Innovation Insight Study

Digital Manufacturing and Connected Supply Chains

June 2023

This report was written in 2022 and the information contained within this report remains correct at the time of production.

Contents

Glossary

AI	Artificial Intelligence
AM	Additive Manufacturing
BIBCOL	Bharat Immunologicals and Biologicals Corporation Limited
CoE	Centre of Excellence
DBT	Department of Biotechnology
DDP	Department of Defence Production
DHI	Department of Heavy Industry
DIO	Defence Innovation Organisation
DPIIT	Department for Promotion of Industry and Internal Trade
DPP	Defence Procurement Procedure
DRDO	Defence Research and Development Organisation
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
DTIS	Defence Testing Infrastructure Scheme
DTTC	Defence Technologies & Test Centre
e-AMRIT	Accelerated e-Mobility Revolution for India's Transportation
EMC	Electronics Manufacturing Clusters
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GITA	Global Innovation and Technology Alliance
GoI	Government of India
GW	Gigawatt
ICMR	Indian Council of Medical Research
iDEX	Innovations for Defence Excellence
IMPRINT	Impacting Research Innovation and Technology
IoT	Internet of Things
LiBs	Lithium-ion Batteries
MEITY	Ministry of Electronics and Information Technology
MNRE	Ministry of New and Renewable Energy
MoD	Ministry of Defence
MoHFW	Ministry of Health and Family Welfare
MRI	Manufacturing Risk Index
MSME	Ministry of Micro, Small and Medium Enterprise

MST	Ministry of Science and Technology
NATRiP	The National Automotive Testing and R&D Infrastructure Project
NDCP	National Digital Communications Policy
NM-ICPS	National Mission on Interdisciplinary Cyber-Physical Systems
NPE	National Policy on Electronics
NRF	National Research Foundation
OFB	Ordnance Factory Board
PLI	Production Linked Incentive
PSA	Principal Scientific Adviser
PV	Photovoltaic
SAMARTH	Smart Advanced Manufacturing and Rapid Transformation Hub
SERB	Science and Engineering Research Board
SIP-EIT	Support for International Patent Protection in Electronics and & Information Technology
SME	Small to Medium-Sized Enterprise
SPECS	Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors
TCOE	Telecom Centres of Excellence
TDB	Technology Development Board
TDF	Technology Development Fund
TIDE	Technology Incubation and Development of Entrepreneurs
UGC	University Grants Commission

Executive Summary

The UK and India have close economic and social relations. India is the UK's second-largest investor. About 850 Indian enterprises in the UK generated USD 67 billion in revenue in 2021, employing around 116,000 people. As of September 2021, the UK is India's sixth-largest foreign investor[1], with a total investment of approx USD 31 billion. Beyond being natural partners, both countries are a force for good against climate change and are already working in close cooperation on a range of essential issues such as defence, health, climate change, and trade[2].

The UK aims to consolidate and develop itself as a global hub for innovation, while India wants to leverage its scientific and innovation strength to drive its aim of becoming the global manufacturing hub and an important participant in global value chains. The role and application of digital tools within manufacturing and supply chain management offer powerful resources to enable the Indian manufacturing sector to become increasingly competitive with its global peers. Research and innovation collaborations between the UK (major research power) and India (one of the fastest-growing economies with the third-largest scientific and technical workforce) can drive shared prosperity and advance common development goals. Solutions built through a collaborative approach have the potential to be scaled at a global level.

Innovate UK KTN commissioned Finovista, India, and Unconventional Connections, UK, to conduct an Innovation Insight Study on Digital Manufacturing and Connected Supply Chains. The study aims to provide a holistic understanding of the potential scale of collaboration between India and the UK. As part of this study, we took a rapid review of India's manufacturing sector to get a broad understanding of its technological status, and the extent of adaptation of automation in the processes. The key insights from the study are:

- **Challenges and barriers to the adoption of digital technologies:** In India the capital equipment is in the pre-industry 3.0 era. Therefore, efforts are being made to build in the intermediary level that will allow small to medium-sized enterprises (SMEs) to reach a maturity level that will help them to become Industry 4.0-enabled. Indian companies, especially SMEs, face many challenges in their journey towards automation and becoming Industry 4.0-enabled: costly and complex solutions for retrofitting the legacy machines, standards for industry 4.0-enabled capital equipment are not defined, interoperability of solutions, solutions fail to demonstrate clear benefits and justify the return on investment (ROI), low awareness of automation solutions, poor digital infrastructure and a shortage of skilled workers.

- **Supply chain automation:** Vendor diversification for de-risking is a global trend following the COVID-19 pandemic. However, with multiple suppliers, the market would add many complexities to the large corporates, especially original equipment manufacturers (OEMs) and also for the Tier 1 or 2 vendors, as they need to align with the processes of their OEMs, to ensure quality and flexibility production systems are in place. This necessitates the requirement and the application of Industry 4.0 concepts.
- **Industrial digital technologies - emerging application areas:** In the Indian context, removal of non-value-added activities, reduction in material wastage, energy saving, and reduction in time taken in a process should be the priority, as all of these result in cost reduction and improved productivity. Track-and-trace, AI and cognitive learning, robotics and process control, data aggregation and analytics, and preventive maintenance solutions have a high use case. Furthermore, solutions that could be implemented on a single process and scaled up gradually would have a high impact on ROI.
- **Key enablers and opportunities for automation:** Increasing emphasis on innovation to create competitiveness initiatives by the Government of India (GoI) through enabling policies, fund flow towards R&D, growing a technology-driven start-up ecosystem, and improved digital infrastructure making remote connectivity possible. Further, COVID-19 has accelerated automation, which has emerged as a key priority to enhance competitiveness.
- **Sectors with emerging opportunities:** We reviewed six sectors under the scope of this study; the emerging opportunities of each sector and possible collaborations are captured in this report.
- **Research and innovation:** In India, the research focuses on software solutions for digital manufacturing, not hardware design and development, which is generally imported. It is also a fact that the Indian Centre of Excellence is mostly engaged or collaborating with the multinational corporations in their R&I work, and not the SMEs. Besides the non-availability of finance, the lack of awareness about the short-term and the long-term gains of digitisation and innovation is the main barrier. Digitisation can help small enterprises create a presence in the local and global markets by acquiring new clients through ecommerce. IT tools, methods like digital production planning and supply chain solutions, would help enhance their operational efficiency and enable SMEs to interact with knowledge networks on virtual platforms. Schemes like ASPIRE, run by the Ministry of Micro, Small and Medium Enterprises (MSME), could be replicated for the manufacturing sector to promote innovation by setting up incubation centres and a network of technology centres.

Potential Areas of Collaboration

Our study highlights potential areas for collaboration in digital manufacturing and connected supply chains. These include a range of themes and specific collaborations across industry sectors:

- **Low-cost automation solutions:** Opportunities for both countries to work together on developing appropriate and cost-effective solutions for achieving automation in the production process. This collaboration needs to address three needs:
  - **Deep collaboration** that brings together sophisticated algorithms with a realistic understanding of the manufacturing context.
  - **Hardware**. For upgrading the legacy machines in the production line, a smart box–plug-and-play solution to convert legacy equipment into smart equipment would be preferred on cost considerations.

  - o **Software**. Open-source, cloud-based subscription technologies that would be affordable for SMEs may provide a solution to the high cost of automation. These could be offered in the form of a monthly or annual per-machine subscription basis. Collaborative research is recommended for building a common open-source platform that should be made available to all, for building open-source automation solutions.
- **Joint standards development:** The UK and India could work together to develop joint standards for Industry 4.0, harmonising them with global standards. This would give a major impetus to the Indian companies, especially SMEs, in gaining clarity on such non-tariff barriers, as often Indian SMEs do not meet certain regulatory standards set in the UK. Joint capacity building workshops for the Indian industry to raise their awareness about UK standards may also be organised.
- **Skilling:** The institutions in this domain and their participation towards improving the skill up-gradation ecosystem for the manufacturing sector in India will help aid with substantial adjustment in terms of the quality of the trained workforce.
- **Data analytics:** Both countries can work together to develop data analytics platforms for Internet of Things (IoT) applications (end-to-end platforms), which are integrated with commercially available IoT devices.
- **High-value manufacturing:** The UK's manufacturing sector is a very high-value manufacturing sector with unique challenges where the quality needs to be controlled diligently, and the system needs to be flexible i.e. moving from one product type to another and having a high level of customer engagement. India could work with the UK in addressing these challenges by leveraging its software expertise. Further, since the UK is much further ahead in high-value manufacturing, it can work with India on the same.
- **Cybersecurity:** It is a global issue, and both India and the UK face similar challenges, thus making a strong case for collaboration aligned to the existing Framework for the UK-India Cyber Relationship.[3]

Emerging opportunities - sector approach: We have identified several sectors that are the focus of major investment and have substantial requirements for digitisation. Indian manufacturing, being at the high-value end, represents a good prospect for investment in the latest technologies from the UK. We have also seen that the demands of business customers for products from smaller manufacturers in the supply chains of major OEMs can drive investment in digital solutions. We recommend that further investigation into the specific needs be addressed through collaboration. The key emerging opportunities from these sectors are as follows:

- **Defence and aerospace.** The UK can work to help India in the localisation of aircraft engine components more efficiently and quickly. The SMEs from both countries could work together to tap into the large domestic (India) and global demand.
- **Automobile.** The battery and battery management system (BMS) is critical in electric mobility. It promises a great area for research collaboration on fuel cells as India aims to look beyond lithium-ion batteries (LiBs).
- **Renewable energy.** Joint research on low-cost solar technology solutions. UK companies manufacturing solar photovoltaic (PV) cells and modules in the UK can work with Indian companies to manufacture these at scale.
- **Electronics.** Collaboration to develop low-cost and trusted solutions on the scale for the world and India's domestic market. Further, both countries could work together on chip designing research to minimise the use of critical metals.

- **Telecommunication.** In order to facilitate the rollout of the telecommunication network (including 5G) and expansion of infrastructure, the GoI has taken policy initiatives such as making sufficient spectrum available for mobile services through an auction, allowing spectrum sharing and trading, removal of additional spectrum usage charge (SUC) of 0.5 per cent for spectrum sharing, and allowing sharing of infrastructure by TSPs. The 5G spectrum auction in India has concluded with a total of USD 19 billion worth of spectrum sold, and 5G has been launched in 50 cities across India. The UK was among the first markets to launch 5G globally, and 5G network investment is accelerating. Both could leverage the collaboration to work in the area of rural connectivity, 5G research for faster rollouts and deployment, healthcare, distance education, manufacturing of network equipment to support rural connectivity and 5G implementation.
- **Biotechnology.** Leverage and build on the existing research collaborations, such as Astra Zeneca's R&D centre at Bengaluru and their partnership with SII, Pune.

Recommendations

We have distilled our findings from our research and recommendations from consultations into an overall assessment of the potential areas of collaboration. However, given the short timescale and limited scope, we suggest the commissioning of a rapid series of deep dive exercises:

- **Centre-to-centre collaborations:** Made Smarter centres in the UK could collaborate with similar centres in India created under Udyog SAMARTH, NM-ICPS and others, and a set of industries associated with these centres, for providing required inputs for research from an industry perspective that will have the critical mass to create innovations. There is an opportunity for UK and India to work together towards R&I in digital manufacturing
- **Co-operation in standards:** Develop a common platform to share information on standards which will help bring about product competitiveness with the participation of the Bureau of Indian Standards (BIS) and the UK body on standards.
- **Academia-to-academia programme** for innovation consulting to handhold SMEs in automation implementation.
- **Organising a bootcamp for start-ups and SMEs** to gain exposure to each other's market.
- **Joint skilling programme** through a common training centre in an industry cluster, using resources from the UK in a virtual lecture, train-the-trainer and demonstration session to share expertise in industrial digital technology (IDT) tools with Indian SMEs.
- **Hackathons/innovation challenges** can be launched for key IDTs such as IoT, AR/VR, AI, blockchain, 5G, cybersecurity, etc. Start-ups and innovators from both countries could work together to develop solutions.
- **Technology demonstration** is critical for establishing seeing is believing; some high-end technologies need to be showcased:
  - **Short-term engagement.** Annual or bi-annual technology showcase and demonstration events should be arranged.
  - **Medium to long-term engagement.** To launch UK India Digital Manufacturing and Connected Supply Chains programme, to match UK digital tech companies with Indian manufacturers and provide funds to develop a demonstrator relevant to the challenges the manufacturers face. This concept has huge potential as a strong model for opening up the Indian market.

Introduction

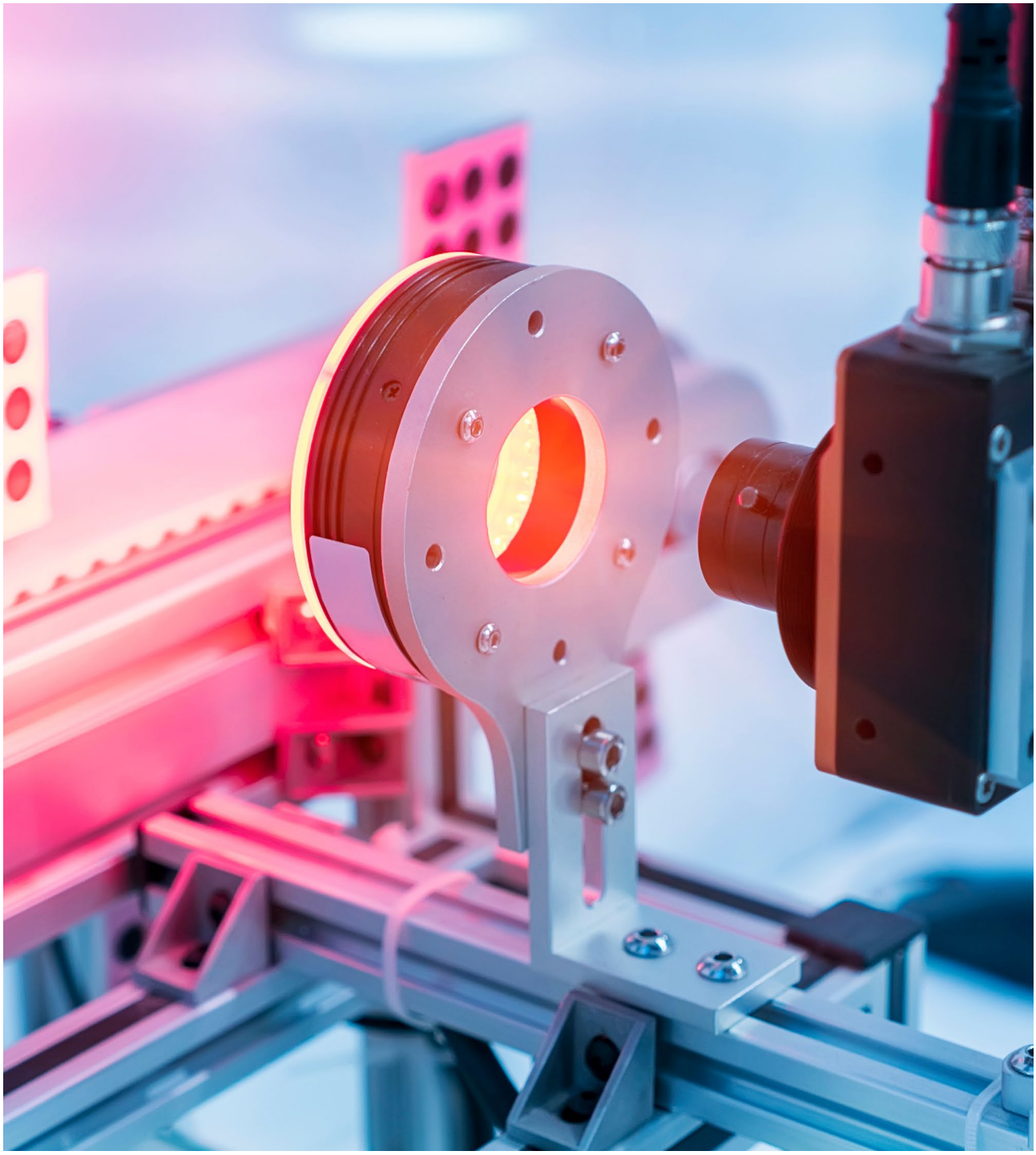
The UK and India's economies are roughly the same in terms of GDP, and together they accounted for 6.6 per cent of global GDP in 2019[4]. However, in terms of bilateral trade, India is the fifteenth largest trading partner for the UK, with a volume of USD 28.3 billion in the four quarters ending Q3 2021[5].

Our bilateral investment relation is at a moderate level with the stock of FDI in India and the UK received from each other representing 0.9 per cent and 0.6 per cent[6], respectively. To unlock the full potential of our bilateral economic relationship, in May 2021, Prime Ministers Johnson and Modi launched Roadmap 2030 with a shared vision of a transformative Comprehensive Strategic Partnership between the UK and India, to double the trade in the next ten years. Roadmap 2030 paves the way for deeper and more robust involvement in critical sectors such as people-to-people interactions, commerce and economy, defence and security, climate action, and health. Further, in January 2022, both sides initiated negotiations for concluding a comprehensive Free Trade Agreement (FTA).

In today's knowledge-driven economy, innovation is the main driver to achieve progress and prosperity. India needs a national-level innovation ecosystem that helps germinate ideas, with the participation of all stakeholders, such as academia, industry, research institutions, government scientific institutions, and financing bodies, which are incubated and then commercialised through business intervention. While India has scientific talent, it lacks the enabling ecosystem to transform innovative ideas into useful realities. India spends less than 1 per cent of its GDP on R&D, lower than most major economic powers. As a result, India continues to lag in the Global Innovation Index (GII) with a moderate 46th rank compared to the 4th for the United Kingdom[7]. India has also realised that faster economic growth can only be propelled through R&D-based innovation. Hence the current year's budget has focused on a research and innovation-driven economy with targets for the next 25 years. The current year's budget allocation for science and technology ministries has shown an increase of 5 per cent. During the recent meeting of the two Prime Ministers, both sides agreed to enhance cooperation on innovation partnership, novel technologies, including ICT and digital products, and work on supply chain resilience[8].

Nowadays, there is increasing demand for the customisation of products and services instead of mass production. However, this requires shorter development time and faster production processes, which in turn creates demand for the application of IT-enabled manufacturing. With an explosion in digital telecommunication and new computing capabilities, there is a real opportunity for industrial digital technology (IDT) to enable the application of newer methods in product design, development, and manufacturing, with tools like computer-aided design, computer-integrated manufacturing, using AI,

additive manufacturing, cloud computing and data analytics. These IDT tools can also help improve productivity, reduce material wastage, cost of production, track-and-trace and visualisation.
In India, however, the digitalisation of manufacturing has some fundamental challenges, especially for small units, i.e. establishing the means of data collection, selection of the appropriate digital tools, additional capital cost, enhanced cybersecurity risk, and managing all the associated changes to working practices, including upskilling the workforce. Successful implementation of IDTs in India will need collaborative teamwork of all stakeholders, such as industry, government, OEMs, academia, and research institutions, drawing on effective practices around the world.



Methodology

Finovista and Unconventional Connections followed a three-pronged approach to conduct a very rapid, targeted Innovation Insight study.

- **Desk-based secondary research:**
  - o A literature survey of available reports/policy papers/consultation notes relevant to the UK-India smart manufacturing landscape and ecosystem.
  - o Research on initiatives of the governments of India and the UK and corporates.
  - o A review of government ministry websites and published data.
  - o A high-level mapping exercise of stakeholders in Indian digital manufacturing and connected supply chains.

- **One-to-one consultation** with ten key stakeholders. These included agencies, organisations, companies and experts from the UK and India. (Please refer to Annex A). The consultation helped in the following:
  - Mapping bilateral R&I opportunities.
  - Understanding the enabling environment for research and innovation.
  - Exploring where there is interest in R&I collaboration.

- **Webinar.** To seek reactions to our findings and stimulate discussion of where the most promising areas for collaboration lie, a multi-stakeholder webinar with two panel discussions, one focused on digital manufacturing and the other focused on the connected supply chain, was conducted. (Please refer to Annex B).

Digital Manufacturing in India

According to official data from the World Bank, India's GDP was worth USD 2.66 trillion in 2020, representing 2.32 per cent of the world economy[9]. In 2020, the manufacturing sector generated 17.4 per cent of India's GDP[10]. Through the Make in India initiative, the GoI aims for the manufacturing sector to make up 25 per cent of GDP and create up to 100 million jobs by 2025[11]. The brief overview and the market size of the various sectors included in this study are shown in Figure 1.

Industry 4.0 focuses on digital solutions to increase productivity and is critical to India's competitiveness compared to global peers. In the wake of the COVID-19 pandemic and emerging geo-political situation, India is being seen as an emerging global manufacturing hub and is ranked second, surpassing the USA to become the second most desired manufacturing destination in Cushman & Wakefield's 2021 World Manufacturing Risk Index (MRI). Initiatives like the Production Linked Incentive (PLI) scheme[12] have been taken by the GoI in 14 sectors to bolster manufacturing and create a competitive advantage, facilitate investment, reform labour laws, boost a technology-driven start-up ecosystem, and encourage R&I.

Initiatives like Make in India, Digital India, Start-up India, Atmanirbhar Bharat, SAMARTH Udyog Bharat 4.0, and the PLI scheme have bought the spotlight back on the manufacturing sector. The sector has attracted interest from global and domestic giants interested in establishing technology-driven manufacturing facilities in India. For example, Samsung at its Noida plant has started manufacturing mobile display panels, followed by IT display panels; Bharti Enterprises has partnered with Dixon Technologies (India), to manufacture telecom and networking products; Amazon India will start with Amazon Fire TV stick manufacturing; Wistron and Optiemus Electronics in India will jointly manufacture laptops and smartphones.

As a result of continued reforms in the FDI policy and improved ease of doing business, foreign investment inflows into India have been consistently rising in recent years, and many large global companies have set up manufacturing bases with advanced manufacturing technologies in India. More than 50 per cent of the world's largest spenders have a R&I presence in India (Figure 2).

This has given an impetus to the growth of digital manufacturing, and subsequently, large Indian corporates are following the trend. For example, Tata Steel's Kalinganagar factory was the first Indian factory on the list of the World Economic Forum's Global Lighthouse Network in 2019[13]. In less than two years, two more of its factories have been featured in the list.

A growing number of new-generation Indian start-ups, have technology and innovation deeply embedded in their business models. For example, India's mobility start-up, Ola, has recently set up one of India's largest electric vehicle (EV) factories adopting Industry 4.0 principles. Automation has emerged as a key priority post-COVID-19, and there is ample intention to automate. Factors like the requirement for the increased distancing of the workforce on the shop floor, as part of COVID-19 protocols, and workforce issues due to labour migration to their native town have further intensified the need for automation. The factory-to-consumer chain has had to change due to the COVID-19 pandemic, and there is a need for greater visibility across the supply chain, with central factory teams requiring comprehensive and up-to-date data on supplies and stocks. A pro-digital approach has improved the shop floor performance with respect to delivery expectations, productivity, and transparency in the supply chain.

However, this digitisation is mainly limited to large companies and has not penetrated well within medium enterprises, SMEs, and micro-enterprises, which form a larger part of the industry, and on which the growth in the Indian economy depends. Capital constraints, the complex nature of technology, poor digital infrastructure, shifting business priorities post-COVID-19, limited availability of a trained workforce and lack of clarity on ROI, have been some of the key barriers. The adoption of Industry 4.0 is at nascent in India, and the country has a long way to go implement these technologies and derive the benefits across its manufacturing base, at scale. However, digitisation is seen by many across the industry as a business imperative and is looking to teach SMEs to play a key role in enabling this transformation. The need for the adoption of automation thus opens up opportunities for partnerships with global leaders in the domain. The GoI is well aware of the constraints faced by the MSMEs and is taking the necessary steps for digital empowerment through the Digital MSME Scheme, with the following objectives:

- To empower and enable MSMEs to harness IT as a medium of communication to revamp access to the markets to update their managerial and technical knowledge through online content, both static and dynamic.
- To provide software interventions, evolving their internal efficiencies by way of intense ICT intake and automating procedures for cost reduction, imparting digital literacy and capacity enhancement for information access, processing, collaboration and dissemination.
- To offer the MSMEs a safe and sound suite of customised digital solutions saving them from the travails of indiscreet and indiscriminate adoption of technology.

Sectors at a Glance

Automotive

USD 118 billion
Indian automobile industry

35 million
People employing

USD 300 billion
projected size of industry by 2026

3rd largest
Automobile market by 2026

Defense & Aerospace

3rd largest
Military spender

3.7% of worldwise military spending

USD 25 billion
turnover by 2025

Telecom

2nd largest
telecom sector in world

4 million
Direct & indirect jobs

USD 126 billion worth Mobile phones manufacturing by 2050

Electronics

USD 65 billion
Electronic hardware production in 2020

USD 300 billion
global electronics powerhouse by 2026

Healthcare & Biotechnology

USD 63 billion
Biotechololology market in 2019

USD 100 billion
Targeted industry by 2025

19%
Increased share in global markert

Energy

500 GW
renewable energy by 2030

5th largest
solar installed capacity

280 GW Solar energy

Figure 1: Overview of the six sectors showing the market size for each sector

The Manufacturing Innovation Landscape in India

Research and Innovation Funding Ecosystem

In India, the central government dominates and drives the R&D agenda. Unlike developed countries, public expenditure is the driving force of R&D in India. NITI Aayog and the Principal Scientific Adviser's (PSA) Office are the two premier organisations under the government set-up that provide directional and policy inputs to other government bodies, to prepare a roadmap to address challenges in specific science and technology domains with the overall objective of accelerating the development agenda.

Among the ministries and departments, the Department of Science and Technology is a major stakeholder in the ecosystem, responsible for science and technology policy and initiatives. The other key player is the Department of Scientific & Industrial Research (DSIR), which runs various domain-specific research institutes and also grants recognition to in-house R&D units established by the industry, offering fiscal incentives for innovative work. In addition, many ministries and departments in the GoI, other than scientific departments, spend on R&D in the development of technologies pertaining to their sectors.

To address the concern regarding the lack of a central governing authority, in 2021 India announced the establishment of the National Research Foundation (NRF) with a budget allocation of nearly USD 6.7 billion[14]. The NRF will improve governance and provide a critical link between R&D institutes, academia, and industry. The PSA's Office has developed the draft plan for the establishment of this foundation.

The Department of Heavy Industries (DHI) is the nodal ministry responsible for policy and initiatives for digital manufacturing. In Figure 3, an attempt has been made to identify the major stakeholders in the GoI's innovation and research ecosystem and give an insight into their relative roles and specific programmes with a high potential for collaboration. For example, UKRI should collaborate with DST for overall research and collaboration, DHI for digital manufacturing-related research collaboration, and ministries like DRDO and the Department of Biotechnology (DBT) for sector-specific R&I initiatives.

Government of India Initiatives

The GoI's Make in India and Atmanibhar Bharat mission has been at the forefront of enabling growth and competitiveness in India's manufacturing sector. It aims to build a competitive edge over global peers and focus on R&I to build long-term competitiveness. The PLI scheme is a major programme launched by the government to promote domestic production in several sectors. The total outlay for the scheme across the 14 sectors, as of March 2022, was over Rs 1.97 lakh crore (USD 25 billion).

In this section, we outline the research and innovation funding landscape, focusing on the key government initiatives.

Further, the key initiatives and strategies for key IDTs have been reviewed as below:

Digital Manufacturing

- SAMARTH Udyog Bharat 4.0. An umbrella programme for the propagation and establishment of an ecosystem of Industry 4.0 technologies in manufacturing, across all companies. The DHI has formulated the Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH) Udyog Bharat 4.0 Scheme. Under this, five Central Engineering Facility Centres (CEFC) have been established. For more information on the centres please refer to Annex C. These centres are working with companies, academia, start-ups and researchers to deliver technical and scientific solutions to manufacturing units in India by 2025 through a knowledge programme, training, awareness and demonstration.
- Scheme for enhancement of competitiveness in the Indian capital goods sector by DHI. The scheme aims to make India's capital goods industry internationally competitive. Eight centres of excellence (CoE) were established, with the participation of eminent academia and R&D institutes. Each of the centres is working on different technologies and domains. For details, please refer to Annex C. Under the scheme, a GoI grant will provide up to 80 per cent of the cost of creation of equipment, machinery hardware and software facilities for the development of new CoEs for technology development, and the augmentation of existing CoEs developed under Phase I. The balance amount shall be contributed by the applicant. Similarly, the government approved the PLI scheme for the automobile and auto component industry for enhancing India's manufacturing capabilities for advanced automotive products (AAT) with a budgetary outlay of Rs. 25,938 crore (USD3.3 billion).
- Centre for the Fourth Industrial Revolution. In 2018, the GoI along with the World Economic Forum launched this centre to boost the capabilities of India in Industry 4.0. Located in Mumbai, this centre joins others in Tokyo, San Francisco and Beijing. The centre focuses on AI and ML, blockchain, drones, IoT, and robotics.
- The DST has launched a National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) to develop smart engineering systems by integrating cyber and physical systems. NM-ICPS has funded 25 technology innovation hubs (TIHs) to strengthen the R&D ecosystem in AI and related fields. These centres are already operational, and each centre is mandated for two international collaborations per year, which opens a great opportunity to work with UK research, academia, and agencies.

In addition, the government has also formulated policies and strategies for IDT. Please refer to Annex D for a detailed insight.

Advance Fuels

The Ministry of New and Renewable Energy (MNRE) has promoted a broad-based hydrogen energy and fuel research, development, and demonstration (R&D) programme. Projects undertaken at commercial, academic and research institutions are being financed to develop green hydrogen, its safe and efficient storage, and its use for power generation and transportation applications via combustion or fuel cells.

Supply Chains and Logistics

The report, Reimagining India's Supply Chain by Arthur D Little and the Confederation of India in 2021[15], stated that the logistics cost in India is around 14 per cent of GDP, which is very high compared to 8 per cent in more developed nations. To optimise the logistics sector, the GoI has taken steps towards creating a world-class infrastructure by developing 11 industrial corridors and 35 multimodal logistics parks at strategic locations, and improving the inter-state movement of goods through FasTag and Good and Service Tax (GST). Infrastructure development initiatives in India are managed by multiple state and national-level departments resulting in a fragmented system.

With an ambition to develop India as the global hub for world-class infrastructure, and break the inter-departmental silos, the GoI has launched PM Gati Shakti, a national masterplan for multimodal connectivity of people, goods and services across India. Under this initiative, a digital platform would be created to integrate 16 central government ministries along with state governments for the planning and coordination of infrastructure projects. The infrastructure schemes from various ministries, including Bharatmala, Sagarmala, inland waterways, dry/land ports, UDAN, and significant economic zones, i.e. defence corridors, pharmaceutical clusters, electronic parks, industrial and agriculture corridors, etc. , would be integrated under this platform. USD 13.2 billion has been allocated towards this initiative to prioritise and reach all mega-infrastructure and connectivity targets by the end of 2025.

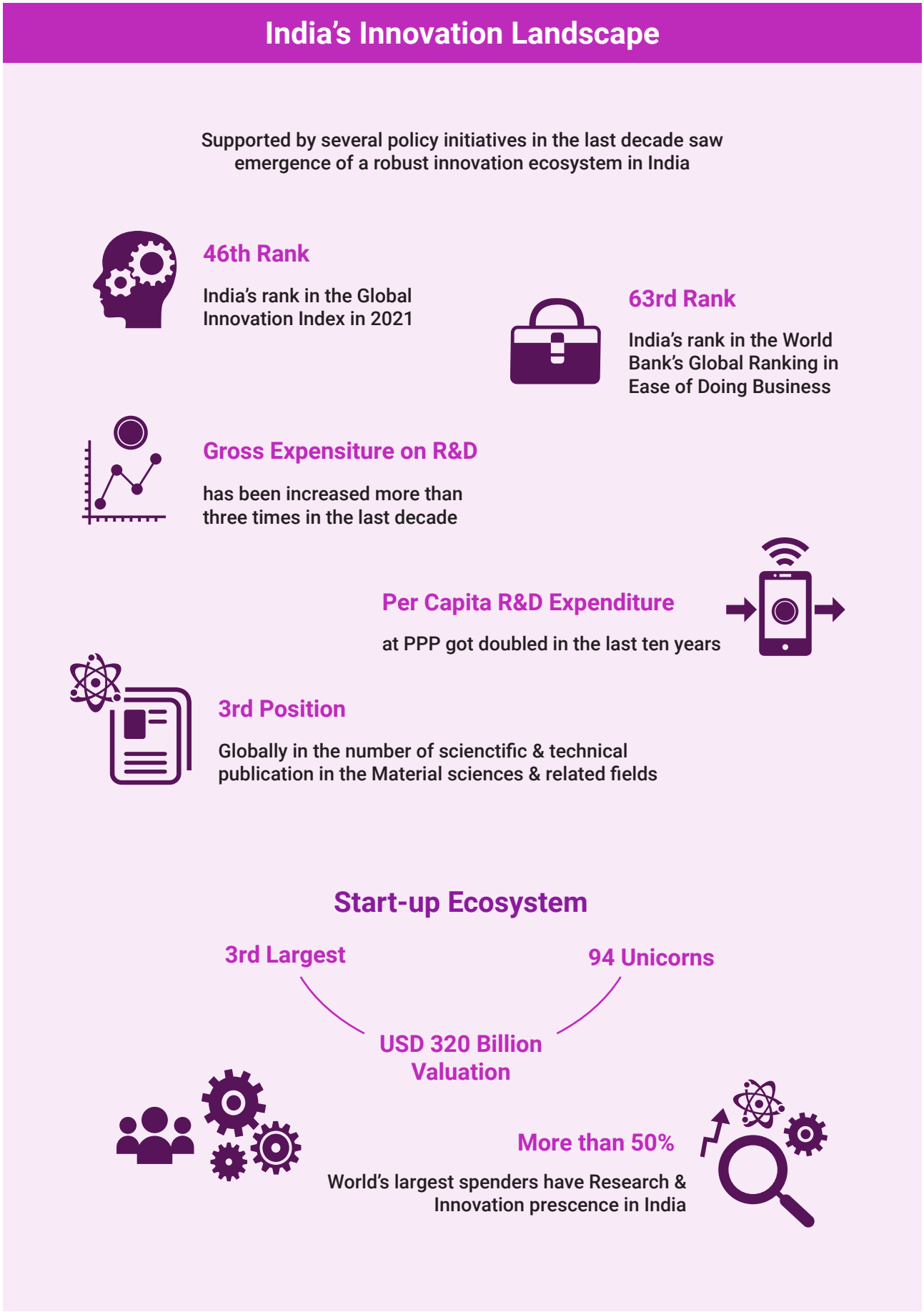


Figure 2: Brief overview of India's innovation landscape

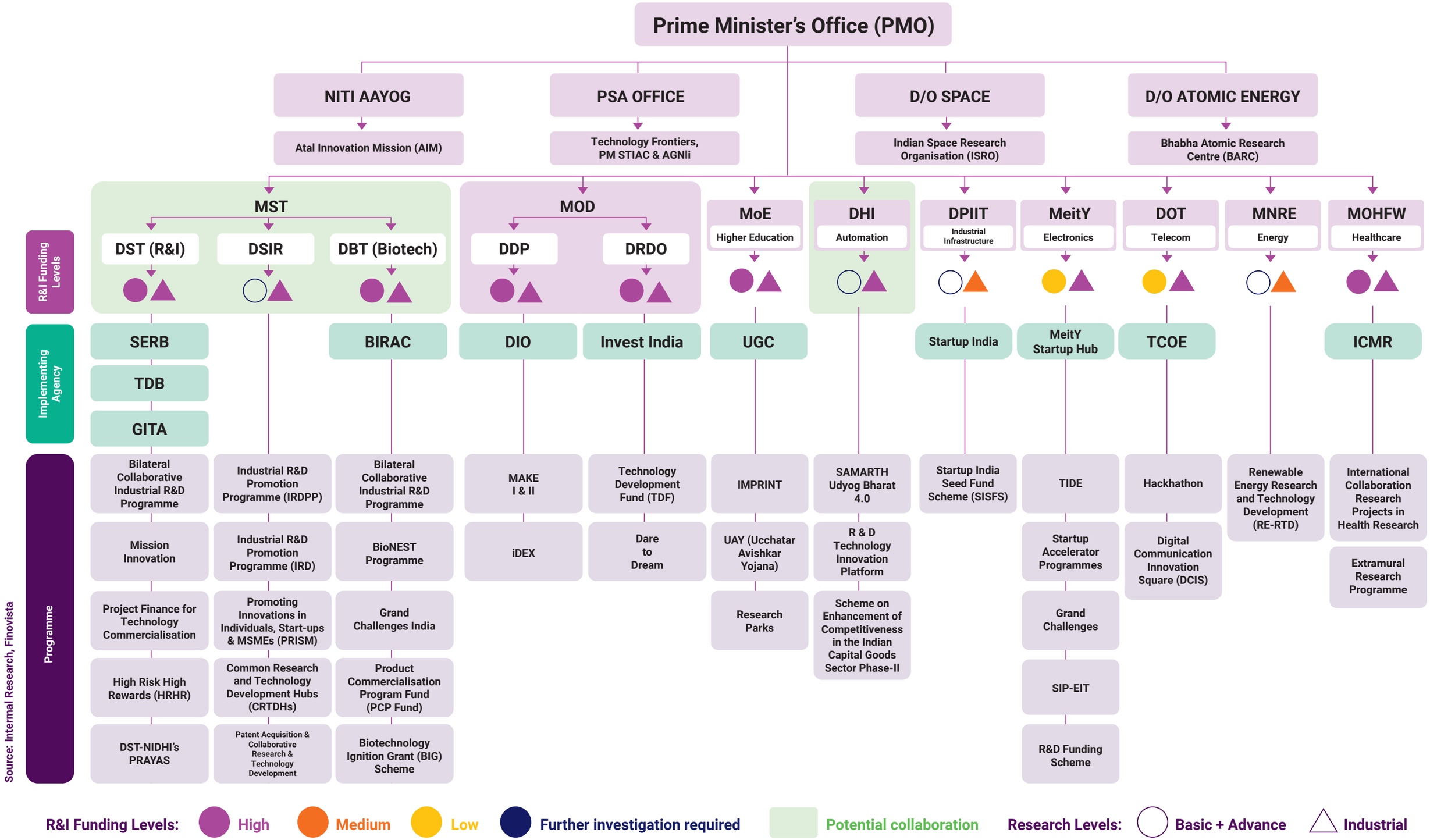


Figure 3: Tabular representation of the innovation landscape and funding in India

* Please refer to the glossary for full forms of the schemes. The above schemes are mapped under the scope of this study

Investment in Digital Manufacturing in the UK

Government-led Initiatives

Made Smarter Research Centres are an important part of the UK government's strategy to support the commercialisation of new technologies that address both technological and societal issues. In 2021, it announced USD 69 million in funding to accelerate innovation in digital manufacturing through the establishment of five new research centres, an "innovation hub", and 37 individual projects to help digitise manufacturing supply chains. This will build on the substantial government investment that has gone into innovation funding and the High-Value Manufacturing Catapult (HVMC) and in digital technologies through the Digital Catapult. Details of the centres are as below:

- The Digital Medicines Manufacturing Research Centre intends to construct digital supply chains that will allow medication to be designed, produced, and delivered on demand, as well as more flexible and efficient clinical trials.
- The Research Centre for Smart, Collaborative Industrial Robotics. The University of Strathclyde is a partner in the Made Smarter Innovation Research Centre for Smart, Collaborative Industrial Robotics, which is working to boost advanced manufacturing by eliminating barriers and fast-tracking the use of smart collective robotics technology to explore full productivity, quality, and the adaptability potential of the UK industry.
- The Research Centre for Connected Factories, led by the University of Nottingham in collaboration with the Universities of Cambridge and Sheffield, aims to develop advanced infrastructure for smart manufacturing that can also be employed for various other configurations to meet actual product, volume specifications, supply chain variations, and disruptions.
- The Materials Made Smarter Research Centre will aim to overcome technological barriers that limit the adoption of novel materials and industrial techniques needed to make the world more sustainable and contribute to net-zero emissions.
- The People-led Digitisation Centre will aim to improve productivity by improving digital literacy.

The Joint Action Plan on Standards for the Fourth Industrial Revolution will promote an agile approach to standardisation to bolster rapid technological transition and foster collaborations between standardisation, policymaking, and strategic research work, all necessary to support innovation across sectors.

Corporate Initiatives

A USD 13 million grant from the UKRI Made Smarter Innovation programme is intended to be combined with equal contribution from the private sector over the next four years to fast-track commercial synergies in advanced and emerging digital technologies across manufacturing supply chains. Various sectors like logistics, pharmaceutical, defence, aerospace and fabrication are covered under the programme.

The Manufacturing Innovation Landscape in the UK

Sustained Investment in Manufacturing Innovation within the UK

Innovate UK, Catapult centres, Made Smarter project, Newton programme, Engineering and Physical Sciences Research Council (EPSRC), research councils, and other organisations, institutes, and programmes in the UK assist manufacturing innovation. Businesses are accustomed to collaborating with university academics to translate new research and technology into commercial products and services.

UKRI, through the EPSRC, has launched several programmes to conduct R&I in manufacturing technologies. The EPSRC's funding is reinforced by assistance for manufacturing paths, particularly through Innovate UK projects and catapult facilities.[18]

Innovate UK supports businesses and partners in identifying and advancing scientific and technological ideas that will boost productivity, generate new jobs and exports, and keep the UK competitive worldwide. Innovate UK has awarded grants worth USD 4 billion between 2020-2021 to science and technology innovations.[19]

The UK government, through Innovate UK, has invested USD 1.3 billion in creating nine catapult networks. The catapult network supports businesses in transforming great ideas into valuable products and services.

The HVMC is a driving force behind the development and success of advanced manufacturing in the UK. In 2020-21[20], the HVMC had USD 637 million in R&D, 5,897 industrial partners and 3,322 SME partners. It is made up of seven centres viz the National Composites Centre, the Advanced Forming Research Centre, Warwick Manufacturing Group, Centre for Process Innovation, Manufacturing Technology Centre, Advanced Manufacturing Research Centre and Nuclear AMRC.

In 2021, the UK government stated its commitment to boost investment in R&D to 2.4 per cent of GDP by 2027 (it is currently around 1.7 per cent). UK businesses represent less than 55 per cent of overall R&D spending.[21]

Supported by this investment innovation in manufacturing, the UK is the ninth leading manufacturing nation and tenth in terms of global exports, with output totalling USD 250 billion in 2019 – retaining this position held for many years due to growth of 7 per cent over the last five years[22]. Nearly 2.7 million people are employed in the manufacturing sector. While some engineering-related industries, such as mining and quarrying, are in decline, the workforce in other sectors, like automotive, aerospace, defence, electronics, chemicals, transportation, and energy, is expanding.

New Initiatives and Infrastructure Investment

Following an industry-led evaluation of how UK manufacturing businesses may benefit through digital tools and innovation, the Made Smarter innovation challenge was created to increase manufacturing through digital technology, innovation, and skills.[23] The programme includes **accelerators, hubs, research centres, R&D labs**, etc. to develop and scale-up IDTs including AI and virtual reality. The public funding available through this challenge is worth USD 193 million in investment, matched by the industry[24]. (Please refer to Annex E).

As per the policy paper titled, Build Back Better: Our Plan for Growth, published in March 2021, the UK government has committed to spending nearly USD 655 million over the next four years to support the advancement and large-scale manufacturing of EV batteries and the associated EV supply chain[25].

The EPSRC has launched a USD 4 million grant available for projects each quarter to support investigator-led proposals from researchers working in the engineering and physical sciences to develop solutions for challenges faced by UK manufacturing.[26]

The UK–India Collaboration

India is the fifteenth largest trading partner for the UK, and several partnerships have been developed to forge R&I. To double the trade in the next ten years and create a stronger bilateral programme, the UK-India Roadmap 2030 has been developed. Under Roadmap 2030 both countries have agreed to forge stronger connections; maximise investment, trade and technological collaboration. The plan also calls for increased military and security collaboration, as well as India-UK leadership in climate, renewable energy, and healthcare, which will work as a global force for good.

The UK and India have a long-standing partnership in R&I, which has resulted in over 258 projects being jointly funded by UKRI and India, with a joint investment of over USD 432 million. The joint projects resulted in 1,665 publications indexed in Scopus and had three times the global average share of academic-corporate collaboration[27]. Some of the notable collaborations are:

- The **Newton Bhabha Fund** is a major bilateral programme to promote R&D collaboration between the UK and India. Upon the launch of the programme, both sides committed USD 66 million for R&I collaboration for five years. The Newton Bhabha Fund is part of the UK's Newton Fund worth USD 490 million for international collaboration.
- **The Joint UK-India Clean Energy Centre (JUICE)** was initiated to bring top researchers from ten UK universities with their counterparts across India to develop technologies significant for sustainable energy systems.
- The **e-AMRIT (Accelerated e-Mobility Revolution for India's Transportation)** webpage was launched as a result of a cooperative project between NITI Aayog and the UK government to raise awareness of electric mobility in India. The portal comprises comprehensive information regarding the adoption of e-vehicles in India.
- **Modern Energy Cooking Services (MECS)** is a five-year programme funded by UK Aid (FCDO) formulated to bring the transition from traditional cooking fuels to modern cooking fuels. Considering the geopolitical situation of India, MECS is conducting its significant operation here, especially concerning creating demand and manufacturing modern cooking devices.
- **The Joint Economic Trade Committee (JETCO)** was formed to facilitate government-to-government discussions on market access. The UK India Business Council contributes the opinions of the UK business community to this process, which aims to assist UK firms in strengthening their ties with Indian businesses and decision-makers and developing new partnerships.
- **TATA Motors**, with its subsidiary Jaguar Land Rover has launched the **National Automotive Innovation Centre** at the **University of Warwick in Coventry, UK**, which is a USD 197 million national centre dedicated to advanced automotive research, design and development.[28]
- **Bharat Forge** has established an **E-Mobility Research & Development Centre** in MIRA Technology Park, UK, where it will **develop components and subsystems for electric cars**.[29]

- **The Digital Catapult has run a programme that matches UK digital tech companies with Indian manufacturers and provides funds to develop a demonstrator that is relevant to the challenges the manufacturers face.** The aim is to expose the UK SMEs to the Indian market and enable them to develop and showcase their technical capabilities and the potential benefits, hoping this will lead to follow-up contracts and collaborations. Our role was to support capacity building in international collaboration for both sides and facilitate a joint workshop. Our engagement with the businesses involved enabled us to identify a few areas where a programme like this could be enhanced and have a greater impact.

Key Insights

The GoI aims for India to become an innovation-led global manufacturing hub and play a critical role in the global value chains. In achieving the target, the role of digital manufacturing technologies is critical as the application of digital tools offers an integrated approach to bring the Indian manufacturing sector on par with its peers.

As part of this study, we took a rapid review of India's manufacturing sector to get a broad view of the technological advancement, and the status of the adaptation of automation. A detailed analysis along with one-to-one consultation with multiple stakeholders from India and the UK was conducted to obtain a first-hand view of the experts. Below is a synopsis of the key insights applicable widely across the industry sectors, followed by a review of six specific industry sectors that interest the UK and India.

Retrofitting of Legacy Machines

For upgrading legacy machines in the production line, **a plug-and-play–smart box solution**, to convert legacy equipment into smart equipment would be preferred on cost considerations. **IoT systems allow manufacturing units to integrate their existing machines and physical** infrastructure with web- and enterprise-based systems into a central location. As a result, the systems allow manufacturers to easily gather the data from all their devices and present it thematically for legacy machines. Many Indian companies engaged in industrial automation are providing such services in this domain. To cite an example, Sarla Technologies, Bengaluru, with **a tie-up** with ATS Global[30] which is active in UK and Europe, is a good example of a partnership between the two countries. The **solution should be easy to install so the SMEs can retrofit the equipment. For the basic feature of Industry 4.0, low-cost sensors/smart boxes fitted with legacy machines and the use of open-source solutions that can be downloaded onto laptop/smartphone systems and can be connected with the machine, which can lead to smart and cost-effective automation. Laptops, smartphones and tablets have a high penetration in India, which can reduce substantial costs for hardware. Mobile device proliferation has already changed the way many workers get their jobs done. Business** managers, engineers and technicians have seen productivity enhancement using their handheld devices. For example, a mobile app from Rockwell Automation permits plant managers to access real-time and historical production data and trends. Operators can see problems, where they may arise, or where additional capacity is available to increase production.

WhatsApp, Digital Payments, UPI Solutions, Accounting Solutions, ERP had a clear demonstration of benefits for end-user and have therefore been widely adapted by Indian SMEs and micro-enterprises.

Indian Businesses – A Strong Focus on ROI

In the Indian market, the cost of automation solutions and implementation is very high. Indian businesses are mostly low-margin, and the COVID-19 pandemic has added to the cost pressures; thus, a strong business case is required to justify the investment in automation. In most of the automation solutions, a clear demonstration of the use case and ROI justification is missing, which is the key barrier to adoption. Most of the automation solutions available in India are developed by multinational corporations based on the standard business practices for the global market. Thus a clear, ready-to-use solution for Indian companies is not available for demonstration.

Skilling – A Major Gap

In the era of automation, specialised skilled resources are not just needed to manage automation but to improve competitiveness in the overall system. Limited information on the products available, their use, and their benefits adds to the complexity. Most companies don't have specialised resources to manage systems driven by advanced technologies. Skilling, up-skilling, and re-skilling are the biggest challenges. Finding appropriately skilled resources is not easy, as the availability of tech-savvy resources for an automated factory is very low in India. There aren't enough institutes in India offering relevant industrial training. The ecosystem for industrial training in India needs an overhaul, as companies can't afford to train the workforce on the shop floor. It will require a combined effort of the skill council, government, and academia to boost training and mentoring. Further, from an SMEs perspective, hiring and retaining are expensive, and in many cases, unviable. The training of people going into business happens in high-end academic labs, which are often out of touch with the business environment, leading to considerable additional on-the-job training, which is wasteful for employers and dissatisfying for employees.

With this in mind, under the Skill India Mission, the Ministry of Skill Development and Entrepreneurship (MSDE) is delivering skills through Pradhan Mantri Kaushal Vikas Yojana (PMKVY), with an objective to impart short-duration skill development training and certification to youth, to make them employable for better livelihood across the country. PMKVY was Mantri Kaushal Vikas Yojana (PMKVY) was initially launched in 2015. The third phase of PMKVY (2020-22) is currently being implemented across the country. Since inception, through to the end of December 2021, 1.34 crore candidates across the country have benefited from the PMKVY.[31]

India SMEs – A Long Road Ahead for Automation

Automation in SMEs is mostly demand-driven, i.e. most SMEs implement automation in their business activities to qualify as suppliers to large OEMs. Large companies have vendor development programmes, and they incentivise their suppliers to align with their processes, including the adoption of Industry 4.0. Further, rather than the scale, the strategic fit is essential, when looking at the adoption of Industry 4.0 technologies. Not all SMEs have a vision for achieving excellence in competing in the global markets, and for such SMEs, the adaption of digital technologies is a complete misfit. For most SMEs, it is essential to spot wastage and processes leading to losses. It is critical to understand whether the problem lies with machinery or with managing resources or materials. Thus, the logical starting point for SMEs is automation through data gathering, storage, analysis and visualisation rather than pushing too quickly towards more sophisticated Industry 4.0 solutions.

For Indian SMEs, the major barriers to automation are:

- **High cost of solutions.** The automation and supply chain software applications are not affordable, and this is the most significant deterrent for change and adoption by SMEs.
- **Infrastructure**. The key barriers are legacy machines, traditional factory layouts, and poor digital infrastructure. Further, selecting a custom-made retrofitting device is critical as it must be compatible with existing machines.
- **SMEs are on a very tight timeline and budget.** They need solutions that are quick to implement and rapidly deliver results in mitigating these risks/reducing costs, etc.

To adopt automation at scale, India needs:

- **Open-source solutions and a subscription model.** Open-source cost-effective solutions that can be adopted widely by SMEs. There could be a small use-base cost involved in scaling up.
- **Automation solutions should be built on a bottom-up approach**, targeting specific issues in the manufacturing and supply chain process. Solutions must be developed to make the machines more effective and the automation priorities have to be determined.
- **Standard platforms for automation** should be developed so that whoever is setting up the factories can implement the same without too much complexity.
- **Demonstration to establish ROI and a business case** for adoption. Demonstrators along with a **set of champion companies** to showcase the benefit of implementation, and this would have a significant impact on SMEs to come on board. Further, handholding by experts and consultants is required. There is an element here where the public-private partnership can happen, where local institutions can play a role. Skilled resources from institutions can work in partnership with SMEs, supported by some demonstrators that they have to implement automation in the company. SMEs can appoint them on a job basis if this facility is readily available, as they may not have the funds to hire a full-time resource.

The role of government is vital here in terms of subsidising the cost of adoption of solutions - both hardware and software - made available to SMEs through a common open source. There cannot be a one-size-fits-all situation; therefore, a pool of experts on automation as a part of a government-supported initiative may help suggest a specific solution to individual manufacturers. The Digital MSME Scheme[32] of the M/o MSME has the objective to make MSMEs digitally empowered and motivate them to adopt ICT tools and applications in their production and business processes to improve their competitiveness in national and international markets, with a total outlay of Rs. 273.24 crore. Several scheme components are to be implemented by implementing agencies (IA), which offers opportunities for a UK-India partnership with UK strength in open source automation.

Supply Chain Automation

Vendor diversification for de-risking is a global trend post-COVID-19. However, with multiple suppliers, the market would add many complexities to the large corporates, especially OEMs and also for the Tier 1 or 2 vendors, as they need to align with the processes of their OEMs to ensure quality and flexibility production systems. This necessitates the requirement and the application of Industry 4.0 concepts. Advanced technologies are needed in supply chains as it brings competitiveness. In the entire supply chain ecosystem, sustainability and the predictability of the process are predominant factors, and there is a strong need to have control of the data points on a real-time basis for Industry 4.0. To maintain more transparency in the connected supply chain, more emphasis should be given to a larger window for the projections and forecasts to the suppliers. For the advancement of the entire supply chain from Industry 4.0 to a connected supply chain, Tier 1 and 2 suppliers must play a crucial role with factors where the cost of affordability of Industry 4.0 has to be very low.

Industrial Digital Technology – Emerging Application

Inside the factory, the automation that would have a high ROI would be the removal or reduction of non-value-added activities, i.e. measurements, inspections, testing, packaging etc., which would lead to significant time and cost savings. In the Indian context, removal of non-value-added activities, reduction in material wastage, energy saving, and reduction in time taken in a process should be the priority as all of these result in cost reduction and improved productivity. Other technologies, like IoT, that can be gradually scaled up, would have a high impact on ROI and can be implemented in one process and replicated with success. Some of the other essential technologies are:

- **AI and cognitive learning**. To analyse data and trends from a futuristic perspective is important, thereby catering to not only issues of today but issues and trends likely to be seen in the future.
- **Robotics and process control.** In India, labour costs are typically very low, and many factories have not optimised workforce deployment or focused on wasteful processes. In this context, full end-to-end automation would not be justifiable, given the costs and time required to secure a ROI. However, there is potential for robots to be incorporated into processes that require frequent adjustment. Such selective application of robots is expected to help make the production process more agile. Robots could also play a role in the production line involving repetitive processes, especially those with safety risks, time consuming, and/or influencing the quality of the final products. Due to demographic advantages, India has a lower cost and stronger workforce compared with the UK, which has considerable strength in technology-dependent solutions. India has the potential to lead the world in human-centric robotics.

- **Preventive maintenance.** This is about accurately predicting and identifying a fault, locating the fault, and acting fast. Machine learning technology has a significant application in prediction, and augmented reality systems can help correct the defect. Especially in large manufacturing set-ups, power plants etc., most of the machines that operate in India have the drawings on paper. Thus routine maintenance needs to be standardised and digitised for optimised efficiency and to avoid machine breakdown and events that halt operations (downtime).
- **Track-and-trace.** Tracking and tracing issues in quality by attaching a digital time stamp to the products (even at the component level) that are being manufactured and delivered. This would mean developing a capability where process and product-level data can be traced back and help the company rectify the product quality and address the delivery issues.
- **Digital twin**. Technology can significantly shorten the time taken to determine the optimum production arrangement by the use of digital simulations or twins. This means factories can build a capability to launch and scale products faster than the traditional approach of prototyping, piloting and testing. However, setting up these simulations in India is complicated by the continued use of legacy and non-standard equipment, requiring each simulation to be developed from scratch.
- **Cybersecurity**. With ever-increasing data on the cloud platforms, vulnerability to cyber-attacks increases, and there is a constant threat of supply chain disruption due to cybersecurity issues. Factories and organisations under cyber-attack can face severe difficulties, like loss of customer information, shop floor data, issues of fleet management, defective manufacturing etc.

Impact of COVID-19

In the wake of the COVID-19 pandemic, digitisation has become the key priority across all sectors. Though some sectors like ecommerce, retail, banking and payments have been at the forefront of digitisation, there has been a cascading effect on the manufacturing sector. The factory-to-consumer chain has become very different due to the pandemic and the emergence of a new wave of direct-to-consumer brands in India. Now, there is greater visibility across the supply chain, and the factory team is much more informed about the manufacturing value chain. The most desirable characteristics for businesses are to be agile, which enables them to improve their responsiveness in the face of changing market conditions and customer demands. The agility of the production line in switching over to a different product range quickly would be extremely valuable in the modern market, which has seen fast-changing customer preferences.

- **Remote connectivity.** The COVID-19 pandemic has resulted in the advancement and acceptance of remote connectivity. The latest emerging digital technologies and the availability of cloud infrastructure, IoT and improved connectivity, have enabled the rapid adaptation of Industry 4.0 tools and techniques. Post-pandemic, most of the factories have restarted with a reduced workforce and resources, which drove the application of digitisation of routine operations and maintenance functions, including monitoring. However, **digital infrastructure** in India has limitations, and the **digital-to-physical layer connectivity** within the factory is a big challenge that must be addressed. It is hoped by many that the rollout of 5G connections will assist in resolving such challenges by massively increasing the data bandwidth available and active collaboration with the industry to look for innovative applications.
- **Focus on automation**. Automation has emerged as another priority and ample intention and trends are observed. Indian companies, especially large corporates and new-age start-ups are

early to gauge the vital need for automation and digitisation, which will have a cascading effect on competitiveness. Many large companies in India with a clear roadmap and resources have switched over to automation in a short period. In January 2022, Simple Energy, an India-based EV maker, partnered with the global technology leader Siemens to drive digital transformation in the EV space[33]. Some other factors emerging during the pandemic, like an increased spacing requirement on the shop floor as part of the COVID-19 protocols, and issues due to labour migration, have further intensified/accelerated the need and pace for automation. As regards the delivery chain, it has evolved in a manner that has necessitated a **pro-digital approach to improve the shop floor performance. The performance on the** shop floor has to match the delivery expectations, and productivity becomes a tremendous issue without automation. Transparency and traceability in the supply chain, i.e. information sharing with the other stakeholders, become easier with digitisation.

- **Research and innovation**. In India, most of the research is focused on software solutions for digital manufacturing and not on hardware, which is generally imported. Emphasis is on developing low-cost technology solutions by bringing down the human cost of the solution, which accounts for a substantial part of the total cost of acquiring technologies. However, in the wake of the pandemic and disrupted supply chain scenarios, research on some critical materials for automation is also underway. Indian academia is active in R&I however most are collaborating with multinational companies. Thus, solutions emanating from the research are not tailored to the requirements of Indian SMEs and corporates. In general, Indian corporates are more inclined towards rapid ROI and are reluctant to invest in higher-risk research that can only provide long-term returns.

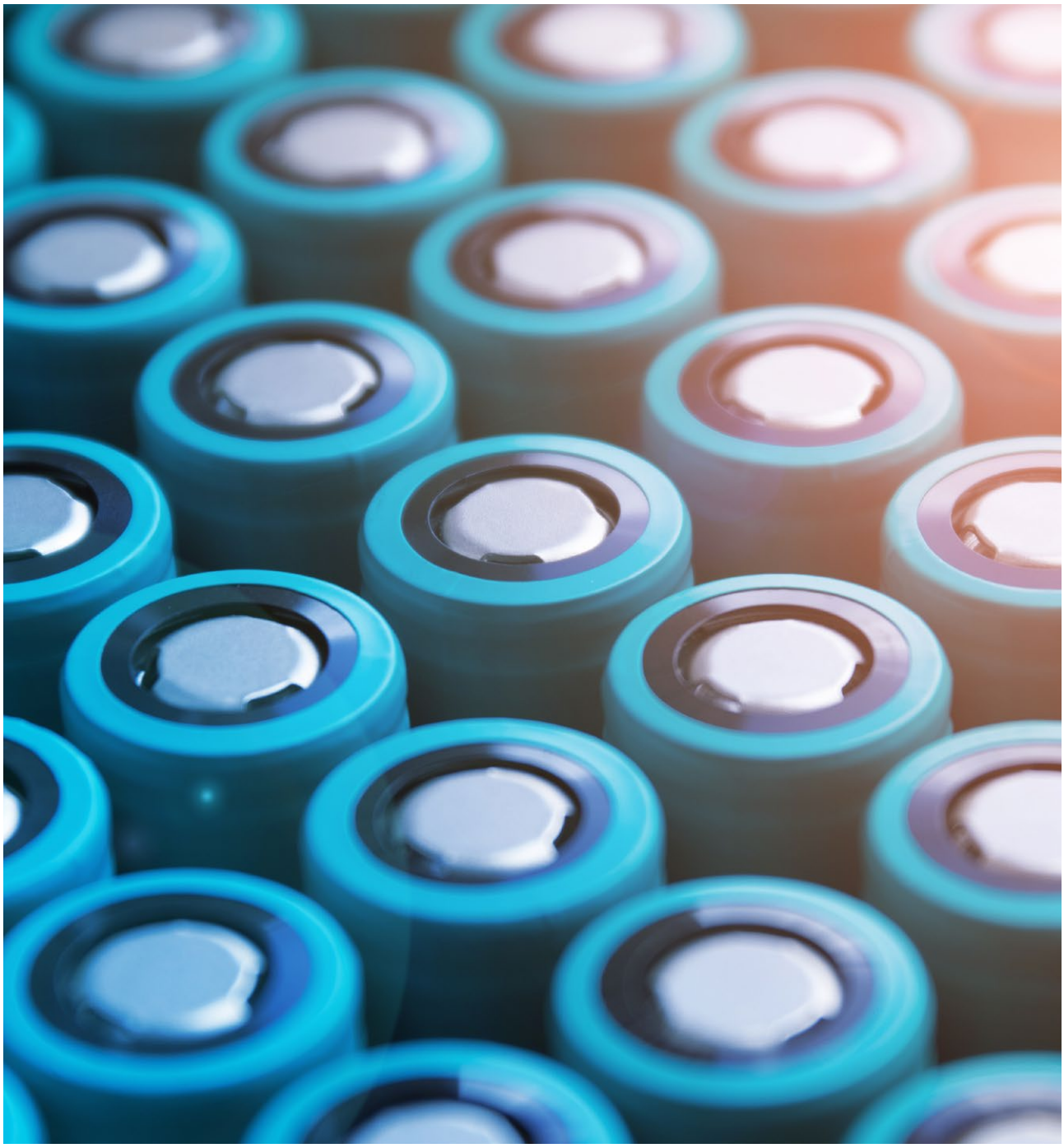
UK–India Business-to-Business Collaboration Challenges

Challenges can arise when UK SMEs seek to work with major Indian corporates around the value of providing capacity building. The concept of funding the development of demonstrators that seek to address real challenges faced by Indian industry has huge potential as a strong model for opening up the market, but a successful programme needs to have the following:

- Building this into top-level government dialogue and comprehensive economic agreements to engage senior management within the Indian corporates as this will facilitate rapid progress and the necessary access.
- Taking a strong, assertive position from the outset in negotiating with the corporates, setting out the UK offer with a clear expectation that the corporate will commit resources and agree to follow-on opportunities should the demonstration be successful; this will ensure they buy into the project.
- The project duration needs to be longer to allow for the significant time required to identify a genuine application with a high potential impact for the corporate; this often requires considerable iterative development and exploration work.
- The preparatory phase of the project should include the corporate drafting of a non-disclosure agreement (NDA) that can be signed quickly by the SME and enable the initiation of open data sharing from the outset.
- Setting out these more favourable terms and conditions for the UK SME will enable the programme to attract a strong field of tech companies and ensure the offer to the corporates will reflect the range of what the UK has to offer.

Key Insights – A Sector Approach

During the initial desk-based research, it was observed that innovation, research, and development were more prevalent in sectors like automotive, defence, telecoms, electronics, healthcare, and energy. These are where there is greater investment in technology and high-value manufacturing, compared to a lot of more conventional manufacturing sectors. They are the most promising in terms of targeting collaboration proposals. We have also seen seen that the demands of business customers for products of smaller manufacturers in the supply chains of major OEMs can drive investment in digital solutions. Accordingly, to have a better insight into these sectors, a focused analysis was conducted covering the sectors previously mentioned.



Automotive

The USD 118 billion Indian automobile industry employs over 35 million people and is projected to reach nearly USD 300 billion by 2026[34]. The automobile industry contributes over 7.1 per cent to the GDP[35] and over 49 per cent to the manufacturing GDP[36]. The focus within the industry has shifted to EVs, with a projected market to be worth USD 7.09 billion by 2025[37]. Sixteen states have launched their policies for EVs, and a recent report by NITI Aayog recommends including EVs in priority sector lending.

Government-led Initiatives

To fuel long-term and sustainable growth, the GoI has adopted initiatives to accelerate the switch to EVs, bolster domestic demand, position India as the global hub for automotive R&D, facilitate investment, and increase allocations for the sector. The Phase II of the **FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles)** scheme was launched in 2019 with an allocation of USD 1.3 billion for three years, a large part of which is utilised as demand incentives[38]. **The Vehicle Scrappage Policy** launched by the GoI in 2021, aims to replace old with new and better vehicles. **The National Automotive Testing and R&D Infrastructure Project (NATRiP)** is a government-aided project worth USD 500 million for the creation of four state-of-the-art R&D infrastructure, automotive testing and homologation facilities, with cutting-edge technology and equipment. **Since 2015, NATRiP has created six testing research centres around the country**.[39] Also, a collaboration between NITI Aayog and the UK government has led to the introduction of the **e-AMRIT** portal which is a site where comprehensive information regarding electric mobility in India is available.[40]

There are significant applications of digital technology across the automobile sector value chain. Product cycles in the automotive sectors are shrinking due to shorter technology cycles and rapidly changing customer needs, which require the participants in the entire value chain to move fast and quickly switch over to meet the market demand. Several technologies, such as automation, advanced robotics, IoT, and data analytics, added value and cost savings, making the operations more sustainable. It has become imperative for all stakeholders across the automotive industry to digitally operate the business from design to after-sales service by building an intelligent and digital supply chain.

An Indian technology-led start-up, Ola, employs advanced techniques for smart manufacturing in its factory in the UK. (Figure 4).

To achieve global manufacturing excellence, India's automobile sector must increase productivity, dependability, and lower rejection rates. OEMs are leading the adoption of digital technologies, but for component manufacturers/suppliers, mostly SMEs, this is a big challenge. Though there is clear intent to adopt digital technologies, most companies lack a clear roadmap for transformation. High cost and lack of a suitable workforce are the biggest deterrents. Increased spending on R&D is required, along with academia and institutions stepping in with the development of relevant courses and training programmes.

OLA'S Digital Factory Technology Led Indian Start-up

10 million
Annual Production

10
Production Lines

3k+
AI Driven Robots

To capture an early and sizable share of India's EV market. India's leading mobility start up OLA has partners with Siemens, as it looks to rapidly build its electric vehicle manufacturing facility.

Running at full capacity, the factory would be able to generate almost 10,000 jobs and has an annual production capacity of 10 million units per year. The factory would be OLA's global manufacturing hub catering to not only dometic demand but also service key markets across Europe, the UK, Latin America, and ANZ.

Built using Industry 4.0 principles the factory deploys over 3000 robots across various functions and uses Siemen's integrated digital twin technology and its own propriety AI Engine and tech stack.

Industry 4.0 technologies are deeply embedded in the manufacturing systems leading to self-learning and continous optimization ensuring higher control on the quality and automation. Further, the entire material handling from raw material to finished.

Source: book.olaelectric.com/futurefactory

Defence and Aerospace

India spends **USD 72.9 billion[41] or 3.7 per cent** of worldwide military spending, making it the **world's third-largest military spender**[42]. Given the security challenges India faces, the defence and aerospace sector has been given a massive push under the **Atma Nirbhar Bharat** initiative to make India self-reliant and a net exporter in this sector. The GoI has set an ambitious target for the defence and aerospace production market to increase to **USD 25 billion by 2025, with exports accounting for USD 5 billion**[43]. The sector has been opened up to private players, creating a great opportunity for collaboration with foreign firms to **Make in India** for domestic and global markets[44]. The budget for 2022-23 proposes to open up defence-related R&D activities to **industry, academia and start-ups, allocating 25 per cent** of the defence R&D budget to them[45].

To position India as the global hub for defence manufacturing and make it a significant player in global value chains, the GoI has taken major initiatives towards strengthening India's manufacturing capability, enhancing competitiveness and indigenisation.

- **74 per cent FDI** through automatic (no approval), and **100 per cent** through the government approval route to encourage foreign investment.[46]
- **Under the PLI scheme, the** Ministry of Civil Aviation has announced **a USD 16 million**[47] outlay to enhance the **manufacturing capability of India in drones and drone components**.
- The **Defence Procurement Procedure (DPP)** has been updated to make Indian-IDDM (Indigenously Designed, Developed, and Manufactured) the most desired category for defence procurement.

Capacity Building

- Restructuring of the 200-year-old **Ordinance Factory Board (OFB)** into seven defence public sector undertakings to improve accountability and competitiveness.
- In Uttar Pradesh and Tamil Nadu, the government has established two Defence Industrial Corridors **to offer a plug-and-play facility to the industries, with single-window clearances, connectivity and infrastructure support and expected investment of about USD 2.7 billion by 2024**[48].
- A first-of-its-kind **Defence Technologies & Test Centre (DTTC)** is being built on around 22 acres in Uttar Pradesh's Defence Industrial Corridor to help the defence and aerospace industry clusters expand faster.

Research and Innovation

- **The Technology Development Fund (TDF)** has been developed as a part of the **Make in India** initiative to make India self-reliant in defence technology, especially for the components; so far (February 2022), a project worth **USD 22 million** has been approved[49]. Further, TDF is also looking to collaborate with international agencies for the bilateral programme.

- To build upon the R&D testing facility, the Ministry of Defence (MoD), GoI, launched a **Defence Testing Infrastructure Scheme (DTIS) in 2020**. Under this scheme, **USD 53 million will be channelled into establishing an advanced testing infrastructure in collaboration with the industry**[50].
- In April 2018, the MoD launched Innovations for Defence Excellence (iDEX) to boost innovation and technology development in the defence and aerospace sector by employing various stakeholders and aiding them with financial and other support to conduct research and development. So far, about USD 133 million has been assigned for iDEX-linked procurement, and this allocation will be increased in future[51].

Industry 4.0 and Defence Manufacturing

The focus in defence manufacturing is on reducing rejection rates and achieving precision. Quality and reliability are two main aspects, and the application of digital technologies in manufacturing can ensure the required precision. With an increasing number of Indian companies getting orders from the defence services, and the sector opening for private players, visibility in supply chains is critical and can be achieved through Industry 4.0. For example, Hindustan Aeronautics Limited (HAL) in India has bagged orders for 83 Indian Light Combat Aircraft TEJAS from the air force. Further, considering time and scale, the digital manufacturing process would play an important role in such a large project. The success of this programme would lead to multiple similar opportunities opening up for other defence companies.

Indian defence manufacturing companies recognise that to participate in global value chains, they must eventually adopt Industry 4.0 technologies, and some have already begun to do so. For example, HAL and the Gas Turbine Research Establishment (GTRE) use 3D technology to build components, particularly engines, for India's aircraft programme. However, the additive manufacturing (AM) capability in defence manufacturing is insufficient. Defence Public Sector Undertaking (DPSU) BEML and Wipro Infrastructure Engineering (WIN) signed a memorandum of understanding (MoU) to collaborate in aerospace, industrial automation, 3D printing, artificial intelligence, and other areas to overcome knowledge gaps.

Telecommunication

The Indian telecommunication sector is the **second largest in the world**, and as of December 2021, the subscriber **base in India was about 1.18 billion**.[52] The sector contributes to **4 million direct and indirect jobs and 7 per cent of total FDI inflows**, making telecoms the third largest sector in terms of FDI.[53]

The rapid growth of digitisation, impetus on rural connectivity and 5G rollouts and deployments have been the key drivers for increased demand for networking and telecom equipment, most of which is traditionally imported. To reduce this dependence on imports and address the growing security concerns around personal data protection, the GoI is working towards building indigenous manufacturing capabilities with a strong focus on R&D.

In the recent announcement of the Union Budget 2022–2023, **5 per cent of the USD 7.3 billion annual Universal Service Obligation Fund is being earmarked for R&D in telecom**[54]. The fund provides financial aid for telecom services in unfeasible rural and remote areas of the country.

Industry 4.0 and Telecom Manufacturing

The integration and implementation of IDTs across many industries have gained traction owing to their numerous benefits, adaptability, and increasing acceptance. Although the application of advanced digital technology in telecom manufacturing is still nascent and requires optimal strategic imperatives to build a robust manufacturing ecosystem. Telecom giants are slowly incorporating **AI-based technologies, blockchain and IoT** in manufacturing and supply chains to increase precision manufacturing, reduce wastage of raw material, improve customer experience and minimise turnaround time[55]. **Nokia** is employing digital twins to break down excessive data existing across equipment and manufacturing processes. The whole set of assemblies, inventory warehousing, as well as testing facilities, have all been combined into a digital twin hosted on **Microsoft Azure**, providing Nokia's factory operations team with a complete, real-time picture of activities on the shop floor. Nokia India has also deployed **autonomous guided vehicles (AGVs)** to assist with the moving of large parts like aluminium castings, which were traditionally transported manually by humans using trolleys[56].

Government-led Initiatives

- To make India digitally empowered and well-connected in the field of technology, the government has launched the **National Digital Communications Policy–2018 (NDCP2018)**. This policy envisages the development of a resilient and affordable telecom infrastructure that will aid digital transition.
- **Digital India** campaign ensures that government services are made available to citizens electronically.
- **National Broadband mission**. The mission was introduced to boost broadband connectivity across the country to bridge the digital divide between rural and urban India. Internet and mobile connectivity will help spread information and knowledge to expand the reach of businesses in the rural countryside.

- The **Department of Telecommunications (DoT) has created a sixth-generation (6G) innovation group** to help push the development of 6G technologies.[57] The initiative will help to create a vision and objectives as well as develop a roadmap for research and development, pre-standardisation, development of applications and products, and action plans for 6G technology, enabling the country to take the lead in the 6G space. [58]
- The GoI has also built the **Quantum Communication Lab at the Centre for Development of Telematics (C-DOT)** in Delhi, and indigenously developed **Quantum Key Distribution (QKD)** solutions that can sustain a distance of >100 km.
- **PLI Scheme worth USD 1.65 billion** in the telecom and networking products sector was launched to boost India's manufacturing capabilities and enhance exports under the Atmanirbhar Bharat campaign.
- The GoI launched **the Bharat Net Project** to provide high-speed broadband connectivity to 0.25-million-gram panchayats (GP) in rural areas, of which over 66 per cent have been successfully connected.

Electronics

In 2020, electronic hardware production was worth USD 65 billion[59], representing 3.6 per cent of the global production, accounting for less than 3 per cent of India's GDP[60]. As per the second edition, i.e. National Policy on Electronics (NPE) 2019, the goal is to make India a **USD 300 billion global electronics powerhouse by 2026**.[61] The sector has shown impressive growth in the recent past with a three-fold increase between 2014 and 2020. Furthermore, to establish India as a global hub in electronics manufacturing and a reliable and trusted partner in global value chains, it is envisaged to increase exports from the sector to USD 120 billion by 2025-26, from the current level of USD 10 billion[53].

Government-led Initiatives

Under the current policy regime, the emphasis is on creating an enabling ecosystem focusing on competitiveness, scale, and exports. The three new schemes under **the National Policy on Electronics (NPE)**, i.e. SPECS, PLI and EMC 2.0, have fast-tracked the growth and led to an increase in India's share in global electronics manufacturing, from 1.3 per cent in 2012 to 3.6 per cent in 2020[62]. Furthermore, the PLI scheme for IT hardware offered incentives for upscaling the production volume of electronics products to gain cost competitiveness. To strengthen the ESDM ecosystem and position India as the global hub for ESDM, the following major schemes have been notified:

- **Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS)** was created with a **USD 440 million budget to boost India's electronics manufacturing** value chain by giving 25 per cent incentives on capital investment in new units and expansion, modernisation, and diversification of existing units.
- **Modified Electronics Manufacturing Clusters Scheme (EMC 2.0)**. The scheme was launched to support the development of first-class infrastructure with shared facilities and services like **ready built factory (RBF) sheds/plug-and-play facilities, with a USD 500** million investment to strengthen the link between the domestic and international markets by improving supply chain responsiveness, lowering logistics costs, etc.
- The **PLI scheme for semiconductor and display board production** was approved by the GoI with a budget of USD 10 billion for semiconductor manufacturing for the next 5-6 years. This scheme aims to boost the chip manufacturing ecosystem in India, especially in the post-COVID-19 era when the supply chain for microchips has been significantly disrupted. This scheme has also attracted the foreign chip manufacturing giants like Foxconn and Wistron to choose India as their manufacturing partner. Semiconductor consumption in India is growing at a rate of 15 per cent, driven by the growth in the electronics manufacturing industry[63]. **India currently meets 100 per cent (equivalent to USD 15 billion) of its semiconductor requirements through imports**[64].

Industry 4.0 in Electronics Manufacturing in India

India needs to focus on emerging technologies to enhance competitiveness and establish itself as the leader in electronics manufacturing. Between 2013 and 2018, robot installations in India saw a compound annual growth rate (CAGR) of 20 per cent[65]. While automation in production equipment originally focused on reducing manufacturing costs and enhancing productivity, its usefulness in enhancing the quality and flexibility of products has become more important to meet changing customers' requirements in a short time delivery period. Higher revenue from manufacturing units set up by multinational corporations has triggered more R&I activities. Large companies like Samsung and Google have set up R&D centres in India.

India is currently the second-largest manufacturer of mobile phones in the world in terms of volume and aims to increase mobile manufacturing tenfold by 2025[66]. However, most of these manufacturers are only doing assembly and testing. Printed circuit board assembly (PCBA) is at the heart of electronics manufacturing. Surface mount technology (SMT) is today the preferred technology for PCBA. SMT lines are fully automated in Indian factories. Local assembly/manufacturing of mobile sets by large multinational corporations like Samsung, Apple/Winston and others have given the required scale of operation for setting up a design and components manufacturing ecosystem, which needs to be leveraged.

Energy

India has set a target of 500 GW of renewable energy by 2030, with solar accounting for more than half of it, i.e. 280 GW.[67] India is ranked fourth in the world for overall installed renewable energy capacity, with 151.4 GW (including large hydro) built, sharing nearly 39 per cent of the country's total power generating capacity, as of December 31, 2021[68]. **India has the fourth largest capacity for wind power, and the fifth largest solar capacity in the world**.[69] As per renewable energy plans, India's solar capacity implementation target will fuel the demand for cells and modules.

The GoI's Make in India and Atma Nirbhar Bharat programmes are assisting solar cell and module firms in establishing new production facilities. However, domestic solar equipment production has been unable to tap into this rising market for solar energy, with imports of cell modules, inverters and solar wafers worth USD 2.55 billion[70] in 2019-2020. India has a limited production capacity to produce 2.5 GW of solar cells and 8 GW of effective solar modules[71], but no local capacity to produce polysilicon and wafers, which are used in the upstream stages of the solar PV production chain.

Government-led Initiatives

The government is making efforts to boost domestic manufacturing of equipment used in non-renewable power generation through various steps, like the National Solar Mission (2010), the Modified Special Incentive Package Scheme (MSIPS), and applying higher customs duty on the import of solar cells. Some recent initiatives are:

- **PLI Scheme**. The government authorised a PLI plan for the solar PV manufacturing industry in April 2021, allocating USD 603 million for high-efficiency solar PV module investment. A total of USD 2.6 billion would be made available for the PLI for the manufacturing of efficient modules, with preference given to complexes manufacturing the entire range, starting from polysilicon to solar PV modules.
- **Increase in customs duty**. To make domestic solar manufacturing more competitive, the government issued an order to increase the customs duty on the import of solar modules to 40 per cent and solar cells to 25 per cent, respectively, beginning in April 2022 [72].
- **Policy on energy storage systems**. The use of energy storage systems in conjunction with renewable energy has the potential to improve power quality and reliability. The policy will seek the active participation of all stakeholders in establishing storage systems and associated manufacturing industries in India.
- **The National Wind-Solar Hybrid Policy**. The policy aims to create an agenda for the development of vast grid-connected wind-solar PV hybrid systems for optimal use of transmission infrastructure and land while also lowering renewable power supply unpredictability and improving grid stability.
- **The National Hydrogen Mission**. Launched in 2021 to make India a green hydrogen hub, setting a target of 5 million tonnes of green hydrogen production by 2030, as well as the development of renewable energy capacity. Further, India is targeting an electrolyser cost of less than USD 1 per kg in the next ten years.

Healthcare/Biotechnology

Healthcare has grown to be one of the most important areas of the Indian economy, and biotechnology, which is a significant component of it, has grown to be worth USD 63 billion in 2019, with a market share of **3 per cent+ in the global biotechnology industry**.[73] Biotechnology can contribute greatly to making India a USD 5 trillion economy with its application in other sectors like drugs and pharmaceuticals, agriculture production, switching over to biofuels, clinical research and development and also through the development of biofertilisers. The government has targeted to grow the biotechnology industry to USD 100 billion by 2025, and increase its share in the global market to 19 per cent[74]. Each subsector of biotechnology is going to have an impact on the economy and can prove to be the hotbed for clinical R&D. Indian biosimilar companies are involved in the extensive R&D models, and according to a report from the Biotechnology Industry Research Assistance Council (BIRAC), more than 52 Indian companies collectively have over 200 biosimilars, which is almost an identical copy of an original product and has no clinically meaningful differences from the drug-authority-approved original product, in the pipeline[75].

Industry 4.0 and the Biotechnology Sector

The use of digital tools will enable companies in India to achieve breakthrough therapies and biosimilars, and manufacture conventional and new drugs more economically using more innovative methods. The shift to personalised medicines necessitates the production of small batches, which can be more efficiently managed with smart manufacturing methods. Moreover, it would also be easier to track users/patients online for feedback and data from fitness apps (such as those of Google or Samsung), offering a pharma company actionable insight about the efficacy of their medicine. Currently, medical records are stored out of sight of unauthorised individuals, and generally kept locked in a cabinet.

Government-led Initiatives

- Biotechnology parks/incubators have been built around the country by the Department of Biotechnology (DBT) to help transform research into goods and services by providing the required infrastructure. Scientists and SMEs can use these biotechnology parks for technology incubation and pilot plant research to speed up commercialisation. India now has nine biotechnology parks operating in different states.
- Biotech Consortium India Limited (BCIL), a corporation supported by the DBT, is the main agency for providing business support services like executing specialised consultancy projects, project management and expeditious transfer of technologies to help biotech goods and processes commercialise faster.
- DBT has also created 15 theme-based autonomous institutions around the nation, as well as two public sector undertakings (Bharat Immunologicals and Biologicals Corporation Limited and BIRAC) for biological manufacturing and fostering the start-up innovation ecosystem.
  - o Biotech science clusters have been formed by DBT. By forming bio clusters, incubators, and technology transfer centres, these clusters developed a technological development and translation network across the country. Four bioclusters have been built so far.

Potential Areas of Collaboration

The UK, ranked fourth in the Global Innovation Index (GII), aims to further consolidate and develop itself as a global hub for innovation. India is growing economically and has the ambition to become an innovation-led global hub for manufacturing and gain a substantial share in international trade.

The prevailing gap in the technology domain between the UK and India in the smart manufacturing sector, which requires integrating all production systems and enabling them to exchange information on a real-time basis for achieving smart production, makes a strong case for technology collaboration between the two countries. Digital transformation of the supply chain is also imperative to achieve real-time visibility, accuracy, and performance management throughout the supply chain extending from the manufacturing plant and warehouse to transportation and, ultimately, the final point of distribution using technology evolution such as RFID. Both countries should look for complementary strengths both in academia and industry, and avoid the risk of reinventing the wheel. Our study highlights the following areas for collaboration:

- **Low-cost automation solutions**. The institutions and scientists in the UK are at the forefront of developing new and exciting technologies, which have the potential to transform the economic landscape of any country. India's manufacturing sector, with a vast base of SMEs and highly competitive labour, opens up huge opportunities for both countries to work together on developing appropriate and cost-effective solutions for achieving automation in the production process. This collaboration needs to prioritise two needs:
  - **Deep collaboration that brings together sophisticated algorithms with a realistic understanding of the manufacturing context.** The UK has considerable strength in developing algorithms and tools that harness data to provide decision support to manufacturers – but these are only as valuable to potential manufacturing businesses as they are relevant to those businesses, and this requires a combination of technical sophistication co-designing with those intimately aware of the realities of Indian manufacturers. There are very strong and well-connected sector bodies across different manufacturing sectors that can act as intermediaries and enable the creation of teams of specialists on both sides who can work together.
  - **Upgrading legacy machines**. For upgrading legacy machines in the production line, a smart box solution to convert legacy equipment into smart equipment would be preferred on cost considerations. The UK, with its vast experience in automation, can develop plug-and-play hardware solutions custom-made for Indian applications. This should be preceded by a detailed survey/ analysis of gaps in Indian SMEs, analysing the processes that are associated with the greatest amount of inefficiency and waste. The solution should be easy to install so that the SMEs can retrofit the machines themselves.

- **Software**. Implementing automation solutions in manufacturing processes requires software, the cost of which will depend on the automation need and the complexity of the design of the system. However, solutions that are commercially available at a high cost will have only a limited market. One solution to this could be through the development and dissemination of open-source, cloud-based subscription technologies that would be affordable for SMEs. These could be offered in the form of a monthly or annual machine subscription. Collaborative research is recommended for building a common open-source platform that should be made available to all, for building open-source automation solutions.

- **Joint standards development.** India has a history of developing its product standards that help protect Indian manufacturers in terms of the domestic market but limit their export potential. The UK, in contrast, with its relatively small domestic market and SMEs' focus on global markets from an early stage, has a much greater experience in working with and seeking to influence international standards bodies. The British Standards Institute (BSI) is highly respected and has a strong track record of building standards in partnership with the industry. **The UK and India should work together in developing joint standards for Industry 4.0 and then use their combined influence to shape global standards**. In the domain of digital manufacturing solutions, the UK and India working together on solutions that fit within low labour cost, high legacy tech contexts could have much wider application outside of India – for instance, across SE Asia and Sub-Saharan Africa – and standards associated with these could lead to huge growth possibilities.

- **Skilling.** The ecosystem for industrial training in India needs an overhaul as the employability of those trained at the industrial training institutes leaves much to be desired, and the companies can't afford to train the workforce on the shop floor. It will require a combined effort from academia, government, and other relevant agencies to work together on the curriculum and practical approaches to education and training. The UK has well-established institutions in this domain, and their participation in the improvement of the skill up-gradation ecosystem of the manufacturing sector in India will make a substantial change in terms of the quality of the trained workforce. In particular, TVET UK is very strong at connecting the UK vocational training sector with those overseas to grow capacity. The challenge to be addressed is the development and delivery models for these skills, given the training has to be offered at a fraction of the cost of the UK. Innovative working with the Indian National Council for Vocational Training and Education could be built into the UK-India Education and Research Initiative (UKIERI) programme, which already has some activities focused on advanced manufacturing.
- **Data analytics**. Developing solutions that enable manufacturers to capture production process data in real-time has huge potential but requires substantial innovation taking into account the state of technology. Simple tools should be possible but will require a different mindset for the detection of issues with processes and equipment, identifying bottlenecks, reducing costs and maximising output throughout the supply chain up to the customer as it lets you understand buying habits and preferences as well. Both countries can work together to **develop data analytics platforms for IoT applications (end-to-end platforms), which are integrated with commercially available IoT devices.**
- **High-value manufacturing**. The UK's manufacturing sector is a very high-value manufacturing sector with unique challenges where the quality needs to be controlled diligently, and the system needs to be flexible, i.e. moving from one product type to another and having a high level of customer engagement. **India could work with the UK in addressing these challenges by leveraging its software expertise. Further, since the UK is much further ahead in high-value manufacturing, it can work with India on the same.**
- **Cybersecurity**. It is a global issue, and both India and the UK face similar challenges, thus making a strong case for collaboration. The UK is a global leader in the cybersecurity space and has a well-developed R&D capability. India has good talent in the area, and the two countries could work together in building business-friendly frameworks for a secure network to provide trusted network solutions.

Emerging Opportunities – Sectoral Approach

The sectors we have investigated all have substantial requirements for digitisation and, being at the high-value end of manufacturing, offer good prospects for investment in the latest technologies from the UK. We recommend that further investigations are carried out to look at where specific needs could be addressed through collaboration, working with the whole sector, including their supply chains. The emerging opportunities that we have identified are as follows:

- **Automobile**. Both countries have agreed to enhance cooperation in the areas of clean transport, and explore collaboration in green hydrogen and battery manufacturing and innovation. India is expected to become the third-largest automobile market in the world by 2026. In India, the focus is shifting to clean transport, with a projected EV market to be worth USD 7.09 billion by 2025[76]. **Battery and BMS is a critical requirement in electric mobility and promises a great area for collaboration**, given the constraints in making LiBs. India wants to look beyond and work on new generations of clean fuels with a focus on green hydrogen. Several Indian companies and institutes have undertaken research projects in this area.
- **Defence and aerospace**. The UK and India have decided to scale up the defence cooperation under the existing **Defence Technology and Industrial Capability Cooperation MoU, through collaboration on light combat aircraft and future fighter jets for the air force**. The GoI has opened this sector for private players, as well as foreign companies, offering huge opportunities for collaboration. The UK is an established global player in terms of its level of technological advancement in defence and aerospace and can be of potential help to India in the **localisation of components of aircraft engines more efficiently and quickly**. The SMEs from both countries could work together to tap into the large domestic demand (India) and global demand.
- **Telecoms**. India's telecoms sector is the **second largest in the world**, and is growing rapidly with the impetus on rural connectivity and 5G rollout and deployment. The GoI is betting big on R&D in this sector and has announced the annual allocation of 5 per cent of the USD 7.3 billion of the Universal Service Obligation Fund[77]. The UK and India have agreed to sign the **MOU on cooperation in the field of ICTs**. Both could leverage the collaboration to work in the area of rural connectivity, 5G research for faster rollouts and deployment, manufacturing of network equipment to support rural connectivity and 5G implementation.
- **Electronics**. India aims to be a global hub in electronics manufacturing and a reliable and trusted partner in global value chains. The country has set an ambitious target to increase exports from the sector to USD 120 billion by 2025-26 from the current level of USD 10 billion[78]. As a trusted supplier that is conscious of its quality and security, India aims to develop an innovation-led manufacturing capability. Under the National Policy on Electronics 2019 (NPE 2019), the strategy is to implement a top-down approach or market pull R&D to accommodate the needs for local manufacturing in the electronics sector. The UK's technological capabilities in hardware manufacturing combined with India's software skills, skilled labour and the large market could help **develop low-cost and trusted solutions on the scale for the world and India's domestic market.** Further, both countries could work together on chip designing research to minimise the use of critical metals.

- **Renewable energy**. India has set a target of 500 GW of renewable energy by 2030, with solar accounting for more than half of that, i.e. 280 GW[79]. The Indian solar industry relies heavily on imports of important components such as solar cells and modules. The rising demand for solar installation in the country underlines the enormous potential for indigenisation across the PV value chain. Further, both India and the UK have recently launched the **Green Grids Initiative** as a critical solution to move the world into a clean and green future, which would further fuel the demand for affordable low-carbon technologies. Well-established UK companies engaged in manufacturing solar PV cells and modules can partner in India for local production of modules which would be mutually rewarding. This also aligns with the recent commitment of the UK government to invest USD 1.2 billion in green projects and renewable energy in India through public and private investments[80].
- **Biotechnology**. It has emerged as an important segment of the healthcare sector post-COVID-19 and hence has become a focus area for both countries. India's biotech sector is categorised into biopharmaceuticals, bioindustrial, bioagriculture, bioIT and bioservices. Within the biopharmaceuticals segment, India has developed into a prominent vaccine manufacturer globally. India also leads in biosimilars, with one of the most biosimilars approved in the domestic market. Within bio-services, India offers a strong capability in contract manufacturing, research and clinical trials. The Centre for Cellular and Molecular Platforms, or C-CAMP, Bengaluru and the Roslin Innovation Centre, University of Edinburgh, have established a sister innovation hub to collaborate in the biotechnology field to address the needs in agriculture and allied areas. Both countries need to explore opportunities for similar arrangements between innovation hubs located in the two countries working in the field for mutual benefit.

Recommendations

This study has established a broad base of understanding amongst the stakeholders for collaborative efforts in achieving a common goal. Given the complementary strengths of the two countries, there is an opportunity to create an R&I ecosystem availing the UK's expertise in R&D and advanced manufacturing, which could be clubbed with India's manufacturing base and huge domestic market that can fuel massive expansion and prove solutions at scale. This should be blended with collaboration between academia for the fundamental research to drive the successful implementation of new generations of start-ups and spin-outs from both countries.

We have distilled our findings from our research and recommendations from consultations into an overall assessment of the potential areas of collaboration. However, given the short timescale and limited scope, we suggest the commissioning of sector-focused deep dive exercises to chart a detailed focus for collaboration.

A joint working group should be formed to develop and coordinate the programme with balanced representation from industry and academia, which meets at regular intervals to develop, monitor, and guide the collaboration. We believe there is an opportunity for the **UK and India to develop a large bilateral programme** – to encourage R&I in digital manufacturing, both sides to consider the large value of bilateral collaborative industrial R&D projects. The forms of collaboration under this programme could include:

- **Centre-to-centre collaborations**. The UK has a very industry-guided research infrastructure with the **Made Smarter centres**. These centres could collaborate with similar centres in India created under **Udyog SAMARTH, NM-ICPS**, and others on a medium to long-term basis, to provide required inputs for research from an industry perspective that will have the critical mass to create innovations. Further, such centres can provide other support to industry, like consulting, training, demonstration and technology up-gradation. Since both countries have already invested significantly to develop these centres, integrating these centres would also help leverage and build on the investment and existing resources.
- **Academia-to-academia programme for innovation consulting**. There is an opportunity for academics from both countries to exchange knowledge, where researchers from Indian academia can visit the UK centres/universities to gain a practical view on how to successfully work with industry, especially SMEs, to implement automation. These visits could be for a longer duration, i.e. 30-90 days. These researchers can then work with Indian SMEs to suggest appropriate tools for automation and handhold them through the process of implementation.

- **Organising a bootcamp for start-ups and SMEs.** Start-ups and SMEs from both countries would gain exposure to each other's market, giving the UK businesses exposure to India's large domestic market, and Indian businesses can gain from UK's innovation-led business environment. Agencies like KTN and Catapults in the UK can structure and manage the programme.
- **Joint skilling programme**. A cluster approach needs to be adopted, as it is easy to implement a skill up-gradation programme as part of a common training centre in an industry cluster. It could be possible to utilise resources from the UK in a virtual session, train-the-trainer and demonstration session to share expertise in IDT tools with Indian SMEs.
- **Hackathons/innovation challenges** can be launched for key IDTs, such as IoT, AR/VR, AI, blockchain, 5G, cybersecurity, etc. Start-ups and innovators from both countries could work together to develop solutions. The focus of these challenges should be to solve real-world problems. These challenges would also help in sensitising the respective industry and academia on the potential of India-UK collaboration. An innovation challenge for UK SMEs to solve the challenges of large Indian companies could be launched.
- **Technology demonstration**. Annual or bi-annual technology showcases and demonstration events should be arranged for SMEs and overall industry. These could be planned as larger events and can also be merged with the announcement of results for innovation challenges etc. Such events can act as powerful tools for increasing awareness about the importance of digital technologies. Further, for **medium to long-term engagement**, a UK-India digital manufacturing and connected supply chain programme would be beneficial. This programme will match UK digital tech companies with Indian manufacturers and also provide funds to develop a demonstrator that is relevant to the challenges the manufacturers face. This concept has huge potential as a strong model for opening up the Indian market.

Next steps

Further Investigation to identifying current gaps of Indian SMEs in specific sectors, with the objectives of maximising efficiency and reducing waste of material resources and time.

Potentially explore a joint working group in digital manufacturing, to develop the future roadmap and monitor the progress, with annual meeting.

Organise a series of round tables to develop the joint bilateral funding programme.

Conduct a series of consultations to explore the potential areas outlined in the report.

Launching of bilateral collaborative industrial R&D programme and bring the Digital Manufacturing and Connected Supply Chains under the overrview of Newton Bhabha Fund or another similar programme.

Agency and Company Profiles

UKRI

UKRI is a non-departmental public body sponsored by the Department for Business, Energy and Industrial Strategy (BEIS). UKRI brings together the seven disciplinary research councils, Research England, which is responsible for supporting research and knowledge exchange at higher education institutions in England, and the UK's innovation agency, Innovate UK.

The organisation partners to shape a dynamic, diverse and inclusive system of R&I in the UK that is an integral part of society, giving everyone the opportunity to participate and to benefit.

Innovate UK KTN

Innovate UK KTN, works towards connecting ideas, people and communities to respond to societal, environmental and economic challenges and drives positive change through innovation. Their diverse connections span business, government, funders, research and the third sector. Through their network of experts, KTN ensures ideas are shared across diverse sectors and communities, so that opportunities are identified for innovation.

Finovista

Finovista is a project management and consulting firm engaged in country representation, project management consulting, capacity building and technology management. Within a short span of time, they have worked extensively with developmental agencies, government bodies, research agencies and businesses across over 10 countries.

With a mission to harness technology and innovation to drive growth of organisations, Finovista offers an integrated suite of services in energy and environment, clean cooking, development finance, healthcare, Industry 4.0 and social enterprise development. Finovista brings forth a unique blend of technical, managerial and project management skill sets, working on three layers structure viz advisor, expert and professional from India and world, who are extremely capable and experienced in executing complex projects.

Unconventional Connections

UC's expertise across innovation, policy development, international project management and extensive network of contacts will help ensure project's success.
The company offers:

- Bringing people together from different organisations and building an effective team delivering challenging projects.
- A structured approach for innovation-focused business collaborations.
- A unique network of contacts and ex-colleagues around the world, particularly amongst government officials and agencies focused on supporting innovation.
- Extensive contacts in international and the UK innovation landscape.
- An understanding of funding schemes.
- Through years of moving into new areas, an ability to rapidly build an understanding of new domains.

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Annex A – Profile of Stakeholders for One-to-one Consultations

Mr Anup Wadhwa

Automation Industry Association (AIA)

Prof Ashutosh Tiwari

Department of Automatic Control and Systems Engineering, Sheffield University

Prof Mukesh Kumar

Department of Engineering, University of Cambridge

Dr Henry Bookey

Fraunhofer UK

Prof Sam Turner

High-Value Manufacturing (HVM) Catapult

Prof Sunil Jha

IITD AIA Foundation for Smart Manufacturing (IAFSM), Indian Institute of Technology (IIT) Delhi

Dr Rahul Walawalkar, Mr Debi Prasad Dash

India Energy Storage Alliance (IESA)/Customized Energy Solutions (CES)

Mr George Paul

Manufacturers' Association for Information Technology (MAIT)

Mr Rajan Varshney

NTPC Limited

Dr A K Jindal/Mr Bharat Parekh/Mr Vishal Khanorkar

Tata AutoComp Systems

Mr G Sundararaman

Wipro Infrastructure Engineering

Annex B –
Multi-stakeholder Webinar

A webinar was conducted, comprising experts from industry and academia. There were 249 registered participants for the webinar, out of which 96 attended.

Agenda

Time GMT/IST	Activity	Panelist
0900/1330 hrs	Welcome	**Dr Geraldine Durand**, Knowledge Transfer Manager Global Alliance, Innovate UK KTN
0905/1335 hrs	Inaugural	- **Ms Geeny George Shaju** Dip CIPR, Acting Deputy Director, UK R&I (UKRI) India, British High Commission (BHC) India - **Mr Krunal Ramesh**, Innovation Analyst - Manufacturing & Materials, Innovate UK
0920/1350 hrs	Presentation on research findings	**Mr Vimal Kumar**, Programme Director, Finovista
0935/1405 hrs	Panel discussion on digital manufacturing Moderator: **Mr Vimal Kumar**, Programme Director, Finovista	- **Prof Ashutosh Tiwari**, Department of Automatic Control and Systems Engineering, Airbus/RAEng Research Chair in Digitisation for Manufacturing, University of Sheffield - **Mr Joe Smith**, Product Lead, Intellegens - **Prof Sunil Jha**, Professor, Indian Institute of Technology (IIT) Delhi & Director, IITD AIA Foundation for Smart Manufacturing (IAFSM)
1020/1450 hrs	Panel discussion on connected supply chains Moderator: **Ms Nicole Ballantyne**, Knowledge Transfer Manager – Manufacturing, Innovate UK KTN	- **Mr Vikas Saxena**, Director & Head - Software Division, Renishaw India - **Prof Mukesh Kumar**, University Lecturer, the University of Cambridge and Research Associate, Institute for Manufacturing (IfM), University of Cambridge - **Mr George Paul**, Chief Executive Officer, Manufacturers' Association for Information Technology (MAIT) - **Mr Khushal Kalra**, Smart Factory, Wipro Infrastructure Engineering
1105/1535 hrs	Questions and answers	
1115/1545 hrs	India internationalisation opportunity for UK advanced manufacturing high-growth companies	**Ms Ciara Fitzgerald**, Head of Innovation & Business Advice, Innovate UK EDGE
1125/1555 hrs	Closing remarks and way forward	**Dr Geraldine Durand**, Knowledge Transfer Manager Global Alliance, Innovate UK KTN

Annex C – Centre of Excellence and SAMARTH Udyog Centre

The Centre of Excellence was formulated to promote R&D and fast-track technology innovation under the Indian capital goods scheme. The Department of Heavy Industry, GoI, has established eight CoEs at various academic institutes as part of their scheme (see below). In addition, to support the transition, SAMARTH Udyog - Industry 4.0 centres, are being established in the country to encourage advanced manufacturing, helping SMEs to employ Industry 4.0 (automation and data exchange in manufacturing technology). See overleaf.

Centre of Excellence under capital goods scheme

CoE	Profile
IIT- Madras, Advanced Manufacturing Technology Development Centre (AMTDC)	The centre is working in the domain of smart machines, intelligent machining process automation, IoT-enabled machining process diagnostics and IoT for machine tool diagnostics/prognosis.
IISc Bangalore, Centre of Excellence in Additive Manufacturing (AM) for high-performance metallic alloys	The centre is working in the domain of additive manufacturing technologies.
CoE Central Manufacturing Technology Institute (CMTI), Bangalore	The centre is working in the domain of hi-tech shuttle-less looms, sensor technology and nano manufacturing.
CMTI Bangalore, the Demo and Development Cell for Smart Manufacturing	The centre is working to boost the adoption of the latest sensors, and actuators technology in the equipment.
CoE, Pune - The Centre for Industry 4.0 (C4i4)	The centre works to fast-track Industry 4.0 adoption in MSMEs by providing a roadmap for digital transformation through consultancy services and skill development.
IIT-Kharagpur, Centre of Excellence in Advanced Manufacturing Technology	The centre focuses on design, unique materials, automation, 3D printing, digital manufacturing, and industrial IoT.
IIT Delhi, AIA Foundation for Smart Manufacturing (IAFSM)	The centre supports and develops smart manufacturing concepts enabling Indian industry to observe, ideate, and test in their facilities.
PSG, Coimbatore - Centre of Excellence in Welding Engineering and Technology	The centre is working on the development of welding automation, including robotic technology.

SAMARTH Udyog – Industry 4.0 centres

Centre	Profile
Centre for Industry 4.0 (C4i4) Lab Pune	The centre promotes and encourages the use of Industry 4.0 technologies through training, awareness, and programmes to assist Indian manufacturers.
IITD-AIA Foundation for Smart Manufacturing	The centre is working on establishing an Industry 4.0 demonstration workshop and conducting related programmes at the IITD campuses in Delhi and Sonipat.
I4.0 India at IISc Factory R&D Platform	In the field of Industry 4.0, the centre will establish India's first industrial R&D application development facilities.
Smart Manufacturing Demo and Development Cell at CMTI	The centre focuses on aerospace, machine tools and automobile sectors. It will be the first fully-fledged Industry 4.0 facility in the country.
Industry 4.0 projects at MHI CoE in Advanced Manufacturing Technology, IIT Kharagpur	The centre works in optimising sensor data and analysing it in a composite engine for optimal machinery conditions.

Annex D – National Strategies and Policies for Industrial Digital Technologies

National Strategy on Blockchain

To foster a trusted digital platform and develop blockchain infrastructure, MeitY, in December 2021, launched the national strategy document to support innovation, R&D, and technology/application development. The strategy also aims to establish India as a global leader in blockchain technology and envisages providing secure, transparent, unique, and trusted digital services to every Indian citizen.

National Strategy on Artificial Intelligence

NITI Aayog was given the responsibility to develop the National Programme on Artificial Intelligence in 2018, with a perspective to support R&D in recent advanced technologies. This strategy document is built upon considering the strengths and potential of India to position itself as a global AI leader. The document also outlines how India may use disruptive technologies to promote social and inclusive growth in keeping with the government's development philosophy.

National Strategy on Additive Manufacturing

In February 2022, the national strategy on additive manufacturing was launched by MeitY to foster an enabling ecosystem for design, development and deployment and to overcome technical and economic barriers for global AM leaders to set up their operations with supporting facilities in India, boosting the development of the domestic market and maximising global market share.

Internet of Things Policy

The GoI produced an IoT strategy as part of the Digital India initiative, to develop smart and connected IoT-based systems for India's economy, society, environment, and worldwide requirements. The policy emphasises human and technological capacity development for IoT-specific skillsets for local and international markets, as well as research and development for all accompanying technologies in the domain of health, defence, smart cities, Industry 4.0, automobile, transportation, supply chain management, etc.

Annex E – Profile of Made Smarter Research Centres

Made Smarter Research Centres are an important part of the UK government's strategy to support the commercialisation of new technologies that address both technological and societal issues. In 2021, it announced USD 69 million in funding to accelerate innovation in digital manufacturing through the establishment of new research centres, an innovation hub and 37 individual projects to help digitise manufacturing supply chains. The details of these centres are given below.

Organisation	Profile
InterAct	Established at Loughborough University, and works with academics from the social sciences to support the innovation and diffusion of digital technologies
Research Centre for Smart, Collaborative Industrial Robotics	Based in Loughborough, Strathclyde, Cranfield, Bristol and Warwick Universities, works in minimising barriers for adoptions of robotics and fast-track their widespread use in manufacturing.
Centre for People-Led Digitalisation	Based in Bath, Nottingham and Loughborough Universities, works towards increasing the digital knowledge and awareness of manufacturers to increase manufacturing capacity
Research Centre for Connected Factories	Based in Nottingham, Cambridge and Sheffield Universities, working on the agility of factoring where production can be easily repurposed in response to changing market demand.
Digital Medicines Manufacturing Research Centre	Based in Strathclyde, Cambridge and Loughborough Universities, aims to create digital supply chains that enable medicines to be supplied on demand and enable clinical trials to operate more flexibly.
Materials Made Smarter Research Centre	Based in Strathclyde, Cambridge and Loughborough Universities, works to overcome technological challenges preventing adoption of new materials and manufacturing processes.

Figure 5: Profile of the six Made Smarter Research Centres

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Head Office

Innovate UK KTN
Suite 218 Business Design Centre
52 Upper Street
Islington
London N1 0QH

Telephone: 03333 403251
Email: enquiries@ktn-uk.org
ktn-uk.org
@KTNUK

Contact Person

Innovate UK KTN
Geraldine Durand
Knowledge Transfer Manager - Global Alliance
geraldine.durand@iuk.ktn-uk.org