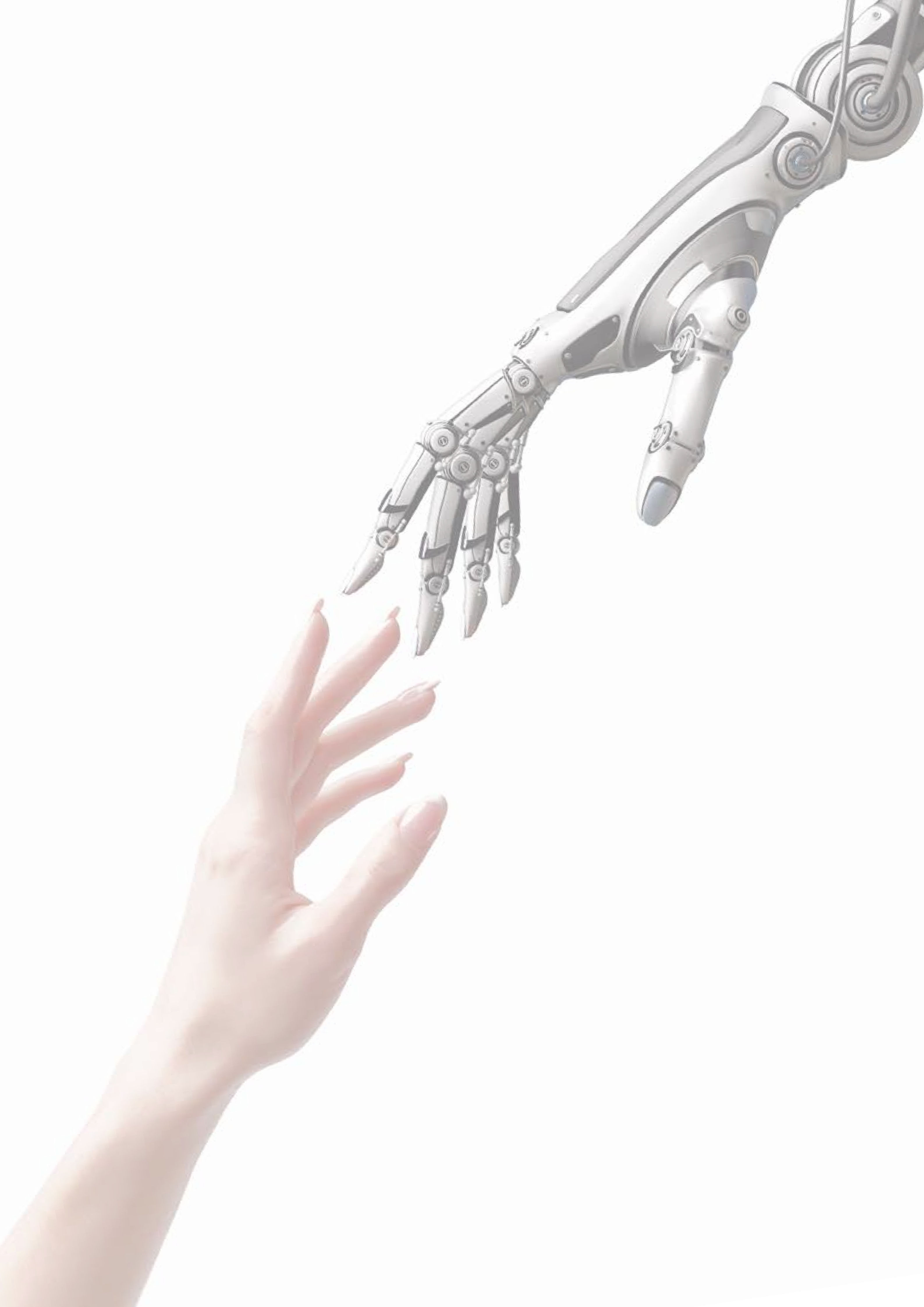
सत्यमेव जयते

DRAFT NATIONAL STRATEGY ON Robotics

July 2023



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EXECUTIVE SUMMARY

Globally, governments and the industry alike are harnessing transformative technologies to respond to opportunities and exogenous shocks. Artificial Intelligence is one such critical technology pivotal in solving national challenges and building economic resilience.

Over the past several years, India has taken concrete steps to encourage the adoption of AI in a responsible manner and build public trust in the use of this technology, placing the idea of 'AI for All' at its very core. India's approach to AI is holistic and ambitious, as evidenced by the breadth and scope of government interventions focused on democratising the benefits of this technology. The Government of India's 'India AI' is an umbrella program that harmonizes existing AI initiatives, from building language models (Digital India Bhashini) for increasing digital accessibility for citizens to skilling programs (YUVAi) demystifying AI for school students, to achieve the common goal of 'making AI in India and making AI work for India'.

AI is expected to have a significant impact in the realm of Cyber-Physical Systems (CPS), which is the common appellation for systems that combine physical and cyber components to perform complex tasks. The interaction of the virtual world with components of physical systems over distributed networks has presented the generational opportunity to power social and economic outcomes for our future. Robotics is a key CPS technology that relies on AI algorithms to process and interpret sensory data, make decisions, and execute actions in the physical world.

India has also made significant strides in the field of robotics, with a focus on developing and harnessing the potential of cutting-edge technologies to promote innovation that leads to sustainable and inclusive development across the economy. This was evidenced by robotics installations in India surging by 54% to 4,945 units in 2021 ranking India 10th for the highest annual installation of industrial robots in the world. However, the effects of the coronavirus pandemic and geopolitical instabilities continue to persist in compromising global supply chains, prolonging the scarcity of critical components and further exacerbating the need for India to achieve self-reliance in robotics.

As economies around the world diversify and recalibrate their supply chains, India has the generational opportunity to strengthen its robotics ecosystem and realign its global positioning. There is an immediate need to undertake comprehensive efforts to develop indigenous capabilities and leverage the potential opportunities from the Robotics revolution. The National Strategy for Robotics aims to position India as a global leader in robotics to actualise its transformative potential. It also builds upon Make in India 2.0 which has identified robotics as one of the 27 sub-sectors to further enhance India's integration in the global value chain. A holistic and coordinated mechanism is envisioned to strengthen India's industrial capabilities, the need for domestic value addition, augmenting employability, and helping India emerge as a "Robotics Hub" for the world. The strategy also aims to fully maximize the benefits of an AI-integrated society by leveraging the momentum of the Government of India's AI initiatives to drive advancements in robotic technology in India.

While Robotics is a multidisciplinary technology that has the potential to transform and disrupt a wide range of sectors and industries, its adoption to date has been primarily driven by economic motivations. However, given the potential of Robotics to catalyse large-scale social transformation, there is a need for national strategies, policies, and programs to converge efforts towards a few priority sectors that are poised to create large-scale socio-economic impact. This strategy identifies four such sectors to prioritise robotics automation in India, namely- Manufacturing, Agriculture, Healthcare, and National Security. The Ministry of Electronics and Information Technology (MeitY), serving as the nodal agency for Robotics, has proposed a two-tier institutional framework to facilitate the implementation of the National Strategy on Robotics, which will be undertaken as the 'National Robotics Mission'. To reap the benefits of deploying robotics at scale, multiple interventions have been recommended across the key pillars of a robotics innovation cycle which include Research and Development, Demonstration and Testing, Commercialization and Supply Chain Development, and Adoption and Awareness.

Research in Robotics in India is still in its nascent stages and requires large-scale concerted and collaborative interventions. The National Strategy on Robotics aims to enhance the research and development capabilities of the robotics ecosystem in India by improving the availability of funding, converging efforts with CoEs for AI and Cyber Physical Systems, establishing platforms for global partnerships, attracting and retaining skilled professionals and funding Moonshot Projects for pathbreaking research innovation.

To build public trust in the technology and ensure its responsible and safe adoption, demonstration and testing have been prioritised. For this objective, the development of infrastructure and demonstration facilities for the testing, validation, and certification of robots has been recommended.

Additionally, to localise supply chains and enable the scaling of robotics innovation, fiscal and non-fiscal interventions are proposed. The strategy recommends innovative funding mechanisms for robotics start-ups to enable commercialisation and the development of supporting infrastructure and policy measures to increase domestic value addition and promote exports.

Further, to increase the penetration and adoption of robots in India, multiple demand-side interventions have also been proposed. Market expansion levers providing fiscal and non-fiscal support, creation of a regulatory framework, awareness campaigns as well as access to network infrastructure have been identified.

As robotic automation furthers the benchmarks of technological aptitude required, there is an emergent need for the development of a skilled workforce. The strategy proposes recommendations to build capacities across the innovation lifecycle with a focus on providing training and education in robotics and related fields. This will help to ensure that India has the talent and expertise needed to compete in the global robotics market.

Overall, the National Strategy on Robotics aims to create a conducive environment for the growth and development of the robotics sector in India, to drive innovation and economic growth, while also improving the quality of life for citizens. This strategy will form an integral part of the overall India AI vision and see the advancement of India's Cyber-Physical Systems objectives.

2

VISION, MISSION & OBJECTIVES

2.1 Vision

The vision for India's National Strategy on Robotics is deeply rooted in the tenets of 'Sabka Saath, Sabka Vikas, and Sabka Prayas', 'Make AI in India and Make AI work for India', and 'AtmaNirbhar Bharat Abyan'.

As part of the overall India AI vision, the National Strategy on Robotics aims to maximise the economic and socio-technical benefits of robotic technology while minimizing risks and associated challenges.

2.2 Mission

- Make India a global hub for the research, design, development, and manufacturing of robotics and promote large-scale adoption.
- Ensure the creation of a sustainable and robust ecosystem for Robotics innovation and entrepreneurship in India.
- Ensure global competitiveness of Indian robotics companies and start-ups.
- Promote the creation of Indian IPR in the field of robotics.
- Nurture a skilled robotics workforce.

2.3 Objectives

- Positioning India as a global leader in robotics for manufacturing, healthcare, agriculture, and national security sectors, by 2030.
- Augmenting the stability and competitiveness of the domestic industrial foundation to increase domestic value addition across the supply chain.
- Fostering and improving the domestic research and innovation ecosystem through targeted investments in alignment with India's robotics priorities.
- Ensuring a coherent and holistic approach to robotics research and innovation in India, including convergence with emerging cyber -physical systems and AI technologies.
- Increasing the penetration of robots in India by augmenting the depth and breadth of its applications and creating new markets domestically and internationally.
- Strengthening India's collaboration with global robotics centers, academic institutions, experts and organisations.
- Establishing governance mechanisms to position India as the global benchmark for the performance, quality, and reliability of its robots.
- Developing a skilled workforce by providing training and education in robotics and related fields.

3

INTRODUCTION

3.1 What is Robotics?

The Bureau of Indian Standards (BIS) defines Robotics as the science and practice of designing, manufacturing, and applying robots (clause 2.16 of IS 14662: 2018). Robotic technology encompasses the design, construction, operation, and use of robots. A robot operates by sensing its environment, carrying out computations for decision making, and performing actions. Sensors in the robot collect and feed measurements to a controller or computer, which processes them and subsequently sends control signals to motors and actuators which allows the robot to interact with its environment. Recently, advances in artificial intelligence (AI) and machine learning have led to the development of more advanced robots that can perform tasks that were previously thought to be exclusive to humans, such as visual perception, speech recognition, and decision-making.

3.2 Types of Robots

The Scope of the National Strategy is limited to the classification of robots as per the Bureau of Indian Standard's standards for robots- IS 14662, as detailed below:

3.2.1 Industrial Robots: Industrial robots are "automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or fixed to the mobile platform for use in automation applications in an industrial environment", where axes refer to the number of moveable joints. The mobile platform is an assembly of components that enables locomotion and can provide the structure by which to affix a manipulator - a mechanism consisting of an arrangement of segments, jointed or sliding relative to one another. Industrial robots are used in manufacturing and assembly line operations, o handle specific automation applications such as picking and placing objects; assembling and packaging; ironing, cutting, or welding; and product inspection, among others.

3.2.2 Service Robots: BIS further defines Service robots as robots for personal use or professional use that perform useful tasks for humans or equipment (IS 14662). Tasks in personal use include handling or serving items, transportation, physical support, providing guidance or information, grooming, cooking and food handling, and cleaning. While tasks in professional use include inspection, surveillance, handling of items, transportation, providing guidance or information, cooking and food handling, and cleaning. Service robots are used in non-industrial environments, such as homes, hospitals, and offices.

3.2.3 Medical Robot: Medical Robot as per BIS is intended to be used as medical electrical equipment or medical electrical systems and is not regarded as an industrial robot or service robot (IS 13450 (Part 4/Sec 1)).

3.3 Artificial Intelligence and Technological Trends in the Field of Robotics

Artificial Intelligence encapsulates a range of methodologies and applications, such as machine learning (ML), natural language processing (NLP), and robotics. It has the capability to embed copious amounts of knowledge in intelligent systems while also significantly augmenting the efficiency and effectiveness of their decision-making in data-rich environments.

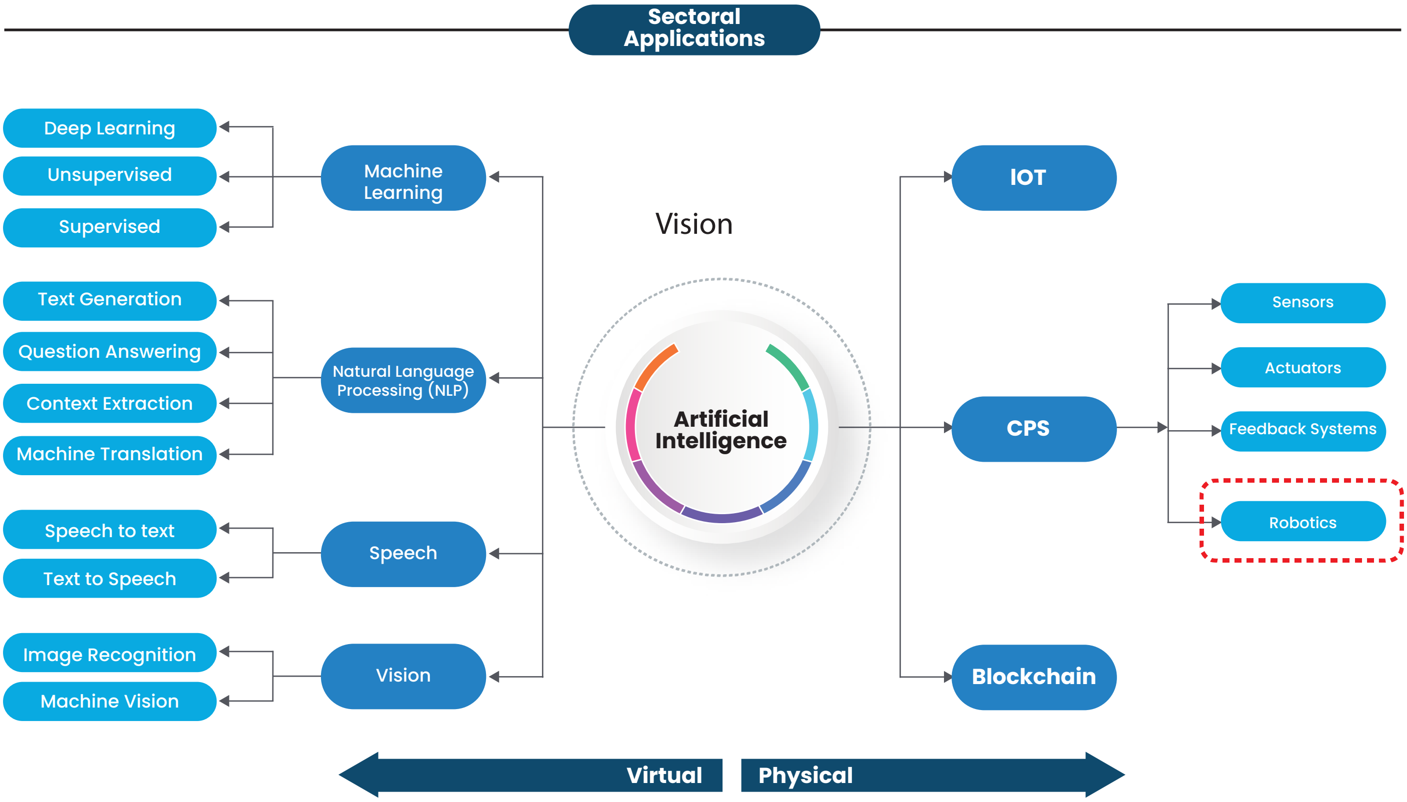


Figure 1: Convergence of AI and Robotics

AI in Robotics

Artificial Intelligence is enabling robots to perform more complex tasks and make decisions autonomously. In robotics, AI aims to better manage variability and unpredictability in the external environment enabling robots to learn from data and improving their performance over time. For example, a robot can be trained to recognize objects in its environment by analysing a large dataset of images and identifying patterns that are characteristic of different types of objects. Once the robot has learned to recognize objects, it can use this knowledge to perform tasks such as grasping or navigating around objects. Learning approaches are being utilised in addressing problems in designing robots. Machine learning algorithms can also be used to improve the control of robots such as using reinforcement learning to optimize the robot's control policies. Also, deep learning techniques such as convolutional neural networks can be used for image processing, such as object detection and semantic segmentation.
Commercial use cases of AI in robotics can broadly be divided into:

- Sense-and-response applications: This refers to real-time robot applications that use sensors, including cameras, to detect the robot's position and the objects it needs to manipulate. Machine learning algorithms aid in the sensing process, while decision-making algorithms help the robot determine the best course of action, such as choosing the optimal force and gripper position for object manipulation and identifying the best path to the target destination. These response algorithms may either be AI-based or a fusion of AI and traditional algorithms.

- Performance optimization: Artificial intelligence is utilized in various ways to enhance process design, robot programming, maintenance, and quality inspection. These applications typically operate offline, where data is collected from robots and other machines, analysed, and then used to modify robot programs.

As applications of robotics evolve, convergence with other emerging technologies will be critical in catalysing the transformational power of robotic automation. A few such technological trends are detailed below:

3.3.1 Autonomous Systems:

Autonomous systems can operate without human intervention, which can increase efficiency, productivity, and safety in many industries. Autonomous robots and drones are becoming increasingly popular in various industries, such as agriculture, logistics, and transportation.

3.3.2 Internet of Things (IoT):

The integration of IoT technology with robots is allowing for real-time data collection and monitoring, enabling better decision-making and process optimization. The Internet of Things movement will facilitate the introduction of increased intelligence and sensing into most robot systems, and we will see a significant improvement in user experience. Sensor technology also plays a crucial role in the functioning of robotics systems. Sensors are used to gather information about the environment, the robot's own state, and the position of other objects. This information is then used by the robot's control system to make decisions and perform tasks. Sensors are also used in mobile robots for localization and mapping, for example, LIDAR and cameras, which are used to detect the environment and navigate in it.

3.3.3 Human-robot collaboration (Cobots):

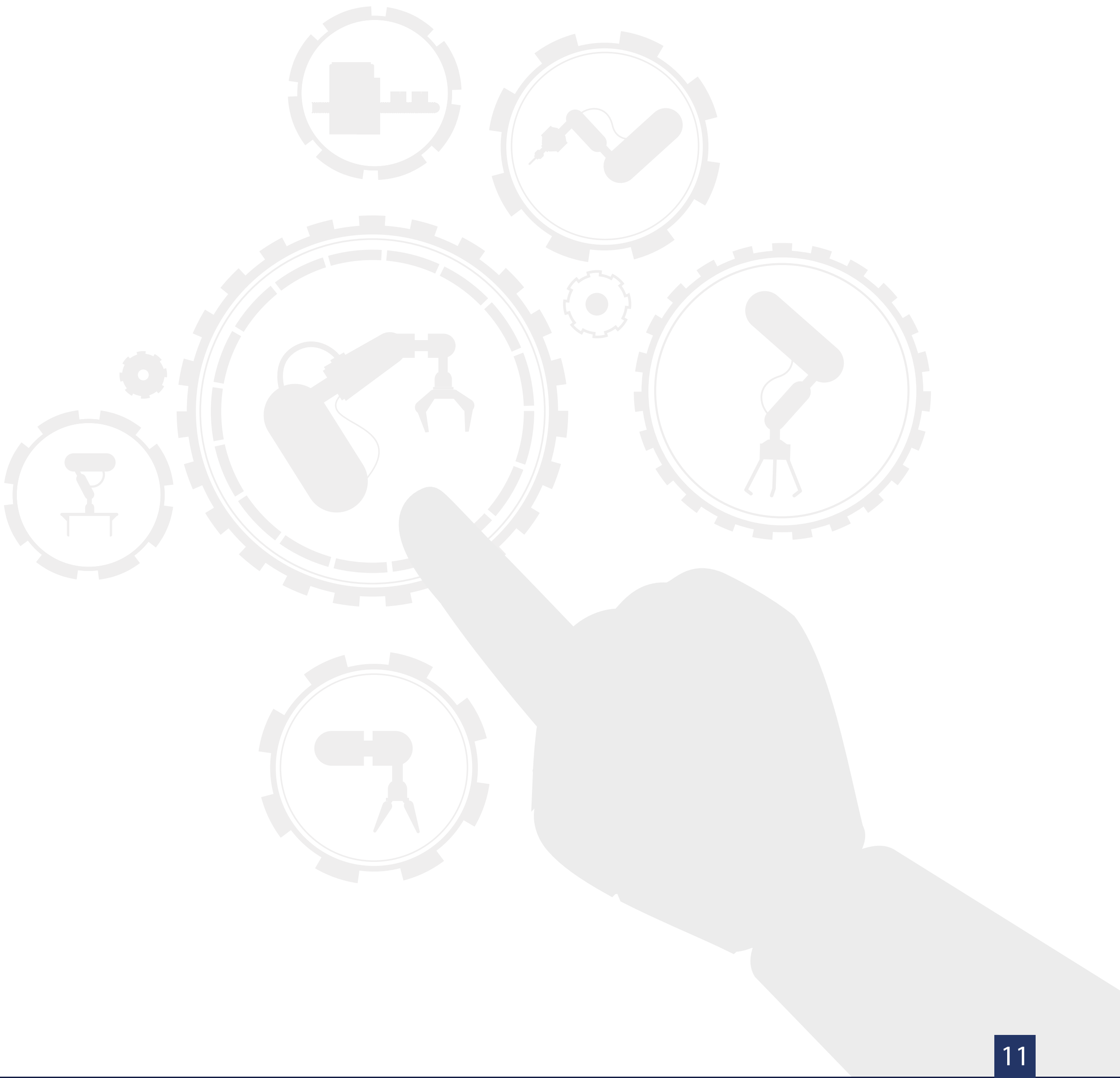
The development of robots that can safely and effectively work alongside humans is becoming increasingly important in industries such as manufacturing and healthcare. Collaborative industrial robots are designed to perform tasks in collaboration with workers in industrial sectors. In such collaborative setups, the heavy lifting is done by the robots (or precision operations) with human workers undertaking higher-skilled jobs such as programming, maintaining, and coordinating robotic operations.

3.3.4 5G and Edge Computing:

The implementation of 5G networks and edge computing is enabling faster data transfer and processing, which is crucial for the real-time control and monitoring of robots. Robotic systems often require powerful computing resources to process the large amount of data that they gather from sensors and to make decisions and execute tasks in real-time. Advanced computing platforms, such as multi-core processors, graphics processing units (GPUs), and field-programmable gate arrays (FPGAs), can provide the necessary computing power for these tasks. Advances in cloud computing and edge computing are also enabling robots to access even more powerful computing resources and share data and collaborate with other robots in real-time. These technologies are also making it possible for robots to process and analyse data closer to where it is gathered, which can help to reduce the amount of data that needs to be transmitted to a central location for processing, thus reducing latency and increasing the response time of the system.

3.3.5 Additive Manufacturing or 3D Printing:

3D printing accelerates product design and reduces cost and waste, thereby increasing the flexibility to create more complex designs. Advancements in 3D printing of soft and flexible materials have been critical for the development of soft robots that are safer and better adaptable to different environments. Soft robotics is a rapidly growing field of robotics whereby the robots are fundamentally soft and deformable allowing adaptive and flexible interactions in complex unpredictable environments. Fabrication of soft robots is highly complex and time- and labour-intensive, therefore 3D printing of soft materials has enabled greater design complexity and faster fabrication of soft robots.



GLOBAL SCENARIO

4.1 Industrial Robots

According to the International Federation of Robotics (IFR) presently there are over 3 million industrial robots operating in factories around the world, with half a million installations added in 2021, representing a CAGR of 14% from 2016 to 2021. Asia remains the world's largest market for industrial robots with 74% of all newly deployed robots in 2021 installed in Asia.

One of the major factors driving the growth of industrial robots is the increasing adoption of Industry 4.0, which involves the integration of advanced technologies such as IoT, AI, and machine learning into industrial processes. This has led to the development of more sophisticated and capable industrial robots, which can perform a wide range of tasks and interact more naturally with humans. The increased demand for automation due to the limited production capacity and the disruptions in supply chains because of the pandemic has led to the electronics industry becoming the largest consumer of industrial robotics with a year-on-year growth of over 24% followed by the automotive and metal & machinery industries. As per the 2022 McKinsey Global Industrial Robotics Survey, automated systems will account for 25% of capital spending over the next five years with the Retail and Consumer Goods industry posed to be the largest spenders. Industrial robots and automation will enable productivity gains, create stable supply chains and solve skilled labour shortages.

According to the World Robotics Report 2022, the five major markets for industrial robots are China, Japan, the United States, the Republic of Korea, and Germany. These countries accounted for 78% of global robot installations. China ranked first in terms of annual installations of industrial robots with 268,200 units in 2022 followed by Japan and USA. China now installs more industrial robots per year than the rest of the world taken together. The growth in China's robotization of industries can be attributed to multiple government interventions including the Five-Year Plan for the robotics industry, released by the Ministry of Industry and Information Technology (MIIT) in Beijing in 2021.

Uptake of robotic automation in these leading countries is supported by strong government support, a focus on economic competitiveness and industrial automation, a skilled workforce, a strong industrial base, and significant investment in robotics R&D and innovation.

4.2 Service Robots

The service robot industry has been growing rapidly in recent years, driven by advances in technology and the increasing demand for automation in various service-oriented industries. Service robots can improve efficiency, accuracy, and safety in service-oriented operations, and can also help to reduce labour costs.

According to the International Federation of Robotics (IFR), the market for professional service robots grew to a turnover of $6.7 billion U.S. dollars globally– up 12% in 2020. In 2021, worldwide sales of professional service robots grew by 37% with more than 121,000 units sold. The growth of this industry is further fuelled by the increasing adoption of robot-as-a-service (RaaS) models, through which robots are leased or rented instead of purchased. Hospitality robots are growing in popularity, registering the largest growth rate of 85% in 2021 and the RaaS fleet size is continuing to grow rapidly. Transportation and logistics grew by 45% with over one out of every three professional service robots sold in 2021 made for the transportation of goods or cargo sector. Sales of medical robots were up 23%, including surgery robots, robots for rehabilitation and non-invasive therapy, and robots for diagnostics.

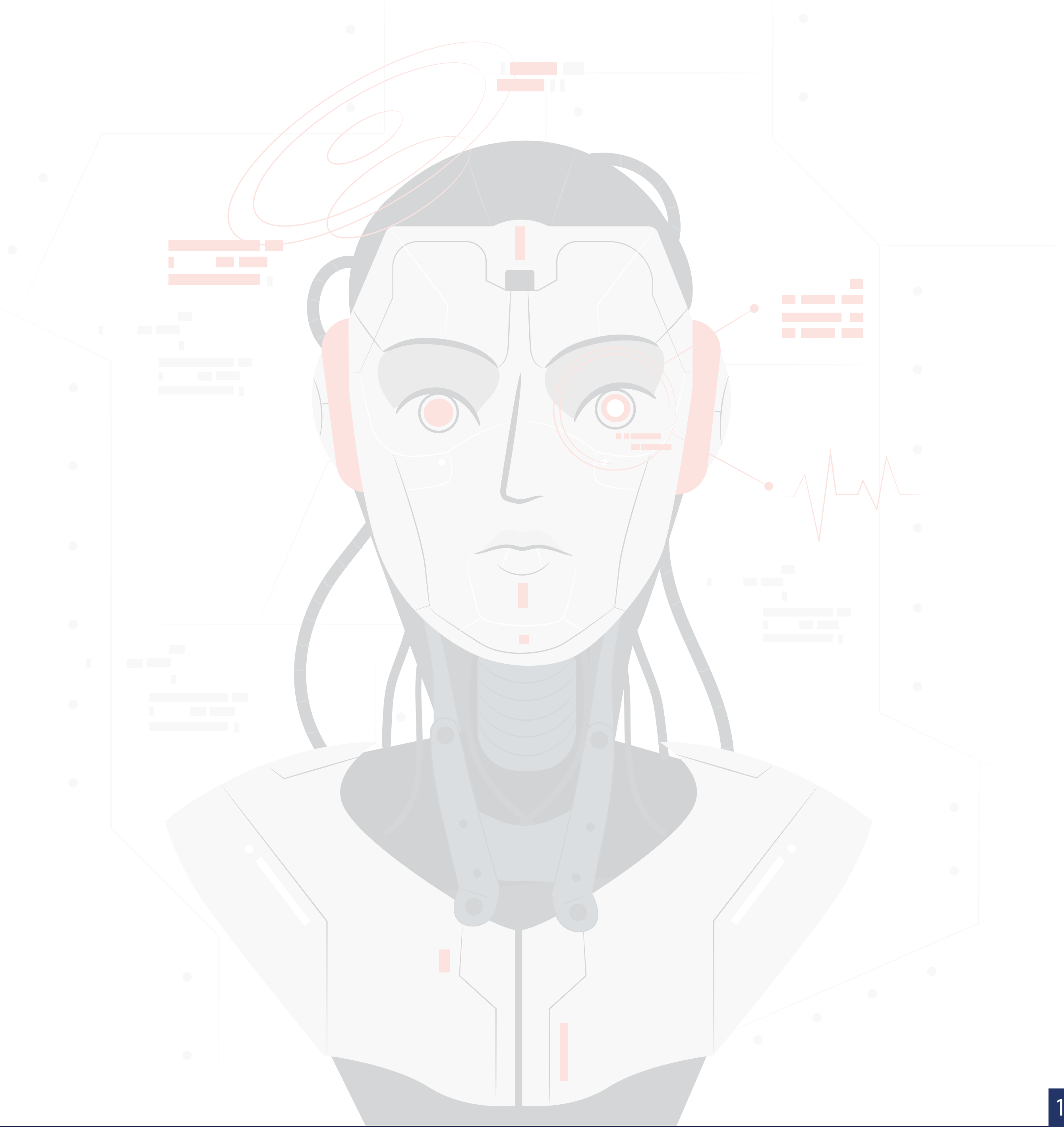
4.3 Global Policy Analysis

National strategies and government policies of global leaders in robotics have been analysed to benchmark best practices and provide strategic recommendations to accelerate India's adoption of robotics.

Countries	Strategy Adopted	Investments	Outcome	Sectors
China	• *14th 5-Year Strategy Plan 2021*: Aims to improve innovation capabilities, build a foundation for industrial development, increase the supply of high-end products, expand the depth and breadth of applications, optimize the overall structure of the robotics industry. • *Key Special Program on Intelligent Robots in 2022*: To implement the 14th 5-Year Plan by supporting advancements in Basic frontier technologies, Common key technologies, Industrial robots, Service robots and special robots. • *Robotics+ Application Action Plan 2023*: Aims to augment robot density to promote high quality economic and social development.	**$ 43.5 million (2022)**	• *14th 5-Year Strategy Plan 2021*: Average annual growth rate of operating income in the robotics industry to exceed 20% • *Robotics+ Application Action Plan 2023*: Develop 100 innovative robotics applications, and over 200 model use cases where those technologies can be applied by 2025.	•Manufacturing • Agriculture • Architecture • Logistics • Energy • Healthcare • Education • Elderly services • Commercial community service • Emergency and extreme environment applications

Japan	*New Robot Strategy (2016-2020)*: - Aims to provide a plan for sectoral robot related R&D projects as well as cross-sectoral activities such as global standardization, regulatory reform, and robot awards and competition. - The World Robotics Summit is organised by the government every year to promote innovation,	**$1370.5 Million for 2020-2025**	• Government and private sector investment in projects related to robots for 100 billion yen. • Expand robot market scale to 2.4 trillion yen (annually)/	•Manufacturing • Service • Nursing and Medical Infrastructure • Disaster Response • Construction • Agriculture • Forestry • Fishery • Food Industry
	- accelerate R&D, and adoption of Robots. - Robot Revolution & Industrial IoT Initiative (RRI) is established as the implementing agency. • Moonshot Research and Development Program: Supports projects aimed to develop robots that could enhance both the physical and mental limitations of the human body and AI robots that evolve alongside humans.		• Reduce Costs for initial introduction of robots by 20% and double the number of human resources for assisting introduction of robots to 30,000 by 2020.	
United States of America	*National Robotics Initiative (NRI) 3.0*: Aims to support fundamental research in the United States that will advance the science of robot integration. • *US DoD Budget For Unmanned System*: Develop unmanned systems and robotics as they are key technology areas that enable the U.S. to counter the range of evolving threats posed on the modern battlefield.	**$15.7 Million (2021-2022)**	• Innovations in Integration of Robotics • Intensive application of robotics in Defence & Space	• Defence • Space • Health • Transportation • Agriculture
South Korea	• *The 3rd Basic Plan for Intelligent Robots (2019-2023)*: Promotes systematic dissemination and diffusion through the selection of potential sectors and assignment of responsibilities for the government and the private sector. • *2022 Implementation Plan for the Intelligent Robot*: Aims to implement the 3rd Basic plan through facilitating full-scale testing of specialized manned or unmanned aerial vehicles, nurture skilled manpower and support industry education.	**$451.23 Million for 2019 - 2023**	• Accelerate market size of the robotics industry (KRW 15 trillion by 2023) • Increase number of companies specializing in robotics valued at over KRW 100 billion- to be at least 20 companies by 2023) • Expansion of the manufacturing robot number (cumulative 700,000 units by 2023)	• Root • Textile • Food and Beverage • Care • Wearable • Medical Care • Logistics

Germany	• *AUTONOMIK (2009-2014)*: Program provided funding for robot-related R&D projects in the fields of manufacturing, logistics, and assembly. • *The PAiCE program*: Emphasizes creation of robotics platform in areas like service, logistics, and manufacturing. •*The High-Tech Strategy 2025*: Supports R&D to advance human technology interaction which enables independence of those in need of care and relieve nurses.	**$ 345.6 million- for all technologies (2021- 2026)**	• Achieve a target of 3.5% spend of GDP per annum in R&D by 2025	• Health • Services • Chemicals • Industry 4.0 • Infrastructure • Agrifood • Mobility & autonomous vehicles

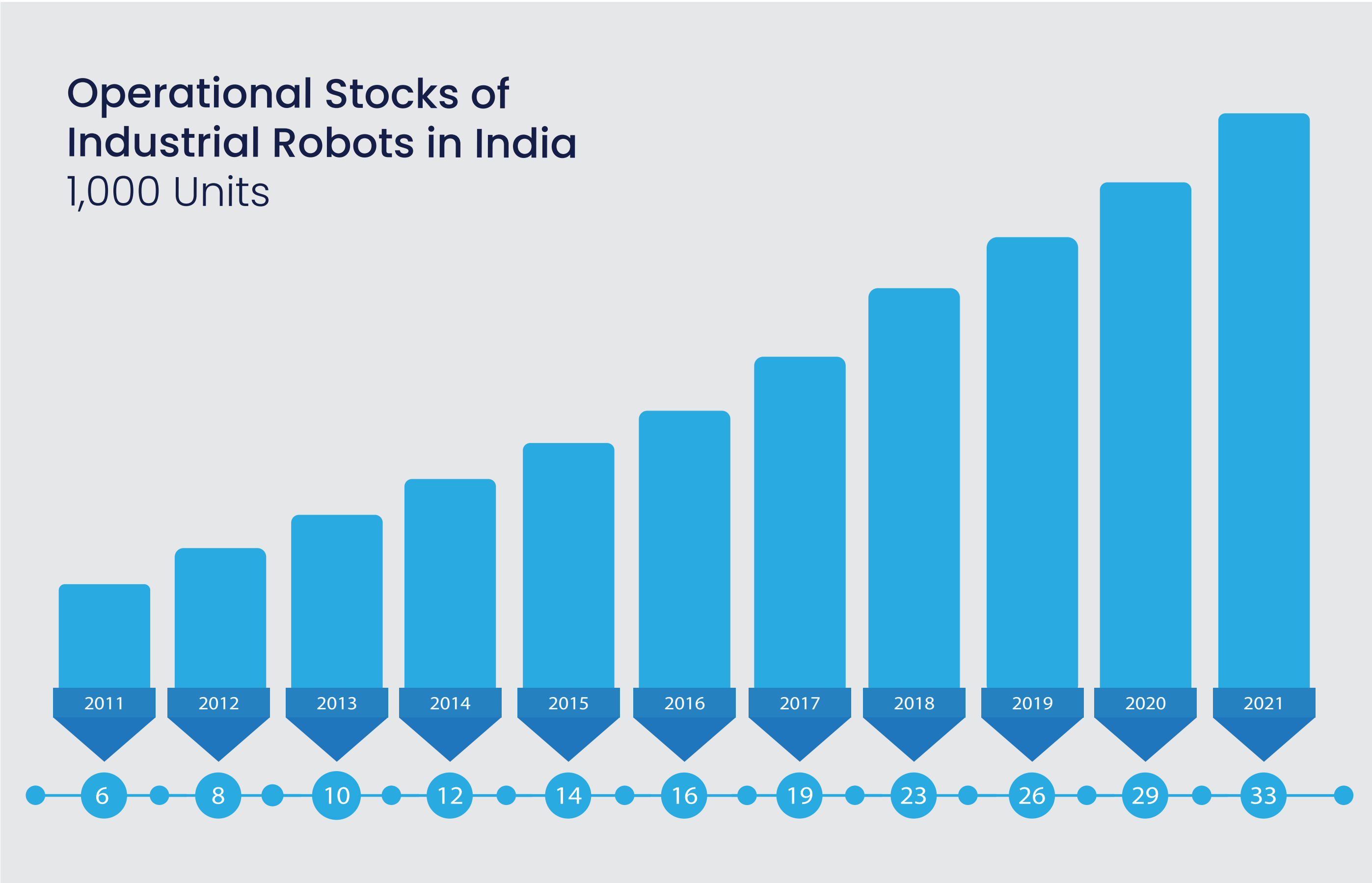


5

NATIONAL SCENARIO

5.1 An overview

In the past decade India has made multiple strides towards strengthening its industrial base with adoption of advanced manufacturing technologies such as robotics enabling productivity gains. Since 2016, the operational stock of industrial robots has more than doubled in India to reach 33,220 units in 2021, averaging at an annual growth rate of 16%. Presently, in terms of annual industrial installations, India ranks 10th globally as per the World Robotics Report, 2022. The long term potential of robotics in India is significant as a catalyst for revolutionizing industries, driving inclusive growth and improving the standard of living.



However, despite its potential, the growth of the robotics ecosystem in India has been slower in comparison to certain developed economies. This can be attributed to several challenges, such as high import dependence, costly hardware components, and insufficient investments in research and development.. Additionally, the dearth of trained personnel for the implementation, integration, and maintenance of robots further hinders the development of the domestic ecosystem. Therefore, to establish India as a global hub for robotics, concerted efforts are required towards mitigation of current ecosystem challenges as well as augmentation of national and state efforts.

5.2 National Efforts

The Government of India acknowledges the importance of Robotics in transforming key sectors of our economy and realising the full potential of Industry 4.0. Several initiatives have been taken in the recent past to catalyse the robotics ecosystem in India.

5.2.1 Research & Development Centres

i. ARTPARK– Technology Innovation Hub under National Mission on Interdisciplinary Cyber Physical Systems (NM-ICPS)

An Artificial Intelligence and Robotics Technology Park (ARTPARK) through a public-private collaborative consortium with seed funding of INR 230 crore ($30 million) has been launched at the Indian Institute of Science (IISc) in Bengaluru. ARTPARK has been set up to leverage AI and robotics, to solve problems unique to India. ARTPARK has the objective of channelising innovations to create societal impact by executing ambitious mission-mode R&D projects in healthcare, education, mobility, infrastructure, agriculture, retail, and cyber-security.

ii. Center for Advanced Manufacturing for Robotics and Autonomous Systems (CAMRAS)

To reduce the import footprint of robotics and autonomous systems in the country, ARTPARK-IISc is in the process of setting up an industry accelerator, the Centre for Advanced Manufacturing for Robotics and Autonomous Systems (CAMRAS). ARTPARK-IISc has received approval from the Ministry of Heavy Industries (MHI) to set up CAMRAS for technology development in robotics and autonomous systems.

Five of ARTPARK's pre-ventures in the areas of advanced cargo drones, robotic actuators, legged robots, autonomous systems charging, and intelligent controllers will form this MHI Accelerator. The organisation will also spearhead a skilling programme to train 2,800 professionals in the field of next-generation advanced manufacturing for robotics and autonomous technologies by 2025.

iii. I-HUB Foundation for Cobotics (IHFC) – IIT Delhi

IHFC is IIT Delhi's Technology Innovation Hub (TIH) for Cobotics. The Department of Science & Technology had sanctioned INR170 crores to IIT Delhi under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) to set up the IHFC, which was incorporated as a Section-8 company by the Institute in 2020. Since its inception, IHFC has been working with its collaborating institutes and organisations and has launched 8 grand projects in the area of Medical Simulators, Healthcare Robotics, Rehabilitation Robotics, Drone Applications, Human-Robot Interaction (HRI)-Intelligence, HRI-Control, Industry 4.0, Intelligent and Secured Communication to fund research and product development in these domains.

iv. Defence Research & Development Organisation (DRDO)

Various laboratories of the Defence Research and Development Organisation (DRDO) are involved in Research and Development in the areas of Robotics and Artificial Intelligence. These include the Centre for Artificial Intelligence and Robotics (CAIR), Research and Development Establishment (Engineers) (R&DE(E)), Combat Vehicles Research and Development Establishment (CVRDE), and Vehicles Research and

Development Establishment (VRDE). R&DE(E) is working on the development of robotic platforms for defence applications. CVRDE and VRDE are involved in the development of unmanned tracked and wheeled vehicles. CAIR is working in the field of autonomous navigation, computer vision processing, and artificial intelligence, for the realization of autonomous robotic and unmanned systems.

5.2.2 Capacity Building Initiatives

i. FutureSkills Prime

The government of India, through MeitY, is creating a revolutionary skilling ecosystem focused on enhancing India's digital talent. Under this initiative, a robust online platform has been created to encourage remote and self-paced learning in the field of emerging technologies. This program aims to offer subsidised access to certified courses to interested participants in any of the 10 identified emerging technologies. These include AI, Blockchain, Robotics, Cybersecurity, Cloud Computing, IoT, Virtual Reality, 3D Printing, Big Data & Analytics, and Web 3.0.

ii. Atal Innovation Mission

With a vision to 'Cultivate one Million children in India as Neoteric Innovators', Atal Innovation Mission is establishing Atal Tinkering Laboratories (ATLs) in schools across India. ATLs have dedicated innovation workspaces where Do-It-Yourself (DIY) kits on emerging technologies like robotics, IoT, etc. have been installed to enable students to get hands-on exposure to these technologies.

iii. e-YANTRA

e-Yantra is a robotics outreach program funded by the Ministry of Education and hosted at IIT Bombay. The goal is to harness the talent of young engineers to solve problems using technology across a variety of domains such as agriculture, manufacturing, defence, home, smart-city maintenance, and service industries.

5.2.3 Make-in-India Robots

i. DAKSHA

Defence Research and Development Organisation (DRDO), under the Ministry of Defence, developed the remotely operated vehicle (ROV) – 'Daksha', an automated mobile platform for multi-purpose payloads. It has stair-climbing capabilities and can be deployed for handling Improvised Explosive Devices (IEDs). Daksha is currently being utilised by the Indian Army.

ii. Vyommitra

Vyommitra is a spacefaring humanoid robot being developed by the Indian Space Research Organisation (ISRO) to function onboard the Gaganyaan, a crewed orbital spacecraft. Vyommitra was first unveiled on 22 January 2020 at the Human Spaceflight and Exploration Symposium in Bengaluru. It will accompany Indian astronauts in space missions and will also be a part of uncrewed experimental Gaganyaan missions before the crewed spaceflight missions

iii. MANAV

Manav is India's first 3D-printed humanoid robot. The two-kilo, two-foot tall robot has an inbuilt vision and sound processing capability which allows it to walk, talk and dance — just in response to human commands. Developed by Delhi's A-SET Training and Research Institute, the humanoid robot is primarily meant for research purposes.

5.3 Current Challenges in the Indian Robotics Ecosystem

The current ecosystem faces a myriad of challenges impacting the development and adoption of robotics in India. These challenges include:

5.3.1 Inadequate Skilled Human Resources

Existing capacity building initiatives are insufficient to support widespread adoption of robotics in India as more targeted efforts are required to address ecosystem challenges. One of the major challenges in robotics manufacturing is the integration of multiple components and subsystems. Robots typically consist of numerous individual parts that must be assembled and integrated in a precise and coordinated manner. This requires a high level of engineering expertise and attention to detail to ensure that the final product meets the required specifications and performance standards. The Indian robotics ecosystem is facing growth impediments due to a dearth of technical expertise and skilled resources. In particular, the limited availability of technically proficient engineers and technicians equipped with the necessary skills to design, develop, and maintain robots is a significant challenge. Moreover, the dearth of skilled personnel specialized in robot maintenance and servicing creates a significant roadblock for translating core and applied research into commercial value propositions. Further, retaining top robotics talent within India has also been a challenge. Technical training infrastructure such as ITIs and polytechnics do not have the necessary facilities to train technicians and upskill existing recourses in foundational jobs in robotics as per industry standards.

5.3.2 Heavy Reliance on Imports

The Indian Robotics supply chain is in its nascent stages, as compared to matured markets for robotic automation like China and Japan which have been able to benefit from economies of scale in their production processes thereby reducing the cost of robots, their subsystems, and components. Given the limited robotic automation in India and the lack of anchor units, the supply chain for robotics has been disaggregated and unable to scale thereby limiting value addition in the country.

Robots are an amalgamation of various advanced technologies, typically consisting of actuators, motors, gearboxes, PCBs, chips, and sensors. While indigenous manufacturing of these components is picking up in India, a significant section of the supply chain is yet to be localized. This import dependency is particularly significant for magnets (a key component of motors), batteries, and chipsets. Robots are also complex systems that are built on specifications requiring stringent quality assurance and may require many of these components to be sourced from specific suppliers. This further increases the import dependencies on certain critical components for which the domestic ecosystem is in nascency.

The production of robotics components requires the use of specific raw materials which can be subject to shortages or price volatility. This can impact the availability and cost of components locally, thereby furthering import dependencies from cost-competitive markets.

5.3.3 High Costs

Many robotics applications require customized solutions that are tailored to specific needs and environments. This can make it challenging to scale up production and achieve economies of scale, as each robot may require unique components, software, and manufacturing processes. Therefore, the high import dependency and lack of scale in domestic production impact the cost and affordability of robots in the Indian market.

From the demand side, integration of robotics in the supply chain is noted to be a long and expensive process. Both preliminary and maintenance costs can make the integration of robotics prohibitively expensive for small and medium-sized enterprises (SMEs). The complexity of robots can also contribute to the cost of maintenance and service. Robots consist of numerous individual parts and subsystems that must be integrated and coordinated in a precise and reliable manner. This can make it challenging to diagnose and repair issues when they arise, which can increase the time and cost of service. This further leads to low adoption of robotics by MSMEs. High ecosystem costs limits domestic demand and disincentivizes adoption of robots.

5.3.4 Technological Limitations

Concerted and collaborative efforts are essential to position India as a frontrunner in building robotic innovation. Presently, foundational research focusing on breakthroughs in core robotic technologies is in the nascent stages in India. To build innovative applications, research priorities must be aligned with ecosystem requirements through greater collaboration between domain experts and practitioners throughout the robotics innovation lifecycle.

Given the complexity and criticality of robotics systems, ensuring high levels of quality and reliability is essential. This requires rigorous testing and validation processes to identify and address any issues before the robots are deployed in real-world applications. Industrial innovation in India is also stifled due to infrastructural constraints. The global competitiveness of Indian robotics manufacturers and startups is impeded by the lack of access to advanced manufacturing facilities to enable rapid and iterative prototyping, sampling, and testing.

5.3.5 Absence of Multidisciplinary Collaboration

Advances in robotic technology are increasingly becoming more interdisciplinary. New-age robots integrate other emerging technologies such as 5G, AR/VR, IoT, and AI among others to improve their functionalities. This interdisciplinary nature further underscores the need for multidisciplinary collaboration among government stakeholders, industry, academia, startups, and other relevant stakeholders. However, the current ecosystem lacks robust mechanisms for such multidisciplinary collaboration both within the domestic ecosystem as well as with global experts.

5.3.6 *Lack of Awareness*

The lack of awareness of robotics stems from the inadequate knowledge and understanding of robotic technology and its potential benefits, which may lead to misconceptions and underestimation of its impact, resulting in a reluctance to invest in research, development, and deployment of robotics solutions. Limited understanding of robotic technologies for improving operational efficiency, reducing costs, and enhancing decision-making also impact its adoption, particularly by MSMEs.

5.3.7 *Limited Governance Mechanisms*

Regulatory frameworks and security arrangements must evolve with growing indigenous robotics use cases to ensure widespread adoption and innovation and alleviate concerns around its safe, secure, and trusted deployment. The absence of separate robotics legislation or legislation for allied technologies like AI, exacerbates privacy and security risks, thereby limiting the adoption of robotic technology. Further, a robust regulatory landscape that also addresses intellectual property protection as well as the protection of robotic systems from cyber threats is currently lacking. Technical standards are also essential for the development and diffusion of robots and they are necessary for assessing how robots report data, for robot ontologies, for interoperability, performance testing, safety, etc.

As indigenous use cases for robotics evolve, it is pertinent to establish as well as adapt standards and certifications contextualised to the Indian ecosystem requirements. enable obtaining licences for the end product. Bootstrapped start-ups and MSMEs are also challenged with obtaining end product licenses due to high costs for certification of robotics products and processes and intermediary components/sub-assemblies.

5.3.8 *Lack of Reliable & Continuous Access to Foundational Infrastructure*

Constant and reliable energy supply is a major challenge for the robotics industry in India, making it difficult for robots to operate continuously and efficiently. Additionally, the absence of dependable and high-speed internet connectivity in some parts of India poses significant limitations to the effective deployment of robots especially for critical applications such as healthcare, national security etc. This also makes it difficult for companies to remotely monitor and control their robots, which can limit the potential benefits of automation.

5.3.9 *Ethical Considerations*

The responsible development, deployment, and adoption of robotics will only be possible through building public trust in the use of this technology. This would require addressing the ethical considerations around the impact of robotics on employment, ensuring transparency where autonomous decision-making is involved, and protecting the privacy, security, and trust of citizens at all points. Individual efforts may have to be undertaken to ensure the fulfilment of each of these considerations, supported by robust redressal mechanisms for citizens.

These challenges need to be addressed through systemic policy and programmatic interventions to promote the growth of the robotics ecosystem in India. These interventions are detailed out under Section 7 “Strategic Recommendations”.

6 FOCUS AREAS FOR ROBOTIC AUTOMATION IN INDIA

The National Strategy on Robotics has identified four priority sectors with the maximum potential of creating large-scale socio-economic impact through robotics adoption and to position India as a global leader in robotics across these sectors by 2030:

1. Manufacturing
2. Healthcare
3. Agriculture
4. National Security

These sectors have been identified basis the parameters detailed below:

Sector	Size	Growth Potential	Potential for Automation	Maturity of Robotic Technology	AI Penetration	Assessment
Manufac-turing	For the first half of FY23, the Gross Value Added (GVA) of the industrial sector has increased by 3.7% surpassing the average growth rate of 2.8% achieved in the first half (of each year) of the last decade	According to the Purchaser's Manufacturing Index (PMI), the manufacturing sector has been in an expansion phase for 18 consecutive months starting from July 2021. The PMI sub-indices suggest that there has been a reduction in the pressure on input costs, an improvement in supplier delivery times, strong export orders, and future output.	Robotic technology can be leveraged for several use cases including: • Logistics and Warehousing automation • Shopfloor transformation through Cobots. • Production automation • Process Optimization	There has been a significant uptake of robotics in industrial automation and industry 4.0 use cases in India. Further efforts are needed toward commercialisation and building low-cost solutions.	The manufacturing and production sectors account for approximately 35% of AI adoption across sectors in India.	The manufacturing and production sectors account for approximately 35% of AI adoption across sectors in India.
Health-care	The share of expenditure on health in the total expenditure on social services by the Government of India has increased from 21% in FY19 to 26 % in FY23 (BE)	The Indian healthcare industry has been growing at a Compound Annual Growth Rate of approximately 22% since 2016.	Robotic technology can be leveraged for several use cases including: • Cleaning and Disinfecting • Safety and Monitory • Surgical Robots • Telemedicine • Rehabilitation and physical therapy	COVID-19-induced safety and hygiene measures have accelerated the adoption of robotics in the Indian healthcare sector. India has also witnessed a growth in robot-assisted surgeries for the past decade.	The pharmaceutical and healthcare sectors account for 50% of AI adoption across sectors in India	To build on the momentum of robotic automation and AI adoption in this sector and reap the social and economic dividends of harnessing the potential of robotics for transforming healthcare, this sector may be prioritised.

Agricul-ture	GVA of agriculture and allied sectors contributes 18.3% in the total economy at current prices. It is also the largest employer of the Indian workforce.	India's agricultural industry has experienced buoyant growth, averaging an annual growth rate of 4.6% over the past six years. Additionally, in recent years, India has become a net exporter of agricultural products, with record-breaking exports of $50.2 billion in FY 2021-22.	Robotic technology can be leveraged for several use cases including: • Precision farming • Cattle grazing and Milking • Crop and Soil Health Monitoring • Crop harvesting • Crop Scouting • Spot Spraying	A number of underlying technologies such as drones and unmanned vehicles have seen significant investments from the public and private sector alike. However, stronger lab-to-market linkages are required for the uptake of robotics in this sector.	There are over 1000 agritech startups in India leveraging AI and other technologies. India is also the third-largest recipient of agritech funding globally. Several commercial use cases of AI have been indigenously developed and adopted. These are well supported by Government initiatives such as Digital Agriculture Mission, Agristack, etc.	Given the importance of Agriculture to the Indian economy as well as the potential of robotics to leapfrog the development barriers faced by this sector, Agriculture may be prioritised.
National Security	The Indian defence sector expenditure is estimated to be 3.3% of the GDP for FY2023-24	In FY 2022-23, India's defence sector exports increased over 10 times since 2016-17 to almost $ 2 Billion.	Robotic technology can be leveraged for several use cases including: • Mine Detection • Surveillance • Remotely operated vehicles • Explosive Ordnance Disposal • Combat robots	Multiple robotics use cases have been indigenously built and deployed with the Indian defence forces.	The Government of India is driving the adoption of AI in the defence sector and has allocated ~ $12.34 million to each service for AI implementation. Ministry of Defence also launched 75 AI-enabled products in 2022 at the first-ever AI in Defence (AIDef) symposium and exhibition	The sector may be prioritised given its strategic importance and the appetite for automation.

As the adoption of robotics grows and as the technology evolves in India, other sectoral priorities may be identified basis the parameters detailed above.

6.1 Manufacturing

The manufacturing sector has been pivotal to India's growth as an economic powerhouse. The government of India, through its flagship, 'Make in India' programme aims to facilitate investment, foster innovation, build best-in-class infrastructure, and make India a hub for manufacturing, design, and innovation across 15 manufacturing sectors. Domestic manufacturing of goods has also been supported through various fiscal and non-fiscal policy interventions such as public procurement orders, the Phased Manufacturing Programme (PMP), and Schemes for Production Linked Incentives (PLI) for various sectors with an outlay of about $26 billion. Tailwinds in the sector have been evidenced in the overall positive growth of Gross Value Addition (GVA) in the sector despite Covid-related disruptions. Moreover, the total employment in this sector has increased from 57 million in the year 2017-18 to 62.4 million in the year 2019-2020.

Globally, the manufacturing industry is at the cusp of major technological transformation and relocation. Evolving operational dynamics in the wake of COVID-19 and geopolitical instability require businesses to de-risk their operations. Hence decentralization of supply chains as well as the transition to Industry 4.0 and automation is being prioritized. To position itself as the manufacturing hub for the world and maintain global competitiveness, the digital transformation of India's manufacturing sector is pertinent. As per NASSCOM, Indian Manufacturing has already started to pivot towards digitization, with $5.5 - $6.5 Bn spent on Industry 4.0 in FY21.

6.1.1 Current Challenges

Despite its promising potential, the Indian manufacturing sector still faces a few challenges, including:

i. Product Quality:

Inconsistency in product quality impedes the global competitiveness of goods manufactured in India. This can be attributed to several factors including limited quality control measures, limited access to advanced technology and machinery, and a lack of standardized processes. To position itself as a global manufacturing hub, India must enforce stringent quality norms for goods manufactured within the country for both domestic and international consumers.

ii. Production Warehousing limitations:

It is difficult to hire and retain workers at warehousing facilities due to the pace of packing an increasing volume of diverse orders, safety hazards associated with lifting heavy loads etc. Additionally, given the limited availability of industrial land in India, smaller warehouses are being constructed especially close to urban centers thereby limiting inventory storage.

To improve efficiency, accuracy, and safety in industrial operations and warehousing, improve product quality and build cost efficiencies, the adoption of robots must be actively promoted in the Indian manufacturing sector.

6.1.2 Potential Use Cases of Robotics in the Manufacturing Sector

i. Logistics & Warehousing Automation:

To help mitigate/eliminate errors, speed up order fulfilment, reduce overhead and running costs, and facilitate better inventory management. Robotic technologies like an Autonomous Mobile Robot (AMR) can be utilised in production warehouses for inventory management activities such as picking, packaging, transportation, sorting, etc. Such robots utilise artificial intelligence, sophisticated sensors, and computing technologies to interpret and navigate their environment.

The rising number of warehouses across the country and increased investments in warehouse automation, along with labour availability issues and growing technological solutions are driving the use of mobile robots in warehouses. With more than 15 new-age Indian start-ups currently functioning in this field, providing optimal solutions to warehousing and logistics, mobile robots are shaping the emerging logistics industry in India. An example of this can be seen in Flipkart, India's leading e-commerce firm. Flipkart had deployed 100 robots to help sort out packages, according to their location at one of its delivery hubs in Bengaluru. The robots were able to process over 4,500 packages in an hour helping the e-commerce firm to streamline its supply chain.

ii. Shopfloor Transformation through Cobots:

Collaborative industrial robots are designed to perform tasks in collaboration with workers in industrial sectors. The automotive manufacturing sector is the largest consumer of industrial robots in India and has been leveraging cobots to streamline shop floor operations, increase worker safety and productivity and improve product quality. German auto-component maker, Bosch's Bidadi plant has cobots, or collaborative robots, working alongside humans.

Bajaj Auto, a leading Indian automotive manufacturer, deployed ceiling-mounted cobots to mitigate the challenge of space constraints in their manufacturing facility. The cobots reduce ergonomic risks faced earlier by their employees by automating highly repetitive & static posture tasks. The adoption of cobots has also led to a reduction in redundancy-led fatigue and errors.

6.2 Healthcare

The Indian healthcare sector is estimated to grow to reach a size of $50 billion by 2025. The government of India has also doubled down on its efforts toward the healthcare sector as evidenced by the increase in the share of Government Health Expenditure in the Total Health Expenditure (THE) of the country from 29% to 41.4% between 2014-15 and 2019-20.

6.2.1 Current Challenges:

The COVID-19 pandemic has shed light on the fault lines within the healthcare sector of India, including:

i. Ageing Population:

National Statistical Office (NSO)'s Elderly in India 2021 report states that there is likely to be an increase of nearly 34 million elderly persons in 2021 as compared to 2011 (104 million). This is projected to rise by around 56 million over the next decade. Therefore, there is an urgent need to augment healthcare services and infrastructure to accommodate the growth in India's ageing population *ii. Limited Infrastructure*:

As per the Rural Health Statistics 2020-21, presently, urban centers in India experience a shortfall of 44.2% of PHCs as per the urban population norms, while there still exists a shortfall of 29% of PHCs and 35% CHCs in rural India. Additionally, only 50% of the country's population has access to 35% of hospital beds. Limited infrastructure in India is one of the primary structural impediments to the accessibility of quality healthcare services.

As has also been evidenced during the COVID-19 pandemic, robotic automation has been pivotal in augmenting the capacity of healthcare services in India and providing welfare support to vulnerable and elderly communities. Additionally, given the ecosystem challenges in the Indian healthcare sector, robotic technology should be utilised to increase the accessibility and affordability of healthcare services.

6.2.2 Potential Use Cases of Robotics in Healthcare

i. Cleaning & Disinfecting Robots:

Healthcare-associated infections affect hundreds of millions of patients every year with 15% of patients estimated to develop one or more infections during their hospital stay. Robots are relevant in alleviating the workloads of health professionals in high-risk jobs like disinfecting hospital areas. Disinfecting robots utilise ultraviolet-C (UV-C) light or hydrogen peroxide vapour (HPV) for cleaning identified areas. Further, Machine learning is utilised to view the space and give proper directions to the robot and the robotic operating system manages the control between the spraying and cleaning.

Lack of adequate sanitation in healthcare facilities is responsible for the high incidence of maternal and neonatal sepsis, which also has a high fatality. Cleaning & Disinfecting Robots will augment the quality of care, operation, and maintenance of hygienic healthcare infrastructure. Moreover, the success of disinfecting robots in India is evidenced by their utilisation by both the public and private sectors in the management of the recent pandemic. Given the shortage of frontline workers and the contagiousness of the virus, disinfecting robots were pivotal in ensuring the safety of healthcare workers and the sterility of healthcare facilities.

ii. Safety & Monitoring Robots:

Telepresence systems use computer vision technology to monitor the patient’s vitals and voice recognition to communicate with the patient. Monitoring of patients through healthcare workers is enabled through two way audio visual communication. AI-assisted vision enables them to measure & take all the vitals without making any contact with the patient. COVID Pandemic has accelerated the requirement for such Robots because of the need for contactless vital sign measurements.

As has been highlighted earlier, India has a large labour shortage in the healthcare sector, across functions. So, to reduce the workload of medical staff, simpler tasks like medicine vending and parameter monitoring can be automated using robots. Additionally, given India’s increasing ageing population, old age dependency ratio, and limited healthcare facilities, robots enable round the clock real time monitoring of patient vitals remotely by healthcare workers.

iii. Surgical Robots:

India got its first urologic robotic installation at the All India Institute of Medical Sciences, New Delhi, in 2006. The following decade saw unprecedented growth in robotic surgery in India. As of 2019, India had 66 centers and 71 robotic installations with more than 500 trained robotic surgeons and over 12,800 surgeries performed with robotic assistance. With the rising demand for surgeons in India, and as more robotic surgeons get trained and surgical specialties increasingly utilize this technology, these numbers are only growing.

Robotic Surgery allows surgery to be performed using small tools attached to a robotic arm. The surgeon uses a computer system to control the robotic arm to which small surgical tools are attached. Surgery can be performed through smaller cuts as compared to conventional open surgery. The small and accurate movements that are possible with this type of surgery have a multitude of benefits when compared to standard surgical techniques. This technology enables surgeons to do complex medical procedures through a small cut that could be done only with open surgery. In India where nearly 70% of surgeries are open surgeries, as a form of minimally invasive surgery, robotic-assisted surgery allows for fewer complications, shorter hospital stays, faster recovery, smaller scars, reduced pain, and blood loss, etc.

6.3 Agriculture

In India, the contribution of the agriculture sector is vital for the economy. The agriculture sector is the largest employer of the Indian workforce, accounting for 18.8% (2021- 22) Gross Value Added (GVA) of the country and registering a growth of 3.6% in 2020-21 and 3.9% in 2021-22. Growth in allied sectors including livestock, dairying, and fisheries has boosted the overall growth in the sector.

6.3.1 Current Challenges

Despite such gains, the Indian agriculture sector faces a few structural and operational issues, including:

i. Productivity per unit of land:

Foodgrain productivity has grown at a very rapid pace in India, mainly driven by rice and wheat. However, in India, because of varying levels of mechanisation and irrigation, there is wide variation in crop productivity. Factors such as fragmented landholdings, inadequate access to irrigation, limited access to technology etc. have limited optimum productivity.

ii. Occupational Hazards:

Traditional farming in India is plagued with certain occupational hazards with significant safety and health risks to farmers. One major hazard is the excess vibrations from operating manual or outdated farming equipment which can lead to musculoskeletal disorders, such as joint pain and back problems. Inhalation of dust also poses the risk of respiratory diseases and disorders while the use of pesticides in farming practices exposes farmers to harmful chemicals, causing long-term health issues. These occupational hazards underscore the urgent need for improved safety measures and modernization in Indian farming practices to protect the well-being of farmers.

The Government of India has made multiple strides to support farmers in enhancing agricultural productivity through technological interventions such as the 'Kisan Drones' initiative. Building on this momentum, robotic automation in the agriculture sector aimed at maximising productivity and addressing safety risks to farmers' welfare, may be undertaken. A few possible use cases of robotic automation in agriculture are detailed below.

6.3.2 Potential Use Cases of Robotics in Agriculture

i. Crop scouting

Crop yields are affected by a multitude of parameters like landscapes, soil compositions, moisture, pest pressure, crop maturity, and others. Good agricultural practices need to be implemented at the right time to ensure a good crop yield. Continuous monitoring of data such as leaf area index, crop growth rate, water stress, etc. plays a critical role in optimizing the variable input parameters at different stages of crop growth. Real-time monitoring of such parameters is a tedious and nearly impossible task for a human to execute, hence robots could be considered an ideal case for such scenarios. Given the labour shortage in India, the adoption of robots can enable continuous monitoring of the crop canopy to ensure the detection of pest attacks & crop diseases at an early stage to prevent any further damage to the crop.

ii. Spot Spraying Robot:

Robot vehicles may be leveraged to spray fertilizers to multiple dense locations which may be difficult to access manually by farmers. With rapid advancements in computer vision and artificial intelligence, contemporary robotic sprayers are equipped with intelligence systems that allow selective spray of targeted areas compared to traditional mechanised uniform spraying across the crop. Utilising such robotic technologies limits the environmental impact of chemicals used, and consumer exposure to pesticides, and prevents the development of resistance to those substances by the pest.

6.4 National Security

The Indian defence sector in 2020 was estimated to be the third largest globally in terms of its military expenditure and is presently valued at $ 122.81 billion. The government of India through its concerted efforts has introduced multiple reforms to make India self-reliant in defence manufacturing and technology. However, to provide for national security in the 21st century, technological excellence must become an integral characteristic of India's military advantage.

6.4.1 *Current Challenges*

Presently, the technology-led growth of the Indian defence ecosystem is challenged by few issues, as detailed out below:

i. Border Management Limitations:

India has over 15,000 km of international borders with seven countries running through diverse terrain including deserts, marshes, plains, and mountains, which may facilitate various illegal activities. Limitations in border management are furthered by a lack of critical infrastructure like observation towers, bunkers, border flood lights, etc which hinders the deployment of hi-tech equipment.

ii. Information and Intelligence Asymmetry

There is a need for real-time intelligence collection, analysis, and appraisal, which needs to be technology-enabled to be real-time given India's multi-agency defence system. To ensure quick decisions in critical security-related matters, it is necessary to introduce technological interventions to cut down unnecessary delays.

To address these challenges, robotic automation in the defence sector may be an integral step toward securing India's national security objectives.

6.4.2 *Potential Use Cases of Robots for National Security*

i. Mine Detection UGVs:

Minefield breaching has traditionally relied on manual practices, procedures, and drills, which are slow and labour-intensive. In the Indian context, the existing system that is being used to carry out minefield breaching is that of trawl tanks. These trawl tanks move in tandem into the minefields and blast the mines when the rollers travel over them. These tanks are redundant over anti-tank mines. There is a lot of delay and effort involved in replacing such trawl tanks which are damaged by such mines during breaching.

Mine detection UGVs, as demonstrated by India's own "Sapper Scout" UGV, are capable of detecting mines and marking mines using an illuminating spray. The UGV has a tracked platform enabling it to move cross-country on all kinds of terrain. Models also consist of a 5-axis robotic arm for cutting the trip wires of fragmentation mines. The UGV has 3 different cameras – one for accessing the detected mine, the second for the mobility of the UGV, and the third for a 360-degree recce of the environment.

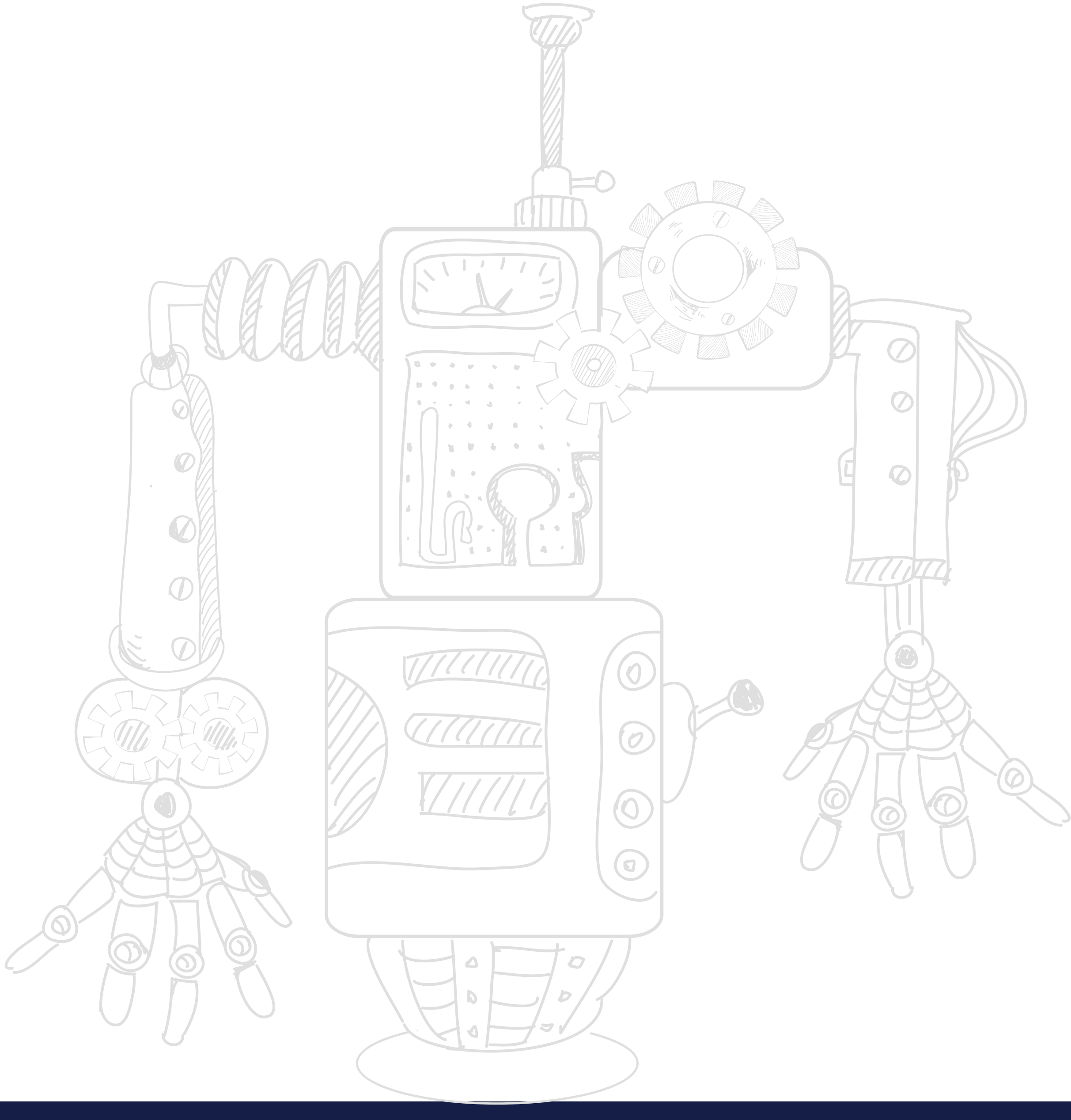
ii. Surveillance Robots:

AI-based surveillance robots are being developed by countries like South Korea and Israel for manning border fences. There is a need to utilise robots and AI for covering gaps in Anti Infiltration Obstacle Systems (AIOS) as well as perimeters of units and installations to create deterrence and enhance the surveillance grid.

India’s Defence Research and Development organisation is developing “Silent Sentry”, a fully 3D-printed rail-mounted robot that slides on a rail that can be installed on fences and AIOS. The robot can be controlled from computers/tablets and Android applications as well as function autonomously within set limits. The robot enables AI-based object detection, autonomous and full-time patrolling, and automatic intrusion detection.

iii. Remotely Operated Vehicle (ROV)

Remotely Operated Vehicles (ROVs) are highly advantageous inspection tools due to their ability to access confined and perilous areas, expedite underwater field inspections, and enhance overall productivity. ROVs play a pivotal role in bomb disposal operations by mitigating human involvement and minimizing potential casualties. They also hold significant importance in counter-insurgency efforts, providing advanced area mapping through their onboard cameras. Moreover, ROVs can be utilized for hostage rescue missions, furnishing critical intelligence on hostile elements and possessing the capability to discharge ammunition.



7

STRATEGIC RECOMMENDATIONS

To enable India's emergence as a global leader in the development and adoption of robotics, a comprehensive, coherent, and efficient deployment of the National Strategy on Robotics may be undertaken as the 'National Robotics Mission'. In the implementation of this mission, a whole ecosystem approach is to be adopted while building strong linkages with industry, academia, and startups, to drive economic growth and a better quality of life through robotics.

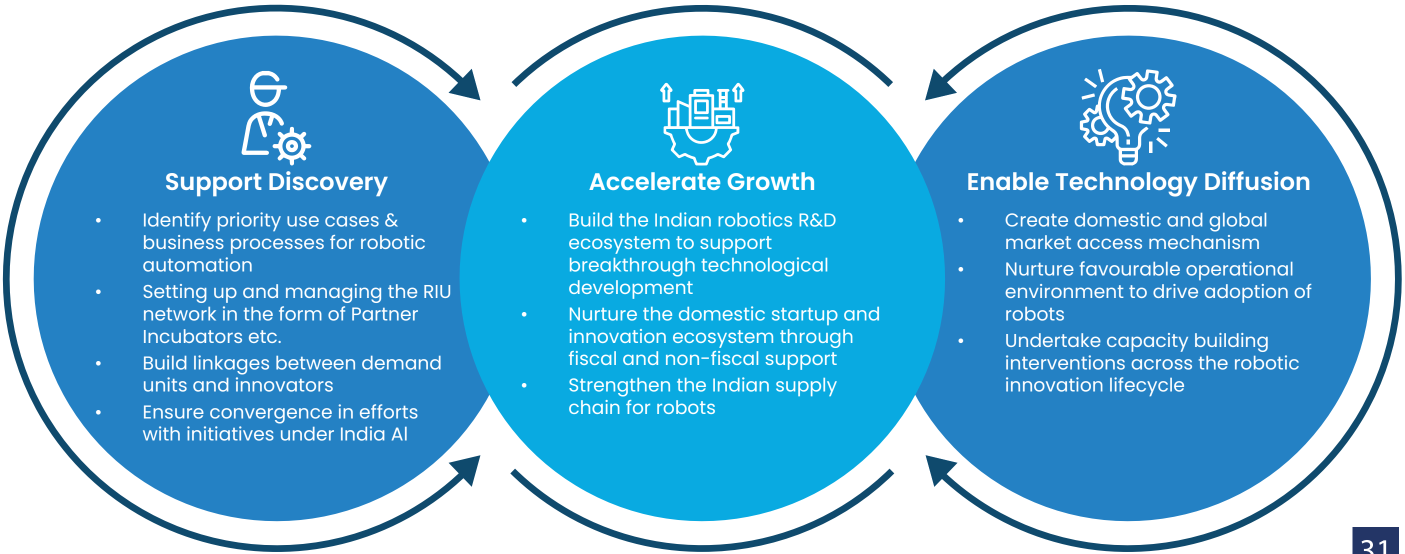
The National Robotics Mission is poised to be an integral part of India's overall vision for India AI and will help India position itself as an early leader in the field of intelligent cyber-physical systems. It is aligned with India's overall AI vision of promoting the adoption and development of AI-enabled technologies across various sectors, such as healthcare, agriculture, manufacturing, and national security.

7.1 Institutional Framework

To ensure streamlined implementation of the National Strategy on Robotics through a whole of ecosystem approach, an agile and highly responsive institutional framework is proposed. The proposed framework will aim to nurture the dynamic robotics startup, research, and innovation ecosystem in India by building synergies with the industry, innovators, and other pertinent stakeholders.

7.1.1 Robotics Innovation Unit:

The Robotics Innovation Unit (RIU) will be an independent agency institutionalized under the Ministry of Electronics and IT as a part of India AI, to lead the implementation of the National Strategy on Robotics. RIU will aim to create a robotics ecosystem that fosters innovation, supports technology development, and drives adoption by engaging the industry, MSMEs, start-ups, individual innovators, R&D institutes, academia, and government organizations. It will facilitate the creation of domestic capabilities across the robotics value chain through funding and other institutional support. The RIU will have a specialized team of technical experts, innovation specialists, etc. to undertake implementation.



A governance mechanism may be envisaged to oversee the overall implementation and provide strategic direction aligned with the National Strategy for Robotics.

7.2 Building the Indian Robotics Ecosystem- Recommendations

To ensure the creation of domestic capabilities and capacity across the innovation lifecycle of robotic technology, a four-pillar approach is adopted. To achieve its objectives, the Robotics Innovation Unit may undertake the implementation of the proposed interventions in collaboration with relevant line ministries/departments.

7.2.1 Research and Development:

To build the foundation of the Indian robotics ecosystem a robust R&D ecosystem needs to be nurtured. Continuous engagement with public and private sector demand aggregators should be ensured, to source potential topics, and problem statements/project definitions to align funding and research priorities as well as establish stakeholder buy-in. This will ensure the alignment of research priorities with ecosystem requirements and technological developments

Potential programmatic interventions that may be leveraged for this objective include:

i. Centers of Excellence in Robotics:

- **Strategic Orientation:** A network of Centers of Excellences (CoEs), both new and existing, may be established to undertake both foundational and applied research and development in robotics. The CoEs undertaking foundational research may aim to create new knowledge and nurture technical expertise to prepare India for the next generation of robotic technologies. Application-based research may be undertaken by CoEs through private sector intervention to solve for applications in priority sectors and support experimental prototyping, as well as small-volume production (for the initial phase of commercialization).

- **Operational Model:** A consortium of new/existing Centers of Excellence in robotics at select locations may be funded to strengthen research and development in robotics in India. The triple helix model of innovation may be adopted to capitalize on the specific expertise of the industry, government and academia. Academia may contribute by generating new knowledge and nurturing technical expertise, the industry may enable market orientation and resources for implementation, while the government would provide the underlying supporting mechanisms to enable collaboration through resources, policies, supply of research priorities/problem statements. This reciprocal relationship will enable interdisciplinary collaborations for technological advancements in robotics, market access, and sustainable economic development. The COEs established should operate in a hub and spoke model with a new/existing COE which will converge efforts of other centers in robotics, AI, and cyber physical systems to enable knowledge transfer, aggregate resources and accelerate innovation in the Indian robotics industry. With state-of-the-art shared infrastructure, the COEs would provide access to prototyping equipment, labs, experiential centers, demonstration and testing facilities, and other robotic resources. Additionally, given the interdisciplinary nature of robotics, a network of experts from across academia and industry both domestically and internationally may be facilitated to mobilise complementary expertise from traditionally distinct domains to address ecosystem requirements.

- **Research Priorities:** To accelerate research around India's national priorities, research grants would be given to projects aligned with the below-mentioned research priorities:
  - Build and design indigenous hardware and software components of industrial and service robots for use cases of national importance.
  - Re-envision architectures and design realizations to improve robot functionality like perception, vision, locomotion, planning, control, etc
  - Build Robots that safely operate alongside human beings by reenvisioning autonomy, adaptability, and evolution in intelligence.

ii. Moonshot Projects:

To achieve leadership in Robotic automation, India must undertake ambitious and groundbreaking exploratory research through mission mode 'moonshot projects'. These projects must aim to push the robotic technology frontier through convergence with Artificial Intelligence to enable large-scale social transformation. They must not be mere extensions of existing research but futuristic ideas that meet the currently unfulfilled needs of users or a disruptive technological trend/scientific area that offers the potential to address critical and practical problems in innovative ways. The research ambitions of the 'moonshot projects' must aim to attract top global talent across disciplines such as engineering, design, law, industry, startups, etc. to collaboratively solve complex problem statements.

COEs identified as a part of the hub and spoke model may propose Moonshot projects which may be structured with well-defined timelines and funding mechanisms, implemented through a portfolio approach.

iii. Higher Education and Research:

Robotics cuts across engineering disciplines like mechanical, electronics, and communications and requires specialized knowledge and training. Therefore, dedicated engineering degrees in robotics are required for undergraduate, postgraduate, and doctorate programs across all higher education institutions. To keep pace with rapid technological advancements in robotics and nurture interdisciplinary collaboration for robotic innovation, the design ecosystem in India must also be strengthened. To support this, curricula of 'Industrial Design' and 'Product Design' in undergraduate and postgraduate courses may include core or elective courses in robotics as well as dedicated postgraduate degrees in robotics design may also be introduced in national design institutes across the country. The Centers of Excellence may also facilitate the training of researchers through Fellowships in collaboration with industry and academic partners both domestically and internationally.

7.2.2 Demonstration and Testing:

Given the capital-intensive nature of robotics automation, organisations, especially MSMEs are often risk-averse to adopting such technologies. To solve this bottleneck, demonstration/field verification are necessary to validate product reliability. Collaborations with major demand units may be facilitated to jointly develop and undertake demonstrations, provide test platforms, and officially promote applications based on field verification and demonstration results

Potential policy and programmatic interventions that may be leveraged for this objective include:

i. Demonstration Centres:

Demonstration centers may be established to serve as platforms for industry, academia, and the public to experience the latest developments in robotics and explore their potential applications. These centers will enable an interactive experience where visitors can control and operate various robots. This experiential learning will be pivotal to nurture trust in robotic technology for investors, industry and the public at large, enabling large scale adoption of robots. It will also allow researchers and innovators to validate novel innovation and use cases in real life scenarios to further refine their innovation. The existing infrastructure of Atal Incubation Centres and Robotics COEs co-located in various colleges / educational institutes across India may be leveraged for demonstration facilities. Additional investments may be made to further build infrastructure facilities for demonstration and testing.

ii. Robotics Innovation Testbeds:

As robotics continues to expand to more application domains, theoretical research is often not adequately translating to large scale application deployments. To address this bottleneck, testbeds are utilised in the development and deployment stage of a technology which includes Technology Readiness Level (TRL) 4-7. The testbed may support innovators with funding, access to physical and virtual infrastructure, knowledge dissemination and capacity building, and partnership support. This policy instrument is uniquely positioned to enable the development of new or improved products and services, evidence-based formulation/amendment of regulations, and market access by building product reliability. The testbeds may also be utilised as remote access shared infrastructure. The proposed testbeds can be co-located with existing testbeds established for 5G use cases.

iii. Regulatory Sandboxes:

These are policy instruments that facilitate live testing of breakthrough innovations in a controlled market-like environment, often under relaxed regulatory conditions. The regulatory sandbox allows the testing of novel technologies and methods in a real-life situation with the involvement of the innovator, the customers, and the regulators. Given the ethical constraints of robotic technology and the limited standards and regulations in India presently, the sandbox will provide evidence for the government to formulate and redesign regulations and policies and ensure alignment with industry needs and technological developments.

iv. Standards and Certification:

Establishing standards for robotic technologies contextualised to the domestic ecosystem requirements is imperative to ensure that robotics products and services meet certain quality and reliability benchmarks, work seamlessly with other products and services, as well address security and privacy risks. Additionally, conformity assessment infrastructure may be augmented to provide domestic and global market recognition to indigenous robotic technology and ensure alignment with global standards and regulations. Indian standard setting bodies would also be encouraged to collaborate with global counterparts to ensure global recognition of indigenous products and enable market access.

7.2.3 Commercialisation of Innovation and Supply Chain Development:

Given the high costs and entry barriers associated with the robotics industry, product commercialisation support through various funding channels is required to enable market entry. Moreover, to scale production for domestic and global markets, targeted investments are required to localise the robotics supply chain and increase domestic value addition.

Potential policy and programmatic interventions that may be leveraged for this objective include:

i. Funding Innovation

- Pilot Programmes: Funding support may be extending for running a pilot program to develop localized technologies for industrial and service robots, and related components and software for large-scale, specialized and emerging applications. Problem statements sourced from public and private sector demand units may be utilised for creating sector specific use cases through a Challenge method or Hackathons. Innovative solutions for India-centric applications of economically viable but high performing robots must be identified. A focus on enhancing the quality and productivity of robotic products and processes and enabling the reduction of product and process costs may be prioritised.

- Alternative Funding: Given the resource intensive nature of developing and scaling robotic innovation, it is pertinent that suitable funding mechanisms be modelled to aggregate resources and support novel robotic technology. Feasibility of other innovative funding mechanisms such as fund of funds, industry mentorship programs, etc may be explored for commercialising robotic technology and nurturing the startup ecosystem.

ii. Startup Advisory Support

Institutional support may be extended to nurture the start-up ecosystem, providing support for the entire range of value added IPR support services like sensitization, protection, and compliance of generated IPs. Additional support through market access, partnerships, mentorship, etc. may also be provided.

iii. Development of Robotics Industrial Zones

Investment in developing industrial infrastructure will be critical in addressing the cost of disabilities associated with manufacturing robotics and its limited adoption in the country. Cluster-based agglomeration supports regional economic growth and integrated Robotics Manufacturing Zones could therefore be established in proximity to end-user industries. Subsidizing critical infrastructure and investing in integrated production facilities will improve accessibility, augment product reliability and support the integration of MSMEs and startups in the robotics supply chain. Therefore, land and other utilities may be provided to robotics manufacturers across the supply chain at a subsidized cost through Plug and Play facilities and Common Facility Centres to ensure better productivity, innovation, and participation.

iv. Fiscal Incentives and Policy Measures

Multiple incentive and policy measures are proposed to accelerate manufacturing of robots in India and enable integration with global value chains.

- **Production incentives:** To position India as the manufacturing hub for robots, design led manufacturing may be incentivized to accelerate production of robots and robot accessories. In line with the existing design-linked, production-linked or capex-linked schemes of the Government of India, suitable incentive mechanism may be formulated to offset ecosystem costs and high capex requirements of the robotics industry. These incentives will aim to build a globally competitive manufacturing ecosystem for robots in India by supporting the domestic industry, increasing value addition and attracting global value chains.

- **Trade Incentives:** To enable Indian robots to be globally competitive, export-oriented incentives may also be considered. Additionally, duty structures may be rationalized to promote indigenous manufacturing of robots, its assemblies / sub-assemblies, and parts / sub-parts / inputs of the sub-assemblies and accessories. A roadmap may be prepared in consultation with industry to analyse the tariff structures for robots and build a tariff schedule to progressively increase economies of scale and value addition in India. This will ensure policy stability and thereby support planning considerations for manufacturers in India.

- **Ease of Doing Business measures:** A conducive business regulatory environment is critical to promote the manufacturing of robots in India. Ease of doing business policy measures such as a single window system for facilitating all licenses and clearances for robot manufacturing in India would further attract investments and increase domestic value addition.

v. Technical Training

The growing applications for robotic devices and systems beget the wide range of knowledge and skills that robotics professionals require. It is critical to identify and promote job opportunities in emerging fields of robotics which can potentially absorb a significant portion of the workforce that may be displaced due to the rise of automation. Additionally, upskilling and reskilling initiatives are essential for the advancement of the Indian robotics industry which faces a shortage of technicians with specialized training in foundational skills, including the repair and maintenance of robots. National Occupation Standards and Qualification Packs, validated by the industry and aligned with the National Skills Qualification Framework, may be established by the Sector Skill Council for identified job roles in the robotics industry. Workers may be incentivised through subsidised training/certification and apprenticeship programs for the identified job roles to impart technical as well as regulatory qualifications. This may be curated in partnership with industry to facilitate experiential learning and facilitated through ITIs/Polytechnics/other government/private-funded training infrastructure. Given the interdisciplinary specialization required, infrastructure upgradation of these institutions would also be needed to ensure effective practical training.

7.2.4 Adoption and Awareness

To support the proliferation and penetration of robotic technology, targeted demand-side interventions may be introduced. Information dissemination strategies may also be curated to increase technology awareness across demographics and augment the adoption of robots. Potential policy and programmatic interventions that may be leveraged for this objective include:

i. Market Expansion Levers:

For the growth and sustainability of the Indian robotics ecosystem, it is important to identify and create new market opportunities. Market expansion mechanisms may also serve to encourage competition to improve product quality and augment accessibility to robotic automation across the country. These measures can help address market failures, foster innovation, and promote economic growth and development.

- **Public Procurement:** Through a Public Procurement Policy for Robotics, the Government of India can also position itself as a demand aggregator and build public trust in robotic systems manufactured in India. The policy will aim to incentivize domestic production over mere import or assembly of products by enabling purchase preference for suppliers who meet the minimum local content requirement. Procurement of robots will be standardised for all Central Ministries/ Departments / Agencies and will be governed through this Policy.

- **Technology Adoption Plan:** A Technology Adoption Plan may be formulated to identify use cases across priority sectors that have the potential of being automated through robotics by 2030. A series of workshops may be organised by different line ministries/departments to identify concrete use cases and evolve sector-specific strategies and milestones. This will have direct economic benefits by enabling market creation for priority use cases and spillover effects of increasing adoption of robots through widespread access.

- **Robot Utilization Plan:** A Robot Utilization Plan may be formulated to enable aggregation of demand and diffusion of robotic technologies for selected industries. Through collaboration with industry partners and the Robotics COE's detailed above, models for utilization of robots for selected business processes may be undertaken. These processes may be identified on the basis of multiple parameters including risky/unsafe (prone to industrial accident) working environments, low productivity, clean manufacturing, insufficient manpower etc. To support the uptake of robotic technologies for the identified business processes as per the Robot Utilization Plan, demonstration centers can also be utilised. Additionally, the RIU in consultation with industry associations and System Integrators may also provide advisory support to startups and enterprises on process analysis, designing the process of automation, improvement of production technology, management assistance in the introduction of robots etc.

- **Financial Incentives:** To support the implementation of the Technology Adoption Plan and the Robot Utilization Plan, organisations could be provided financial assistance for the adoption of robotic technology. In sectors of strategic and social importance- lease or rental assistance could also be extended to the end user to improve accessibility and adoption of robots. Further, subsidies and exemptions in certification costs for early stage-startups and MSMEs may also be extended. These benefits may be facilitated through existing technology upgradation schemes by prioritizing the adoption of robotic technology for automation.

- **International Immersion Programs:** Indian robotic innovation should be globalized by enabling cross-fertilization of ideas with matured markets. Targeted programs may be institutionalised to help Indian start-ups and MSMEs access new markets, build global networks and collaborate with other robotics startups/MSMEs internationally. These programs may facilitate visits to other countries where start-ups and MSMEs can meet with potential partners and customers. Institutional support may be provided for Indian robotics start-ups and MSMEs, such as market analysis and business intelligence data.

ii. Governance Mechanisms:

Establishing guidelines and requirements for the security, privacy, and liability assessment and assignment for robotic technologies is also pertinent to augment the adoption of robotics. This could involve requirements for data encryption, secure authentication, secure data storage, as well as compliance with all relevant legislation and policies. A framework for the ethical use of robotics systems and Robotic Process Automation (RPA) may also be developed to preserve the rights of individuals. The framework should ensure that the use of robotics systems and RPA is fair and transparent and that all stakeholders are aware of how these technologies are being used and how they may be impacted. Additionally, governance mechanisms must also be established to address the social implications of the widespread adoption of robotics, including measures to mitigate job losses, re-skill workers, and address any potential societal disruptions. Both outcome-based and risk-based regulation may be adopted for the governance of robotics technology depending on the specific technology, its potential risks, and the desired outcomes. Governance mechanisms must be designed to be flexible enough to adapt to the expanding capabilities of robots, new use cases, and novel forms of human-robot interaction while also incorporating robust consumer protection frameworks.

iii. Awareness and Capacity Building

- **Capacity Building:** Given the rapid advancements in automation, it is pertinent to insulate our workforce to potential technological disruptions and nurture robotic innovation in India. Supplementing the STEM curricula of schools with coursework on robotics, automation, and mechatronics will be essential to build a foundational understanding of the technology. To enable this, the infrastructure and network of existing schemes such as Atal Innovation Mission and the Department of School, Education & Literacy's Samagra Shiksha Abhiyan may be leveraged to train and mentor interested students to design and develop projects using robotic technology related to their coursework. Schools and colleges may organize robotics competitions providing recognition and rewards to encourage students to learn robotics and apply their skills in a competitive setting. It is also important to provide teachers with the necessary training and resources to be able to effectively incorporate robotics into their classrooms. This may include leveraging ongoing initiatives for digital skilling such as FutureSkills Prime.

- **Showcase and Exhibitions:** Promotion of breakthrough technologies developed in India and building awareness through experiential learning with annual international showcases/exhibitions may be undertaken. This would also provide a platform for roboticists in research and industry globally to debate and discuss technical challenges and technological development. Marketing assistance incentives can also be extended to MSMEs and startups for participation in such international exhibitions and trade fairs.

iv. Network Connectivity:

Investments in communication infrastructure development and access to low latency cellular technologies are essential for the mass adoption of robotics. Continued connectivity enables robots to exchange information needed in collaborative tasks, and allows monitoring or manual control by operators. For example, 5G can enable robots to communicate with each other and with other devices more reliably and with lower latency, which can improve the performance of robotics systems. 5G networks are much faster than previous generations of cellular networks, which can be beneficial for robotics applications that require large amounts of data to be transmitted quickly. It can enable robots to transmit high-resolution video streams and other data-intensive applications.

CONCLUSION

Global market driving forces have pushed companies to restructure business models to prioritise both cost efficiencies and supply chain security, as evidenced by the increased adoption of automation. Capitalizing on the potential of this technology, globally, both the government and private sector are investing in robotic automation systems to augment economic productivity and catalyse social transformation.

The National Strategy for Robotics is, therefore, an important foundational step as part of the government of India's overall AI strategy to keep pace with technological development, mitigating risks and devising a strategic plan to actualise the potential of this technology. It is an imperative step for the development and diffusion of robotics and intelligent cyber-physical systems in India to establish global recognition in robotics across the manufacturing, agriculture, healthcare, and national security sectors.

The strategy assesses the long-standing challenges faced by critical sectors of our economy and highlights the potential of robotic automation in addressing these impediments. Strategic interventions have been identified to address the key deterrents to robotics innovation in India today and enable the utilisation of this technology for achieving sustainable development and large-scale social transformation. It focuses on strengthening all pillars in the innovation cycle of robotic technology, while also providing a robust institutional framework for ensuring the effective implementation of these interventions. A whole-of-ecosystem approach is adopted to ensure the engagement of all relevant stakeholders to drive innovation, development, deployment, and adoption of robotic technology in India.

Overall, the strategy aims to bring about a paradigm shift in the field of Robotics for India and enable the country to become a global leader in the research, design, development, and manufacturing of robotics. The Ministry of Electronics & IT (MeitY) will work with various Government organizations and other stakeholders in implementing this strategy and maximising the transformation potential of Robotics for India.

The National Strategy for Robotics is an evolving document and may be revised in the future to ensure alignment with market conditions.

REFERENCES

1. World Robotics Report, 2022 (World Robotics Report 2022)
2. 2022 McKinsey Global Industrial Robotics Survey (https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/unlocking-the-industrial-potential-of-robotics-and-automation)
3. India's Robot Wonder (https://ifr.org/ifr-press-releases/news/indias-robot-wonder)
4. India's Robot Boom Hits All- Time High (https://ifr.org/ifr-press-releases/news/indias-robot-boom-hits-all-time-high)
5. ARTPARK (https://www.artpark.in/)
6. I-HUB Foundation for Cobotics (IHFC) – IIT Delhi (https://www.ihfc.co.in/)
7. DRDO(https://www.drdo.gov.in/)
8. FutureSkills Prime (https://futureskillsprime.in/)
9. Robotics in India (https://journalsofindia.com/robotics-in-india/?print=pdf)
10. PIB (https://www.pib.gov.in/PressReleasePage.aspx?PRID=1882145)
11. India Industry 4.0 Adoption: A Case to Mature Manufacturing Digitalization by 2025 (https://community.nasscom.in/index.php/communities/industry-40/india-industry-40-adoption-case-mature-manufacturing-digitalization-2025)
12. Rural Health Statistics 2020-21 (https://main.mohfw.gov.in/newshighlights-90)
13. Elderly in India 2021 (http://www.indiaenvironmentportal.org.in/files/file/Elderly%20in%20India%202021.pdf)
14. Investment Opportunities in India's Healthcare Sector (https://www.niti.gov.in/sites/default/files/2021-03/InvestmentOpportunities_HealthcareSector_0.pdf)
15. WASH in healthcare facilities (https://www.unicef.org/india/what-we-do/wash-facilities#:~:text=Healthcare%2Dassociated%20infections%20affect%20hundreds,et%20al.%2C%202011)
16. Robot Assisted Surgery in India: SWOT Analysis (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6961426/)
17. Farm mechanisation: Ensuring a sustainable rise in farm productivity and income (https://ficci.in/spdocument/23154/Online_Farm-mechanization-ficci.pdf)
18. Trends in World Military Expenditure (https://sipri.org/sites/default/files/2021-04/fs_2104_milex_0.pdf)
19. Defence Expenditure (https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1895472#:~:text=Of%20this%2C%20Ministry%20of%20Defence,the%20Budget%20of%202022%2D23.)

20. AiDef (https://www.ddpmod.gov.in/sites/default/files/ai.pdf)
21. Application of Robotics in Agriculture-An India Perspective (https://www.researchgate.net/publication/342096836_Application_of_Robotics_in_Agriculture_An_Indian_Perspective
22. Economic Survey 2022-23 (https://www.indiabudget.gov.in/economicsurvey/doc/echapter.pdf)
23. State of AI in India 2022 (https://analyticsindiamag.com/the-state-of-ai-in-india-2022/)
24. Industrial sector facts: (https://pib.gov.in/PressReleasePage.aspx?PRID=1894918#:~:text=The%20Overall%20Gross%20Value%20Added,Union%20Minister%20for%20Finance%20%26%20Corporate)
25. How AI will transform Indian agriculture. (https://indiaai.gov.in/article/ai-impact-on-india-how-ai-will-transform-indian-agriculture)
26. Agriculture sector facts: https://pib.gov.in/PressReleasePage.aspx?PRID=1894900
27. AI for agriculture: How Indian farmers are harnessing emerging technologies to sustainably increase productivity (https://www.weforum.org/impact/ai-for-agriculture-in-india/
28. Defence Export Facts (https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1912885)
29. Artificial Intelligence in Robotics (https://ifr.org/downloads/hidden/IFR_Artificial_Intelligence_in_Robotics_Position_Paper_V02.pdf?utm_source=CleverReach&utm_medium=email&utm_campaign=Paper+Download&utm_content=Mailing_12323895)
30. Health Expenditure Estimates (https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1919582)
31. Understanding the new five-year development plan for the robotics industry in China (https://ifr.org/post/understanding-the-new-five-year-development-plan-for-the-robotics-industry-in-china)
32. China to boost density of manufacturing robots (https://english.www.gov.cn/statecouncil/ministries/202301/20/content_WS63c9d296c6d0a757729e5e28.html)

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