in planning for sustainable development from a geoscientific perspective. Tenant and Gilmore[5], in a study on governance and mortality in cyclone-affected nations for the period 1996–2016, showed that countries with more effective governance have lower mortality rates. This is well exemplified in the case of India, post-enactment of the Disaster Management Act in 2005 and subsequent formation of the National Disaster Management Authority (NDMA) and State Disaster Management Authorities. Though our post-disaster management is excellent, as exemplified by an active NDMA, the prevention part requires attention. It is important to note that the cost of protective measures is likely to be a fraction of the scale of losses witnessed in recent climate-change-induced disasters, and this is the need of the hour in the present context. Despite decades-long valuable inputs from organizations such as the Geological Survey of India, Indian Space Research Organisation and many others, the accelerated climate change appears to render these inputs inadequate. Thus, we need to have qualified and trained specialists in each district of hill states who must be entrusted with the task of studying, planning, and monitoring land characteristics, natural processes and anthropogenic interference to bring out a unified approach to multiple development activities, be it large infrastructure projects or urbanization within specific areas. These basic inputs are large-scale thematic maps on geology, geomorphology, neotectonics and probability of natural hazards. Use of India's enhanced remote sensing capabilities, as well as modern tools such as artificial intelligence and machine learning, which are being applied in various geoscientific domains[6], can be effectively utilized. This will necessitate an expertise-based administration, and such planning will be robust, cost-effective and people-friendly in the long run. This can also be a significant step in the right direction for fulfilling the ambitious goal of India becoming a developed nation in a few decades.

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COMMENTARY

Opportunities of 'Make in India': a path towards 'Aatmanirbhar Bharat' or Self-Reliant, India

Amrita Chaudhary and Pratishtha Pandey

Globally, science, technology and innovation are gaining prominence. Research and development (R&D) is India's main driving force for sustainable economic growth. The 'Make in India' (MII) initiative by the Government of India (GoI) motivates the Indian manufacturing sector with aim to make India a global centre for manufacturing via foreign investors. In this regard, India became a hub for foreign investors with a 76% rise in the foreign direct investment (FDI) equity inflow of the manufacturing sector from financial year (FY) 2020–21 (USD 12.09 billion) to FY 2021–22. One of the key objectives of MII is job creation and skill enhancement in the country. In this context, the Department of Science and Technology, GoI, continuously contributes to improving the science and technology infrastructure through several funding programmes. This note provides a brief overview of the achievements of MII and its scope in scientific R&D.

The Indian economy is rising day by day, with an estimation of 7% gross domestic product (GDP) during the year 2022–23 (ref. 1). This development has been guided by a fusion of key features like good domestic utilization, funding and a young workforce. Research and development (R&D) is one of the areas contributing to Indian economic output. According to the 2021 data of World Development Indicators, World Bank, India holds fifth position in the world economy[2,3]. The Department of Industrial Policy and Promotion was renamed Promotion of Industry and Internal Trade (DPIIT) in January 2019 under the umbrella of the Ministry of Commerce and Industry, Government of India (GoI). The major initiative of DPIIT is to reinforce the manufacturing and financing domain of the country. In this regard, the DPIIT launched the 'Make in India' (MII) initiative on 25 September 2014. MII aims to expand the manufacturing sector at the rate of 12%/annum by 2022 to generate 100 million jobs and assure a 25% contribution to the GDP[4]. MII is the first 'Vocal for Local' initiative that aims to promote India's manufacturing sector at global level. It helps attract foreign investors to India for the manufacturing domain. The main aim of MII is to manufacture goods with zero defects without compromising on environmental standards. MII was initiated in two phases, viz. MII-I and MII-II were launched in 2014 and 2020 respectively. The objectives of MII-I are to attract to draw interest of

foreign investors in making India a global manufacturing centre, increase foreign direct investment (FDI)-oriented jobs, and increase exports. MII aims to make 'Aatmanirbhar Bharat' or Self-Reliant India in manufacturing and focuses on 27 specific sectors. There are 15 manufacturing sectors and 12 service sectors. DPIIT is synchronizing manufacturing activities, and the Department of Commerce, Ministry of Commerce and Industry, GoI, is harmonizing the services sectors.

As shown in Figure 1, MII covers diverse sectors. However, this note provides only a brief overview of specific areas in the field of science and technology (S&T).

Research and development in the field of science and technology

Defence and space

GoI has selected the defence and aerospace sector to persuade native manufacturing infrastructure through necessary R&D under the 'Self-Reliant India' mission. The Indian military ranks third in the world, spending 2.15% of the country's GDP[5]. GoI has introduced two committed defence industrial corridors in Tamil Nadu and Uttar Pradesh respectively, for defence manufacturing and upgradation of existing infrastructure and human capital under MII-II[6]. This sector manufactures several advanced products like gun systems, aircraft, helicopters, missiles, tanks, diesel–electric attack submarines, etc. which are being used by the Indian Armed Forces[7]. The Indian space programme is fruitful and cost-effective. The country is appreciated all over the world for its lunar probes, satellites and Mars operation[8]. The two major operational launch vehicles launched during 2015–22 are the Geosynchronous Satellite Launch Vehicle (GSLV, $n = 9$) and Polar Satellite Launch Vehicle (PSLV, $n = 30$). The other space initiatives include Mars Orbiter Mission (MOM) or Mangalyaan, Chandrayaan-3 Mission (India's mission to the moon), AstroSat Mission (India's first observatory mission for astronomy) and Aditya-L1 Mission (India's first solar observatory in space)[9]. Indian Space Research Organisation has launched various foreign satellites, spacecraft, launch vehicles and the second developmental flight of Small Satellite Launch Vehicle (SSLV) during 2014–23 (refs 10, 11).

Pharmaceuticals and medical devices

India has earned the reputation of being the 'pharmacy of the world' due to the widespread acceptance of Indian medicines in numerous countries. It is the world's third-largest producer of generic and cost-effective medicines and vaccines, and the fourth-largest in Asia in the manufacturing of medical devices[12]. It is the leading supplier of diphtheria, tetanus and pertussis (DPT), bacillus Calmette–Guérin (BCG) and measles vaccines. In 2020–21, a 1.32% contribution to the Indian economy was from the gross value added (at 2011–12 constant prices) of the pharma sector[13,14]. India's pioneer vaccine, ROTAVAC against the rotavirus, was launched under the National Immunization Programme in 2015, which paved the way for the fast development of 'Covaxin' in the country during the COVID-19 pandemic. The important outcomes of 'Atmanirbhar Bharat' are the world's first noninvasive intranasal COVID-19 vaccine (iNNCOVACC) and India's first m-RNA vaccine (GEMCOVAC®-OM), an Omicron-specific mRNA-based booster thermostable vaccine[15,16]. CERVAVAC is India's first indigenously developed vaccine produced by collaborative efforts of Serum Institute of India (SII), Department of Biotechnology (DBT), Biotechnology Industry Research Council (BIRAC) with Bill & Melinda Gates Foundation through the 'Grand Challenges India' programme[17].

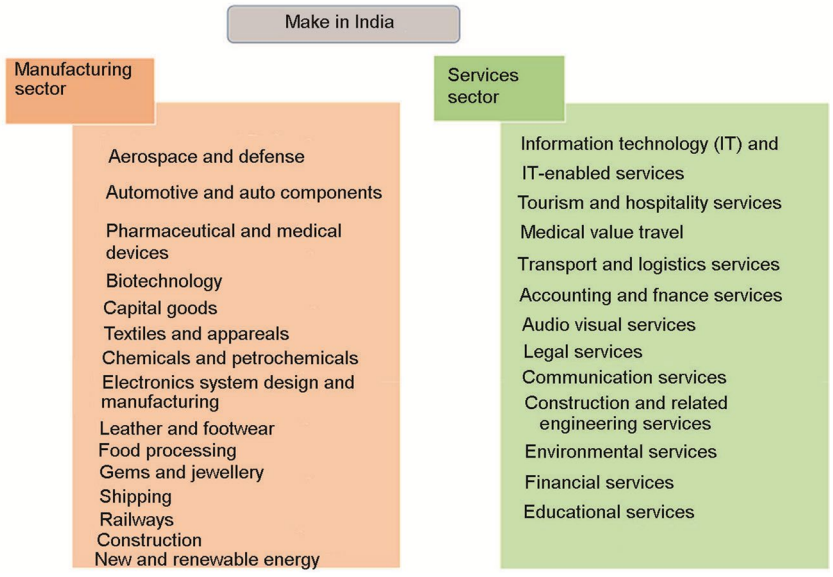

Figure 1. List of manufacturing versus services sectors under the 'Make in India' initiative.

Biotechnology

In the field of biotechnology, India is in the 12th position globally and third in the Asia-Pacific region[18]. Under MII-1, DBT has initiated an MII Facilitation Cell at its public sector venture, BIRAC in 2015–16 for three years, 2018–21 for three years, and further extended up to 2026 for five years. BIRAC supported various start-ups to develop products and technologies along with commercialization. During the last 10 years, there has been a rise in the Indian bio-economy as COVID-19 enabled a major thrust. This diverse sector focuses on agricultural biotechnology, healthcare and industrial biotechnology. As per India Bio-economy Report June 2022, there is rise in biotech start-up base from 2010 to 2021 with cumulative expansion of 26.6% in 2021 (ref. 19).

Electronics system design and manufacturing (ESDM)

The Ministry of Electronics and Information Technology (MeitY), GoI facilitates MII by promoting R&D for manufacturing semiconductors, micro-electro-mechanical systems, chips and fostering the Digital India programme. There was a 51.56% increase in the export of electronic goods during 2021–22. The national supercomputing mission supported the petascale supercomputer Param Shakti, a high-throughput computational facility for large-scale problems[20]. Some of the key achievements of MII in ESDM are the supercomputer PARAM PORUL, modern semi-conductor

devices and signal chips[21,22]. In this context, the Digital India programme facilitates the specialized and individualistic business component – India Semiconductor Mission (ISM), to enable the manufacture of sustainable semiconductors and display ecosystems with a Rs 76,000 crores (>10 billion USD) impetus package[23]. An announcement in the *Economic Times* stated that Micron Technology, an American chipmaker, will invest approximately $825 million to build new chip and testing facilities in India, enabling the release of the first MII semiconductor chip by December 2024[24].

Food processing

The geographical location, soil type and seasons make India an agriculture-dominant country. The country holds first position in milk, spices and millets production and second position in aquaculture production, sugar export, production of food grains, fruits, vegetables and wheat[25–27]. India ranks third in fish production, fourth in sea-food export, fifth in millet and coffee export and eighth in meat production[28]. Some important outcomes of MII in this sector are as follows: the Indian Council of Agricultural Research (ICAR) has developed a new, heat-resistant wheat variety (HD-3385), soil testing laboratories (499 permanent, 113 mobile, 8811 mini and 2395 rural level) have been set up, and increased bio-ethanol production and blending which involves grain-based, molasses-based and dual-feed distilleries to produce 1G ethanol[29,30]. The United Nations (UN) has declared 2023 as the International Year of Millets, considering the proposal of GoI. Under this programme, GoI will sponsor post-harvest value addition, increase domestic use, and promote and brand millet-based products worldwide[31].

Steady progress in the Indian manufacturing sector

The economic growth and investment in S&T are associated, as exemplified by the UN, the European Union and the United Kingdom[32]. The two key determining factors of the manufacturing sector in any country are (i) combined global manufacturing output and (ii) percentage of contribution of the sector in a country's formal gross domestic product (GDP)[2]. FDI inflow is a crucial player in India's economic development and is an imperative source of non-debt finance. An official press release by the Press Information Bureau (PIB) mentions that the Indian manufacturing sector is booming and is rapidly becoming the preferred destination for foreign investments. There has been a 76% rise in FDI equity inflow (FDI-EI) of the manufacturing sector from financial year (FY) 2020–21 (USD 12.09 billion) to FY 2021–22 (USD 21.34 billion)[33]. During FY 2022–23, FDI-EI of the top five countries into India is represented in Figure 2 *a*, with Mauritius having the highest value (26%). Among the Indian States, Maharashtra leads with 29% FDI-EI (Figure 2 *b*), while the leading sector in India is the services sector with 16% FDI-EI (Figure 2 *c*)[34].

DST programmes augmenting MII

GoI is making significant efforts to grow human capital through the Skill India initiative for the younger generation, and striving for global manufacturing to India through its MII programme[35]. For innovations in S&T, DST provides funds for infrastructure and workforce. In this context, a few initiatives are worth mentioning, like Sophisticated Analytical Technical Help Institute (SATHI), Fund for Improvement of S&T Infrastructure in Universities and Higher Educational Institutions (FIST), Promotion of University Research and Scientific Excellence (PURSE), Sophisticated Analytical Instrument Facilities (SAIF), and Synergistic Training program Utilizing the Scientific and Technological Infrastructure (STUTI)[36].

DST has identified 26 key scientific laboratories and test equipment of sufficient local capacity and competition based on details from procuring entities and other stakeholders. Considering the need to focus on the availability, affordability and manufacture of high-quality equipment to facilitate the grantee agencies, scientists and other stakeholders, the Scientific Research Infrastructure Management and Networks (SRIMAN) policy has been formulated for an easy and clear process of procurement, maintenance, access and sharing of equipment and infrastructure for research[37]. DST serves as a nodal department for scientific laboratories and test equipment to promote MII, manufacturing and production of goods and services in India for generating income and deployment. Its focus areas in S&T are supercomputing designing, assembly and installation, equipment of the Indian Railways using ultra-modern technologies, advanced manufacturing technologies (AMT), technical research centres (TRCs) for technology and product development (Figure 3). The five major areas of DST for MII are discussed below.

Advanced manufacturing technology

According to the goal of the National Manufacturing Policy and its prominence towards MII, DST has initiated AMT to support several important projects in five specific domains, viz. (i) Nano materials and surfaces, (ii) robotics and automation, (iii) precision manufacturing, (iv) manufacturing process of pharmaceuticals and biomanufacturing, and (v) Advanced forming and near net-shaped processing. The Technology Development Programme of DST helps foster indigenous and innovative technologies for development and deployment.

Technical research centres

TRCs have been established in five autonomous institutions of DST to support necessary laboratory facilities and product development.

Uchchatar Avishkar Yojana (UAY)

This programme is collaboratively supported by the Science and Engineering Research Board (SERB), DST, and the Ministry of Human Resource Development (MHRD), GoI, renamed the Ministry of Education (MoE), intending to nurture innovative research that can influence the demands of industry directly. For this, the SERB, MHRD, and industry share of funding are 25%, 50%, and 25%, respectively.

Impacting Research Innovation and Technology (IMPRINT)

DST, in partnership with MoE, GoI, executes this programme for funding in presence across nation (PAN)-IIT and the Indian Institute of Science to solve various engineering challenges for the benefit of society.

Technology Mission for Indian Railways (TMIR)

This is an endeavor of DST, Ministry of Railways, Ministry of Education (MoE)

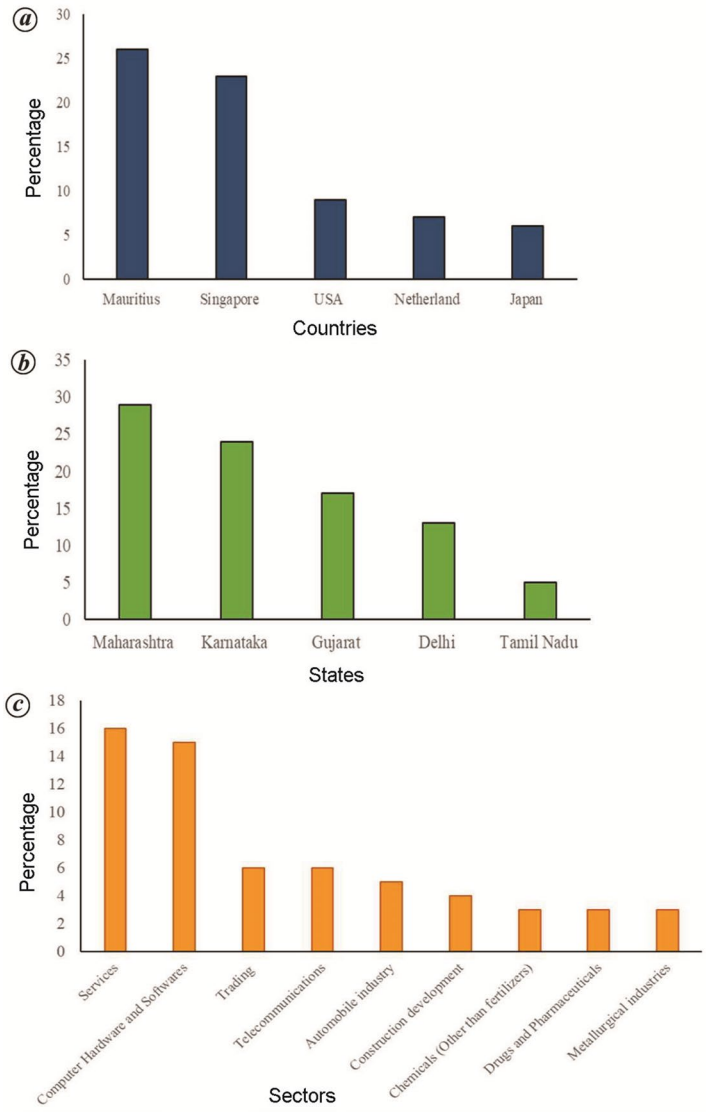

Figure 2. Recent trend of foreign direct investment (FDI) equity inflow for the financial year (FY) 2022–23. ***a***, FDI equity inflow into India. ***b***, Indian states having the highest FDI equity inflow. ***c***, Sectors with the highest FDI equity inflow in India.

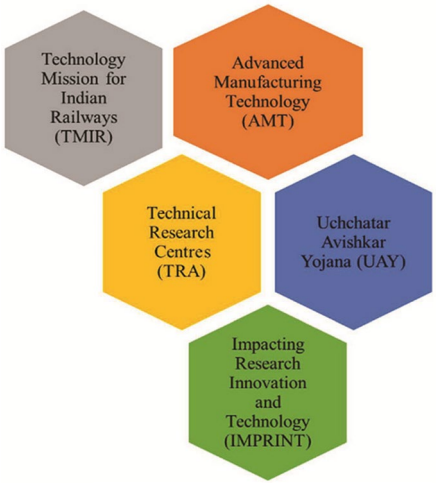

Figure 3. Focus areas of Government of India, Department of Science and Technology programmes for the MII initiative.

(Formerly known as Ministry of Human Resource and Development (MHRD)) and Ministry of Industry GoI to develop advanced and innovative technologies for upgradation of the Indian Railways on an investment sharing model. A milestone achievement is the Vande Bharat Express, which is equipped with advanced, state-of-the-art safety attributes, i.e. KAVACH technology with 30% electricity through an advanced regenerative braking system.

Future scope and challenges

The MII initiative has made several significant achievements in diverse areas of S&T. In addition, its focus is to emphasize quality without compromising on quality to generate more workforce and expertise. This requires strict surveillance on the manufactured products to maintain quality.

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