indicate a strong CAGR of over 20% between 2025 and 2033, aiming for a market size of $2.5 - $4.8 billion by 2030.
- **Job Creation**: The industry is expected to create thousands of jobs, particularly in manufacturing, software development, data analytics, and the crucial field of Remote Pilot Training Organizations (RPTOs).
- **Industry Efficiency**: Drones drastically reduce the cost and time of inspections in sectors like power transmission, mining, and oil & gas, directly boosting corporate profitability and infrastructure rollout speed.

1.3.2. Good Governance and Social Impact

The Indian government is a major anchor customer for drone services, leveraging them for massive, public-facing projects that enhance governance, transparency, and social welfare:

Government Scheme/Use Case	Strategic Objective	Impact
SVAMITVA Scheme	Creation of accurate land records and property rights across rural India.	Surveyed over 310,000 villages, reducing property disputes and enabling digital land management.
Namo Drone Didi Initiative	Women's empowerment and rural entrepreneurship.	Training women Self-Help Groups (SHGs) to operate drones for agricultural services (Drone-as-a-Service model).
Digital Sky Platform	Simplified flight permissions and airspace management.	Creating a user-friendly, digital interface for all drone operations, promoting "No Permission, No Take-off" (NPNT) compliance.
Healthcare Logistics	Last-mile delivery of critical supplies.	Successful BVLOS trials for delivery of vaccines and blood units to remote, inaccessible regions (e.g., in Telangana and the North East).

1.3.3. Technological Sovereignty (Atmanirbhar Bharat)

Achieving self-reliance in the drone ecosystem is a core strategic goal, articulated in the vision to make India a "Global Drone Hub by 2030."

- Policy Intervention: The Drone Rules, 2021 (liberalizing operations) and the PLI Scheme (incentivizing manufacturing) work in tandem to encourage local design and manufacturing.
- The Component Challenge: Despite the government push, India remains heavily reliant on imported components, particularly advanced sensors (LiDAR, Thermal), flight controllers, and high-end propulsion systems, with import dependencies estimated at over 80%. The strategic imperative is to bridge this gap to ensure resilience against global supply chain disruptions and geopolitical risks.
- Dual-Use Technology: Non-defence drone expertise directly feeds into military capability. Advancements in civilian AI-powered autonomous navigation, swarm technology, and battery endurance can be quickly adapted for defence and internal security applications, strengthening the nation's overall security architecture.

1.4. Policy Foundation: The Drone Rules, 2021

The Drone Rules, 2021, and subsequent amendments and policy decisions were a paradigm shift from the highly restrictive 2018 regulations. Key features include:

- Trust-Based Regulation: The framework shifted from a permissions-heavy system to one based on self-certification and trust.
- Airspace Liberalization: The creation of Green Zones (requiring no permission for flights up to 400 feet) greatly expanded the available airspace for civil operations.
- Reduced Bureaucracy: The number of mandatory forms and fees was drastically reduced, and security clearance for pilot licenses was replaced by basic checks (Aadhaar/Passport).
- Reduced GST: The Goods and Services Tax (GST) on drones has been rationalized to a uniform 5%, further making the technology more affordable for end-users, especially in the agriculture sector.

The confluence of market demand and a favorable policy environment have set the stage for an exponential acceleration in the adoption and indigenous manufacturing of non-defense drones in India.

Global Trends and Regulatory Models

The rapid evolution of India's drone policy must be benchmarked against and informed by the major global trends and established regulatory frameworks. The international landscape is characterized by accelerating technological advancements, increasing manufacturing consolidation in Asia, and divergent regulatory philosophies in the West.

2.1. Global Market Dynamics and Technological Advancements

The worldwide commercial drone sector provides a blueprint for India's domestic aspirations.

2.1.1. Market Growth and Segmentation

The global commercial drone market was valued at approximately $13.86 billion in 2024 and is projected to reach $65.25 billion by 2032, exhibiting a robust Compound Annual Growth Rate (CAGR) of 20.8%. This growth is driven primarily by:

- Inspection and Surveillance: Utilities, energy (oil, gas, wind), and construction dominate application spending due to the high return on investment (ROI) from reduced inspection time and improved safety.

- Logistics and Delivery: The 25–150 kg segment is forecast to see a high CAGR, driven by the development of Electric-Vertical Takeoff and Landing (eVTOL) aircraft for cargo and, eventually, passenger transport (Urban Air Mobility).
- Precision Agriculture: Drones for spraying, seeding, and crop health monitoring are becoming standard tools in advanced farming economies.

2.1.2. Convergence of Technologies

The future of non-defense drones is intrinsically linked to adjacent high-technology domains:

- Artificial Intelligence (AI) and Autonomy: AI-powered flight control systems enable true autonomy—drones that can sense, process, and navigate complex environments without constant human intervention. This is essential for scaling BVLOS operations.
- Advanced Payloads: Miniaturization of highly sophisticated sensors, particularly LiDAR (Light Detection and Ranging) and multi-spectral sensors, enhances the quality and detail of data collected, making drones invaluable for high-precision mapping and 3D modeling.
- 5G and Edge Computing: The rollout of 5G networks provides the high-speed, low-latency connectivity required for real-time control and data transfer for massive drone fleets, while edge computing allows data processing to occur onboard or close to the drone, rather than relying on distant cloud servers.

2.2. The Regulatory Philosophies of Leading Aviation Bodies

India's regulatory framework (Drone Rules, 2021) attempts to blend the flexibility of European systems with the standardization found in North America. Understanding the dominant global models is vital for achieving interoperability and attracting foreign investment.

2.2.1. European Union Aviation Safety Agency (EASA) Model: Risk-Based Flexibility

The EASA framework is characterized by a risk-based philosophy, classifying operations into three categories:

- Open Category (Low Risk): Basic operations (VLOS, low altitude, light drones) with minimal bureaucracy, often requiring only an online exam.
- Specific Category (Moderate Risk): Covers advanced operations like BVLOS, night flights, or operations over restricted areas. These require a Specific Operations Risk Assessment (SORA) submitted for approval. This path provides clear guidance for innovators to safely push operational boundaries.
- Certified Category (High Risk): For operations involving large aircraft or carrying passengers (UAM), which are subject to certification requirements similar to manned aviation.

Key takeaway for India: The EASA model offers a blueprint for scaling BVLOS operations through methodical risk assessment, which India is working to adopt.

2.2.2. U.S. Federal Aviation Administration (FAA) Model: Standardized and Conservative

The U.S. system is built around the FAA Part 107 rule, emphasizing a standardized, pilot-centric approach:

- Standardization: A single Remote Pilot Certificate allows commercial operation of any drone under 55 lbs (approx. 25 kg).

- Waiver Dependence: Advanced operations (BVLOS, flights over people) are fundamentally restricted unless the operator obtains a specific, case-by-case Waiver from the FAA, making the pathway to large-scale, automated operations slower and less predictable.

Key takeaway for India: The FAA model highlights the importance of standardized pilot training and the complexity of managing safety in a high-density environment.

2.3. Manufacturing Dominance and Geopolitical Dependencies

China's overwhelming dominance in the global drone manufacturing space is a critical geopolitical trend impacting India's strategy:

- Market Concentration: Shenzhen-based DJI holds an estimated 70% of the global commercial and consumer drone market. This dominance stems from an integrated manufacturing ecosystem, high-volume production, and competitive pricing.
- Supply Chain Vulnerability: Western nations, including India, remain heavily reliant on China for low-cost, high-volume drone components, including motors, flight controllers, and specialized circuit boards.
- Security Risk: The reliance on foreign-manufactured hardware and software raises significant national security concerns, especially regarding potential data exfiltration and embedded vulnerabilities.

India's PLI Scheme and focus on Atmanirbhar Bharat (Self-Reliant India) are a direct strategic response to mitigate this manufacturing dominance and secure the national supply chain, classifying the drone sector as a matter of technological sovereignty.

2.4. Future Airspace Integration: UTM and UAM

The ultimate global goal is the safe and seamless integration of millions of drones into the national airspace, which requires two critical systems:

2.4.1. Unmanned Traffic Management (UTM)

UTM is a fully automated, primarily digital and software-based air traffic management ecosystem designed for Very Low Level (VLL) airspace (below 400 feet).

- Purpose: The UTM system, often called U-space in Europe, is responsible for flight authorization, real-time tracking, congestion management, and collision avoidance (de-confliction) for unmanned aircraft.
- Global Challenge: Fragmentation of regulatory approaches, economic uncertainty regarding public vs. private funding, and ensuring interoperability between different UTM service providers (USSPs) are the primary global hurdles.
- India's Plan: India's National UTM Policy Framework (2021) envisions a centralized Digital Sky platform working with private USSPs to manage VLL traffic, mirroring global best practices but with an accelerated timeline.

2.4.2. Urban Air Mobility (UAM)

UAM, the highest-risk application of drone technology, involves the use of electric Vertical Take-Off and Landing (eVTOL) aircraft for intra-city passenger and heavy cargo transport.

- Integration: UAM vehicles share key technological advancements with smaller drones (electric propulsion, autonomous flight software) and will operate within the future UTM/ATM integrated airspace.

- Status: While currently in the advanced development and certification phase globally, many countries anticipate the first commercial passenger routes to begin by 2025-2030. India is strategically positioning itself to be a fast follower in this space due to its densely populated urban centers.

Detailed Sectoral Applications in the Indian Scenario

The practical deployment of non-defense drones in India is driven by the country's unique challenges—vast geography, fragmented land holdings, rapid infrastructure buildout, and last-mile connectivity issues. This chapter explores the primary sectors where drones are currently delivering maximum economic and social impact.

3.1. Precision Agriculture: The Kisan Drone Revolution

Agriculture, which employs over half of India's workforce, is the largest potential growth area for small, affordable drones. The application of drones in agriculture, often termed "Kisan Drones," is central to the government's push for precision farming.

Application	Strategic Value for India
Crop Spraying	Largest Use Case. Drones apply pesticides, fungicides, and fertilizers with high precision, saving water (up to 90%) and chemicals (up to 30%), and mitigating worker exposure to hazardous substances.
Crop Health Monitoring	Using multi-spectral and thermal sensors to assess the Normalized Difference Vegetation Index (NDVI), identify areas of stress, pest infestation, or nutrient deficiency long before they are visible to the human eye.
Soil and Field Analysis	Detailed mapping before planting helps determine optimal soil moisture, nutrient levels, and topographical features for precise seeding and water management.
Insurance Claim Assessment	Rapid, accurate post-disaster assessment of crop damage for faster processing of Pradhan Mantri Fasal Bima Yojana (PMFBY) claims.

3.1.2. Government Support and Market Size

The market for agriculture drones in India was valued at approximately $243.60 million in 2024 and is projected to reach over $2.1 billion by 2033, reflecting a CAGR of over 24%. This rapid growth is directly fueled by state intervention:

- Subsidies: The government provides substantial financial assistance, including a 100% subsidy (up to a ceiling) to government-run agricultural institutions and a 40-50% subsidy for individual farmers, farmer producer organizations (FPOs), and Custom Hiring Centers (CHCs) for drone procurement.
- "NaMo Drone Didi": This scheme specifically targets rural women's empowerment by training them to become drone pilots and entrepreneurs, ensuring the Drone-as-a-Service (DaaS) model reaches the last mile.

3.2. Infrastructure and Mapping: Safety and Efficiency

In construction, energy, and mining, drones eliminate the need for dangerous manual inspection, reduce project overruns, and provide irrefutable data for audit and planning.

3.2.1. Geospatial Mapping (SVAMITVA)

The SVAMITVA (Survey of Villages and Mapping with Improvised Technology in Village Areas) scheme is the world's largest drone mapping project.

- Objective: To provide records of rights to village household owners, enabling them to use their property as a financial asset (e.g., for bank loans).
- Scale: The project involves the mapping of millions of land parcels across rural India, demonstrating the capability of drones to achieve high-resolution cadastral surveying at unprecedented speed.

3.2.2. Inspection and Monitoring

- Energy and Power: Drones use thermal imaging to inspect thousands of kilometers of transmission lines, solar farms, and wind turbines for hot spots, physical damage, and defects, minimizing downtime and maintenance costs.
- Construction and Highways: Bodies like the National Highways Authority of India (NHAI) mandate regular drone surveys for progress monitoring, quality assurance, and land acquisition for highway projects. This enhances transparency and accountability.
- Mining: The Indian Bureau of Mines (IBM) has mandated drone surveys for all large mine lease areas (over 50 hectares or 1 million tonnes of annual excavation). The rapid deployment of drones in mining—mandated by bodies such as the Indian Bureau of Mines for tasks including slope stability analysis, stockpile measurement, and environmental monitoring—has outpaced the development of a skilled workforce capable of interpreting complex geospatial datasets. This skill gap poses a significant challenge to the effective and safe adoption of drone technology in the sector

  Applications include:

  - Stockpile Volume Measurement: Accurate and rapid calculation of excavated material.
  - Slope Stability and Safety: High-resolution 3D mapping identifies unstable mine walls and hazardous areas, improving worker safety.
  - Environmental Monitoring: Tracking compliance, reclamation of progress, and dust suppression.

3.3. Logistics and Healthcare: Last-Mile Connectivity

Drones represent a leapfrog technology for logistics, bypassing India's congested roads and challenging terrain, particularly in the mountainous regions of the Himalayas and the remote Northeast.

3.3.1. Beyond Visual Line of Sight (BVLOS) Projects

The path to scaling commercial logistics hinges on BVLOS operations. Several key projects have established the technical feasibility:

- "Medicine from the Sky" (Telangana & Arunachal Pradesh): This landmark initiative, supported by the World Economic Forum and NITI Aayog, successfully delivered vaccines, blood bags, and critical medicines. In the Himalayan region, delivery times were slashed from 8 hours (by road) to just 22 minutes (by drone), proving the life-saving potential of the technology.
- Commercial Trials: Major logistics and e-commerce players (e.g., Blue Dart, Flipkart, Swiggy) have conducted pilots for commercial and grocery delivery, laying out the foundation for dedicated drone delivery corridors soon.

- Targeted Payloads: Drones are ideally suited for high-value, time-critical, or temperature-sensitive payloads (e.g., vaccines, anti-venom, diagnostic samples) that are typically small (2-5 kg payload capacity) but require rapid transport.

3.4. Disaster Management and Emergency Response

Drones are becoming essential tools for the National Disaster Response Force (NDRF) due to their rapid deployment capability in inaccessible, post-disaster environments.

- Search and Rescue (SAR): Drones equipped with high-powered zoom cameras and thermal sensors locate missing persons in collapsed buildings, forests, or areas affected by floods and landslides.
- Damage Assessment: They provide quick, high-resolution imagery to assess the scope of damage, aiding planning for relief efforts and resource allocation.
- Public Safety: Local police forces are increasingly using drones for crowd control, surveillance, and monitoring high-risk public events.

Key Gap Areas and Constraints

While India's "Drone Rules 2021" and associated policies like the Production-Linked Incentive (PLI) scheme have created a highly encouraging environment for the drone ecosystem, several technological, regulatory, and economic constraints must be addressed for the country to achieve its vision of becoming a global drone hub by 2030.

The key gap areas are detailed below:

A. Technological and Manufacturing Dependence

1. Component Import Dependency (The 'Atmanirbhar' Gap) The fundamental constraint on India's goal of self-reliance (Atmanirbhar Bharat) in the drone sector is the heavy dependence on imported components. Over 80% of core parts—including sensors (e.g., LiDAR), autopilot systems, flight controllers, and high-performance batteries—are still sourced from abroad, predominantly from China. This reliance creates supply chain vulnerabilities, increases input costs, and limits indigenous intellectual property development.
2. High R&D Costs and Funding Gaps Developing advanced drone technologies (such as swarm technology, high-altitude UAVs, or high-efficiency components) is capital-intensive. India's deep-tech sector often struggles with securing adequate venture capital, which tends to favor consumer technologies. This funding gap, combined with high research and development (R&D) costs, impedes local innovation and the necessary technological leapfrogging required to compete globally.

B. Regulatory and Policy Implementation Gaps

1. The BVLOS Bottleneck The most critical operational regulatory gap is the absence of a fully streamlined and operational framework for routine, commercial Beyond Visual Line of Sight (BVLOS) flights. BVLOS is essential to unlock large-scale applications like drone-based logistics, last-mile delivery, and widespread infrastructure surveillance. While trials have been conducted, the lack of a clear, standardized roadmap, definitive operational rules, and defined safety and liability standards prevents commercial entities from planning and deploying these high-impact services nationwide.
2. Certification and Digital Sky Slowdown Despite the liberalized 2021 rules, which reduced forms and fees, on-the-ground implementation remains slow. Startups and manufacturers frequently report significant delays in obtaining essential approvals, such as type certification and airspace clearances, often resulting in months of waiting before a product can enter the market. The Digital Sky platform, intended to be a simplified single-window system for permissions, is

reported to be underutilized and occasionally poses challenges for navigating necessary compliance and flight authorizations.

3. Airspace Management and Counter-Drone Ambiguity The exponential growth in drone usage necessitates the rapid development of robust Unmanned Traffic Management (UTM) systems. Integrating a large volume of low-altitude drone traffic safely alongside conventional manned aviation remains a complex technical and regulatory challenge. Furthermore, the regulatory landscape for counter-drone (C-UAS) systems lacks clarity, particularly regarding the legal framework for the neutralization of rogue drones by civilian or law enforcement agencies, which slows the adoption of necessary security technologies.

C. Economic and Operational Hurdles

1. High Capital Cost and Affordability For end-users, especially in the agriculture sector—a major area of application—the initial capital investment is a significant barrier. A typical agricultural spray drone can cost between ₹5 lakh to ₹10 lakh. Although subsidies are available, this high cost limits adoption among small and marginal farmers, who often resort to a "Drone-as-a-Service" model rather than outright purchase.
2. Technical Constraints Operational performance is constrained by several technical limitations:
   - Battery Life and Flight Time: Limited battery capacity restricts the endurance and range of drones, particularly for heavy-payload or long-distance applications, necessitating frequent battery swaps and limiting coverage area per flight.
   - Payload Capacity: Enhancing a drone's payload capacity without sacrificing flight performance or battery efficiency remains a key technological challenge for logistics and high-volume spraying tasks.
   - Weather Dependency: Drones remain highly sensitive to adverse weather conditions, such as strong winds, heavy rain, or extreme temperatures, which can disrupt scheduled operations and affect stability.
3. Infrastructure Deficiencies The widespread commercial use of drones requires extensive ground infrastructure that is currently underdeveloped:
   - Charging and Maintenance Stations: A sparse network of strategically located charging, battery-swapping, and maintenance/repair stations (MRO) limits operational reach and increases downtime, particularly in remote areas.
   - Connectivity: Reliable, high-bandwidth network connectivity (including 5G penetration) is crucial for real-time control, monitoring, and fast data transmission, and is still limited in many rural and semi-urban operational areas.

D. Human Capital and Security Challenges

1. Severe Skill Gap A critical shortage exists across the value chain, including certified drone pilots, specialized maintenance personnel, and advanced AI/data analysts capable of processing the vast datasets collected by drones. The current educational infrastructure offers limited specialized, high-quality drone training courses, making the cost of skilling high and hindering the development of the necessary workforce for future demand.
2. Data Privacy and Cybersecurity Vulnerabilities Drones are powerful data collection platforms, raising substantial data security and privacy concerns, especially when operating in surveillance, mapping, or logistics roles.
   - Cybersecurity Risk: The common use of commercial off-the-shelf (COTS) components and foreign software makes drones vulnerable to cyberattacks, including hacking, data leakage, and GPS spoofing. India needs a stronger indigenous software base to mitigate these risks.

➢ Privacy Regulation: The legal framework lacks comprehensive, specific data protection laws that clearly address the infringement of privacy caused by drone-based surveillance, creating a potential gap in public trust and regulatory oversight.

Recommendations for Deployment and Local Development

To achieve the strategic goal of making India a "Global Drone Hub by 2030," a coordinated and time-bound strategy is required to address the gaps in both operational scaling (Deployment) and indigenous manufacturing (Local Development).

Recommendations are structured into short-term (1–3 years), medium-term (3–5 years), and long-term (5–10 years) horizons.

Part A: Deployment (Scaling Operations and Use)

This category focuses on policy and infrastructure changes necessary to maximize the use of drones across various sectors.

Timeframe	Key Recommendation Areas	Specific Actions
Short Term (1–3 Years)	1. BVLOS Regulatory Rollout	Finalize and notify the BVLOS operational framework with clear safety, insurance, and liability standards, transitioning from experimental trials to commercial deployment in low-risk, designated corridors (e.g., medical, logistics).
	2. Standardized Skill Development	• Launch a national program to achieve the target of 100,000 certified drone pilots by enhancing the capacity and standardization of Remote Pilot Training Organizations (RPTOs), including subsidized training for marginalized groups (e.g., Drone Didi scheme). • Offer tax rebates, grants, and subsidies to organizations and individuals who complete certified drone data analytics and MRO programmes. • Expand initiatives like the "Drone Didi" scheme to include technical data analysis and MRO skills, ensuring broader participation and last-mile reach in rural and remote areas.
	3. Digital Sky Optimization	Streamline the Digital Sky Platform to ensure automated, near-instantaneous flight permissions (NPNT) for operations in Green and designated Yellow Zones, reducing bureaucratic friction.
	4. Cybersecurity Risks	Develop and Enforce Drone-Specific Cybersecurity Standards • Mandate robust encryption for all drone communications and data storage. • Require secure authentication and access controls for drone operation and data management. • Establish regular software and firmware update protocols, with secure update mechanisms. • Introduce incident reporting requirements for cybersecurity breaches involving drones.

Timeframe	Key Recommendation Areas	Specific Actions
Medium Term (3–5 Years)	1. Unmanned Traffic Management (UTM) Implementation	Implement a phased rollout of a National UTM System, focusing first on major urban and industrial corridors (Smart Cities, logistics hubs) to safely manage high-density drone traffic and enable real-time tracking and collision avoidance.
	2. Drone Infrastructure Network	Establish a pilot network of dedicated Drone Ports and Charging/Swapping Stations (Drone Hubs) along key logistics corridors to support long-range BVLOS cargo and delivery services.
	3. Public Acceptance and Data Security	Conduct large-scale public awareness campaigns and ensure the rapid notification and enforcement of the Digital Personal Data Protection Act (DPDP Act) principles regarding drone data collection to build public trust.
Long Term (5–10 Years)	1. Full Airspace Integration	Achieve full, seamless integration of UTM with the conventional Air Traffic Management (ATM) system, allowing medium and heavy lift drones to operate reliably in shared airspace.
	2. Urban Air Mobility (UAM) Readiness	Develop the regulatory and technical sandbox environments necessary for the testing and deployment of Urban Air Mobility (UAM) vehicles (drone taxis and heavy cargo), positioning India to be a fast-follower in this futuristic sector.
	3. Specialized Application Mandates	Mandate the use of certified drones for specific high-risk or high-value activities in government sectors (e.g., 100% of all major highway inspections, railway track safety checks, and land boundary mapping).

Part B: Local Development (Boosting Manufacturing and R&D)

This category focuses on policies and incentives necessary to address import dependency and foster indigenous technology.

Timeframe	Key Recommendation Areas	Specific Actions
Short Term (1–3 Years)	1. Component-Focused PLI Expansion	Expand the scope and budget of the PLI Scheme to explicitly target the domestic manufacturing of high-value, high-import components (e.g., flight controllers, advanced sensors, and specialized drone batteries), rather than just final drone assembly.
	2. Testing and Certification Ecosystem	Establish a network of accredited, world-class testing and certification labs (Modeled after QCI) for drone hardware and software to ensure quality, security, and global export compatibility.

Timeframe	Key Recommendation Areas	Specific Actions
	3. Design-Linked Incentive (DLI) for Software	Introduce a specific DLI scheme to incentivize Indian companies and startups to develop and commercialize indigenous, secure autopilot software, AI algorithms, and mission planning systems, reducing reliance on foreign code.
Medium Term (3–5 Years)	1. Dedicated R&D Hubs	Establish regional Drone Technology Clusters (Drone Parks) in partnership with academia (IITs, IISc) and private industry, offering shared resources, seed funding, and a regulatory sandbox for quick prototyping and testing.
	2. Strategic Component Indigenization	Set aggressive, phased indigenization targets (e.g., 75% local value addition) for government drone procurement (Defence, Agriculture, SVAMITVA), making it mandatory for companies to prioritize local component sourcing.
	3. Drone MRO Ecosystem Development	Provide tax holidays and incentives to set up Maintenance, Repair, and Overhaul (MRO) facilities for high-end drones and their components, preventing costly and time-consuming foreign repairs.
Long Term (5–10 Years)	1. Core Technology Development	Launch a national mission to fund fundamental research into next-generation drone technologies such as high-density hydrogen fuel cells for extended endurance, and advanced micro-propulsion systems.
	2. Global Standard Setting	Actively engage in international aviation bodies (e.g., ICAO) to influence the development of global standards and protocols for UAS, positioning Indian certification and technology as a global benchmark.
	3. Indigenous Counter-UAS (C-UAS) Integration	Mandate the seamless integration of indigenously developed C-UAS detection and neutralization technology into all critical infrastructure security plans and the National UTM system.

Part C: Integrated Recommendations for Scaling Non-Defence Drone Adoption

1. Skill Development and Workforce Readiness (All Sectors)

- How:
- Launch a national skill development programme to certify at least 100,000 drone pilots, data analysts, and MRO specialists within three years, with sector-specific modules for mining, agriculture, infrastructure, and logistics.
- Partner with leading academic institutions (IITs, IISc) and industry bodies to design curricula covering geospatial analytics, 3D modelling, and safety-critical applications such as slope stability in mining and crop health monitoring in agriculture.
- Establish regulatory sandboxes and hands-on training environments at operational sites (mines, farms, infrastructure projects) for practical skill acquisition.

2. Sector-Specific Upskilling and Collaboration

- Mining:
  - Develop targeted short courses and workshops for mining engineers and geologists on drone data analytics, slope stability assessment, and environmental monitoring.
- Agriculture:
  - Expand training for farmers and FPOs on precision agriculture techniques, NDVI analysis, and insurance claim assessment using drone data.
- Infrastructure:
  - Train civil engineers and project managers in drone-based geospatial mapping, progress monitoring, and safety audits for highways, power lines, and construction sites.
- Logistics and Healthcare:
  - Upskill logistics professionals in BVLOS operations, payload management, and last-mile delivery protocols.
- Disaster Management:
  - Provide rapid training for NDRF and local police in search and rescue, damage assessment, and crowd monitoring using drones.

3. Incentivized Skill Building and Adoption

- How:
  - Offer financial incentives (tax rebates, grants, subsidies) to organizations and individuals who complete certified drone data analytics programm.
  - Expand initiatives like the "Drone Didi" scheme to include technical data analysis skills, ensuring broader participation and last-mile reach in rural and remote areas.

4. Mandate Certified Personnel for Critical Data Interpretation

- How:
  - Update sectoral regulations to require certified professionals for interpreting drone data in high-risk operations (e.g., mining slope stability, infrastructure safety audits, disaster response).
  - Integrate skill requirements into procurement policies for government projects and public sector undertakings.

5. Continuous Monitoring and Feedback

- How:
  - Implement regular audits and feedback mechanisms across sectors to assess skill gaps and training effectiveness.
  - Use stakeholder input to update training programmes and ensure alignment with evolving technological and operational needs.

6. Privacy and Data Protection

- How:
  - Ensure all drone operators comply with the Digital Personal Data Protection Act (DPDP 2023) by obtaining informed consent, providing clear privacy notices, and implementing robust data security safeguards.

➢ Advocate for sector-specific guidelines addressing drone-based surveillance and geospatial data, to close regulatory gaps and build public trust.

Summary Table: Sectoral Action Points

Sector	Key Skill Gap Addressed	How to Action Recommendations
Mining	Slope stability, geospatial analytics	Targeted courses, regulatory mandates, hands-on training
Agriculture	Precision farming, NDVI, insurance	Farmer training, FPO workshops, "Drone Didi" expansion
Infrastructure	Mapping, safety audits	Engineer upskilling, project-based sandboxes
Logistics	BVLOS, payload management	Logistics professional training, operational pilots
Disaster Mgmt	SAR, damage assessment	NDRF/police rapid training, scenario-based exercises
Privacy	Data protection, consent	DPDP compliance, sectoral guidelines, public awareness

NOTES

Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government and civil society through advisory and consultative processes.

CII is a non-government, not-for-profit, industry-led and industry-managed organisation, with around 9,700 members from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 365,000 enterprises from 318 national and regional sectoral industry bodies.

For 130 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. CII charts change by working closely with the Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness, and business opportunities for industry through a range of specialised services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

Through its dedicated Centres of Excellence and Industry competitiveness initiatives, promotion of innovation and technology adoption, and partnerships for sustainability, CII plays a transformative part in shaping the future of the nation. Extending its agenda beyond business, CII assists industry to identify and execute corporate citizenship programmes across diverse domains, including affirmative action, livelihoods, diversity management, skill development, empowerment of women, and sustainable development, to name a few.

For 2025-26, CII has identified "Accelerating Competitiveness: Globalisation, Inclusivity, Sustainability, Trust" as its theme, prioritising five key pillars. During the year, CII will align its initiatives to drive strategic action aimed at enhancing India's competitiveness by promoting global engagement, inclusive growth, sustainable practices, and a foundation of trust.

With 70 offices, including 12 Centres of Excellence, in India, and 9 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and USA, as well as institutional partnerships with about 250 counterpart organisations in almost 100 countries, CII serves as a reference point for Indian industry and the international business community.

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