ADVANCING INDIA: A TRANSFORMATION OF ITS ADVANCED MANUFACTURING ECOSYSTEM

An IU SPEA Capstone Project for the Confederation of Indian Industry

Abstract

This report, compiled at the request of the Confederation of Indian Industry (CII), examines the current state of Advanced Manufacturing (AM) in India, provides international case studies of AM best practices, and recommends policy imperatives for the Indian government, and private and public sector firms alike to create an ecosystem suitable to Advanced Manufacturing.

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I: The Definition of Advanced Manufacturing

- Advanced Manufacturing is the industrial capability of an economy to customize every unit of manufactured output while simultaneously deploying the scale advantages inherent to traditional manufacturing. Such customization allows producers within and across an economy's industrial sectors to meet every demand of each individual customer, without undergoing the expensive and slow retooling of any manufacturing processes.
- Advanced Manufacturing in Indian industry will be characterized by the phased introduction of decentralized, flexible large-item, small volume, mixed-flow production supported by data sharing and based on full interaction between humans and machinery.
- Public and private sector engagement brings advances in automation, infrastructure, and human resource development—particularly in retraining and skill development. Introduced in the Indian context, this engagement will aim toward nurturing a comprehensive ecosystem to support the development of Advanced Manufacturing in India. This blend of technologies will help to increase employment and grow Indian global market share.
- The primary technologies being used to empower this fourth industrial revolution worldwide are the advances introduced by 3D printing, the internet of things (IoT) information exchange, extensive computer modeling techniques, and remote frequency identification (RFID) asset tracking.
- Customized application of the technologies allows innovators to customize their specifically target the advantages they need to compete. Collaborative operations and public private partnerships enable firms to develop applications that fulfill the needs of their industry, environment, and company culture.

Advanced Manufacturing in Indian industry will be characterized by the phased introduction of decentralized, flexible large-item, small volume, mixed-flow production supported by data sharing and based on full interaction between humans and machinery. Public and private sector engagement will bring together advances in automation, infrastructure, and human resource development, particularly retraining and skill development, aimed at nurturing a comprehensive ecosystem to support the development of advanced manufacturing in India.

Advanced Manufacturing builds upon the advances in automation and infrastructure by bringing together machines, advanced analytics, decentralized intelligence, and people at work. Decentralized intelligence helps create intelligent object networking and independent process management, with the interaction of the real and virtual worlds representing a crucial new aspect of the manufacturing and production process. This process uses localized data collection to create real-time feedback for the manufacturing and design process. This is characterized by large-item, small volume, mixed-flow production supported by data sharing and manufacturing based on full interaction between humans and machinery, using IoT technology such as RFID tags.

"The First Industrial Revolution used water and steam power to mechanize production.

The Second used electric power to create mass production. The Third used electronics and information technology to automate production."[1] The Fourth Industrial revolution is beckoning; to unlock the full potential of its manufacturing sector, India must draw upon all four revolutions.

II: The Challenges of India's Development - Expansion of the Manufacturing Sector

In recent decades, India has kept a steady growth rate, despite years of global economic crises. The country is consecutively viewed as having the highest potential to assume a position of economic leadership globally. Keeping this pace, however, requires a lot to be done. To be sure, Prime Minister Narendra Modi endlessly pushes for important reforms, and has worked to create a stronger entrepreneurial environment in India. One of his projects, the "Make in India" initiative, sets lofty goals for India's manufacturing sector in general. Although such political willingness and motivation to grow are crucial, India is burdened by structural challenges that must be addressed.

The challenges mentioned in this section will need to be addressed. Finding solutions is crucial for the development of Indian manufacturing. For example, the country's waning infrastructure and internal transportation system is one of the largest hurdles preventing success. The country must build more than 10,000 kilometers of highways to meet the needs of its burgeoning economy. Most of the railways are over 100 years old and need urgent care and substantial modernizations. Overall, the total investment required to fill the infrastructure gap is calculated to be 1.5 trillion US dollars. Similarly, the communications and energy sectors need immediate attention. To feed the growing industrialization and urbanization demanded by the country's populace, the energy capacity needs likewise to improve.

The Indian rule of law is similarly concerning. Corruption and a waning property rights regime directly affect the country's "Ease of Doing Business" ranking and Economic Freedom Index.[2] Importantly, such concerns also impede industrial development.

Education serves as starting point for, and ultimate foundation to, India's development. Demographically, the country's population base for the next two or three decades will skew significantly younger than older. Today, most new graduates in India are considered unemployable; though in possession of a degree and the requisite formal training, they still lack the necessary knowledge and skills to work in the positions needed. The imbalance of female equality and low literacy rates are also worrisome; such systemic troubles further intensify the drying pool of skilled labor.

The Indian tax system has improved dramatically. Regardless, a lot must still change. The taxation of commercial profits is among the highest rates in the world. For example, the corporate

tax rate for foreign companies sits at a burdensome 42 percent. When added to the bureaucratic and time costs, the taxation process in India is exceedingly hostile to business firms and industrial growth.

India faces a lengthy road ahead. Advancing the manufacturing sector – bringing its economy to the doorstep of a Fourth industrial revolution – starts with boldly tackling each issue mentioned above. While Prime Minister Modi's new policies and projects make India attractive to investors, growing a sustainable, successfully developing advanced manufacturing requires the proper cultivation of a dynamic economic ecosystem. It is mission critical to deliberate remove every impediment.

To be sure, however, the Indian government and its people seem very eager to follow such a path. We move in the next section to highlight small pockets where success is already taking root.

Identified Indian Successes in Advanced Manufacturing

The Bosch Group

- The Bosch Group (the Group) is an innovative global supplier of technology and services. The company operates in four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology.
- The Bosch Group comprises Robert Bosch GmbH and its roughly 450 subsidiaries and regional companies in some 60 countries. Including its service partners, Bosch's global manufacturing, engineering, and sales network covers nearly every country worldwide.
- To further build upon its strength in innovation, the Bosch Group is a pioneering user and supplier of Industry 4.0 technology. Bosch constantly develops and improves the efficiency of this technology to help the Group and other manufacturing companies keep up with the trends of the industry.
- The ownership structure of the Bosch Group guarantees for entrepreneurial freedom. This freedom allows the company to make and maintain long term planning, and to invest significant amounts of capital upfront to protect its future.
- Over the past decade, Bosch has more than tripled its sales in India. Since 2010, the Bosch Group has turned its attention to strategizing locally, instead of merely globally. It invested large sums of money for the expansion of manufacturing and research facilities in India. In 2014, the Group opened a new research and technology center focused on the development of connected technologies. This expansion – Bosch's largest development center outside of Germany – is located in India. The facility offers affordable solutions to its own local market, allowing for a better understanding of consumer needs and preferences. This strategy gives Bosch India an opportunity to establish relationships and the ability to leverage scale advantages with low costs and government support.

- With experience in implementation and vast representation, Bosch was well prepared to use its Industry 4.0 expertise to transform the facilities in India to compliment the vision of India's 'Make in India' policy. After the launch of the policy in 2014, the following year Bosh had initiated the implementation of Industry 4.0 in its 15 locations in India.
- Bosch India utilizes information from its partners across the globe, giving Bosch India the capacity to drive the country's Industry 4.0 development.[3] To assist India's manufacturing sector in a transition towards Industry 4.0 implementation, Bosch India hosts forums and conferences on Industry 4.0 solutions and implementation. The Group also partners with other manufacturing companies in India to offer consultation based on its experience and provide solutions that will enhance their digital journey.

General Electric

- General Electric (GE) is a multinational conglomerate founded and headquartered in the United States. According to Forbes in 2012, the company was the fourth largest in the world. Having a presence in India since 1902, GE deals in a cornucopia of industries, including aviation, capital, energy connections, healthcare, intelligent platforms, lightening, oil & gas, thermal power, transportation, water, wind energy and measurement.
- In 2014, GE had over 13,000 employees in India. To this day, the company prides itself on its great involvement of India's infrastructure, healthcare and technology development.[4]
- In large part, General Electric has recently invested in India to attend to an eleven-year contract, acquired in November 2015 from the Indian government, to supply and maintain a fleet of one thousand diesel locomotives. This deal, valued $2.6 billion USD, is the largest ever made in India.[5] GE plans to invest $500 million USD by 2017 to build new service and manufacturing facilities and maintenance bases. Those locations are planned to produce 4500 hp and 6000 hp diesel-electric freight locomotives.
- General Electric built its first smart manufacturing factory in India in the city of Pune, which opened its doors in February 2015.[6] The investment, costing $200 million USD, is the size of 38 football fields, and covers 67 acres of land. GE plans to manufacture a wide range of products—from jet engines to locomotive components—for diverse markets, including aviation, oil, gas, rail, and power generation. The company seeks to unite all the manufacturing necessary under a single roof, allowing GE to adapt quickly to fluctuations in demand.
- GE's new factory opened in 2015 deliberately fit the government's specifications provided in its "Make in India" campaign. Not surprisingly, Prime Minister Modi participated in the inauguration of the factory.[7]
- The Pune facility plans to hire 15,000 workers to work the production lines, support the infrastructure, and inspect 3D printers and laser technology. Most of the workforce will be highly skilled, with a quarter of the workers to be females, located on the shop floor. Also, Pune's factory will export a half of its output to other GE locations around the world.
- This experience demonstrates the spillover effects that crucial investments in India can

have. GE, as a company already operating within India, competed for government contracts and stimulated the application of advanced manufacturing.

Tata Power

- Tata Power is India's largest integrated power company with a significant international presence. The company has an installed generation capacity of 10496 MW in India and a presence in all the segments of the power sector, including Generation (thermal, hydro, solar and wind), Transmission, Distribution and Trading.
- TATA Power has over 200,000 employees and a distribution base of approximately 2.6 million customers. Some of its bulk customers include BEST Railways, Port Trust, BARC Refineries, and other important installations in Mumbai.
- Its international presence is vast, and includes strategic investments in Indonesia, through a 30% stake in a coal mining operation and a geothermal project; in Singapore, through Trust Energy Resources and the shipping of coal for its thermal power generation operations; in South Africa, through a joint venture (Cennergi) to develop projects in sixteen different African countries; in Australia, through investments in enhanced geothermal and clean coal technologies; and in Bhutan, through a hydro project partnership with the government of Bhutan.
- With a proven track record of technological innovation, TATA Power is an industrial leader in implementing Technology 4.0. Currently, the company trends toward automation and data exchange in manufacturing technologies, excellence in project execution, and world-class safety processes.[8]
- Tata Power Group's FY16 Revenue stood at Rs. 36,461 crores (including regulatory income /expense) up by 6 percent, compared with Rs. 34,367 crore (including regulatory income / expense) last year. The Company's growth plans include steady capacity additions yearly, taking its current installed capacity to 26000MW by 2020. At the end of August 2013, its market capitalization was $2.74 billion (INR 182 billion).[9]
- Tata Power has been using Advanced Manufacturing technologies for slightly over 10 years. In a vast country like India, power asset management, consumer services are a major issue. In such a scenario, digitization and use of big data analytics is imperative to ensure consistent, uninterrupted supplies to the consumers. Tata Power employs its Industry 4.0 expertise in digitization and big data analytics in real time, and improves compliance with regulatory requirements as well as to improve operational efficiency.
- The Company has also partnered with the Australian company Sunengy Pty. Ltd. to build the first floating concentrated solar PV plant in India. It has also partnered with Airbus Defense and Space to manufacture a complete fly-away C295 aircraft, and collaborated with TERMA to integrate and deliver surface surveillance radars for the Navy. As a leading domestic player in Strategic Engineering, the Division is now globally recognized for harnessing its "Systems and Engineering" capabilities and has been appraised at Maturity Level 5 of CMMI for Development.[10]

- Tata Power has focused on innovation since the first assembly line was established. The integration and interplay of Tata Powers product lifecycle management (PLM), factory automation and digitalization is crucial to this progress, which forms the basis of Industry 4.0 as the future of advanced manufacturing.
- Tata Power invests in training each of its 200,000 employees to meet Industry 4.0 Advanced Manufacturing standards. Apart from being a low-cost country, India also has a great potential of highly skilled individuals: as previously mentioned, most of the population is age 28 or under. This potential is largely capable of addressing an array of advanced manufacturing related solutions. This is something that can be scaled up by other companies to boost the industry because of increasing competitiveness of the economy. Industry 4.0 will change the qualification of the people needed. There will be less blue collared employees as their skill sets will be upgraded and more IT and data specialists in the coming days. This will also bring a new era of growth and wealth for the masses of the country.

Huawei

- Huawei, a giant Chinese telecommunications company, started manufacturing smartphones in India in October 2016 in partnership with Flex Telecom[11]. It set up a manufacturing plant in Chennai, and has been producing the Honor series phones with the capacity of making 3 million units by the end of 2017.
- Huawei captured 30% of the Indian market in 2016 compared to 21% in 2014. Its latest manufacturing initiative is part of its commitment to the Government of India's 'Make in India' vision by harnessing local talent, coupled with the infusion of high-tech Research and Development (R&D) expertise and knowledge into the country[12]. Huawei's largest overseas R&D center has been established in India for 17 years.
- Huawei aims to increase its presence in India due to India's potential in the smartphone market and the country' Make in India campaign. Huawei will strengthen its after sale services with 30 exclusive Huawei service centers and expand its distribution network by partnering with more than 300 distributors in India.
- To strengthen its global recognition, Huawei is focusing on R&D, Internet of Things, mass production, and increasing productivity by smart manufacturing. It can be said that Huawei is adapting advanced manufacturing well in line with the fourth Industrial Revolution—including robotics, nanotechnology, virtual reality, 3D printing, the Internet of Things, artificial intelligence, and advanced biology.[13]
- Huawei has also been collaborating with many Advanced Manufacturing companies like ABB, General Electric, and KUKA by signing memorandum of understanding agreements. For example, Huawei and KUKA will work together in areas such as Cloud computing, big Data, Mobile Technology Industrial Robots to help customers embrace Advanced Manufacturing.[14]
- Huawei's Narrow Band-Internet of Things (NB-IoT) solution won the gold medal for New

Technologies and Products at the 2016 World Internet of Things Exposition, which shows the high recognition from the IoT industry.[15]

III: International Case Studies of Best Practices

This section describes eight of the most successful international examples of Advanced Manufacturing. According to Deloitte's 2010, 2013, and 2016 Global Manufacturing Competitiveness Surveys, China was ranked as the most competitive manufacturing nation. Recently, however, Deloitte projects China's slippage from its pre-eminence before the year 2020. The United States, Germany, and Japan represent the three most dominant developed economy nations from a manufacturing competitiveness perspective.[16] South Korea (ranked fifth), Taiwan (ranked seventh), and Mexico (ranked eighth), and Kazakhstan (thus far unranked) represent developing examples. While the level of involvement and identity of supporting players changes from case to case, the case studies below suggest one constant in manufacturing success: top-down initiatives on the part of the national government.

Specifically, each country's subsection details the timeline of Advanced Manufacturing's adoption, its impacts on output and labor, and lessons that might be drawn from each case for India--as illustrated through company case studies.

Country	**View of Advanced Manufacturing**	**Key Advice for India from this Case Study**
China	*Made in China* and *Internet Plus* are tools to propel itself from industry 2.0 to 4.0 by increasing its labor productivity, encouraging innovation, and integrating the Internet into all its industries.	Ensure the accuracy of data on its employment and manufacturing outcomes to ensure MII objectives are accurate and realistic.
U.S.	Necessary redirection of sufficient resources and investment toward research and development throughout all advanced technology and manufacturing sectors.	Coordinate heavily the overhauling of industrial policies and initiatives from top-down, yet ensuring that local measures, rules, and regulations align.

Germany	*Industrie 4.0* means that industrial production machinery no longer simply "processes" the product, but that the product "communicates" to the machinery what to do.	An enabling manufacturing environment requires the input and commitment of individuals at macro and micro levels alike.
Japan	*Connected Factories* is an independent functioning system based on highly integrated subsystems.	SMEs could play a major role in the creation of employment opportunities, particularly for women and the elderly excluded from formal economic activities.
South Korea	The focus of *Manufacturing Innovation 3.0* is a shift of methods to produce competitive products.	Developing industrial clusters in key manufacturing markets could foster innovation and employment generation for smaller firms and cost advantages for larger firms.
Taiwan	Views Advanced Manufacturing as one of its strengths; ITRI, R&D organization helped with innovation and ingenuity.	Boost technological research and development with the creation of an organization like Taiwan's ITRI, with a mission to increase relevant international partners, entrepreneurship, and innovation.
Mexico	Required by and in furtherance of manufacturing conditions and ecosystem created by free-trade and regional trade agreements, specifically NAFTA.	Leverage manufacturing and labor capabilities into national trade, emphasized in bilateral and multilateral economic agreements.
Kazakhstan	Part of an ambitious diversification program, aimed at developing targeted sectors like transport, pharmaceuticals, telecommunications, petrochemicals and food processing.	Establish Special Economic Zones for Advanced Manufacturing with a tax-free regime and special conditions for investors regulated by unique law, open to firms that promise to contribute to economic growth in key Advanced Manufacturing sectors.

China: Implement Policy Boost for Manufacturing Upgrade to Address Productivity Issues

Background

- China is the world's largest producer of manufactured goods and its general manufacturing industry accounts for 40% of the country's GDP. However, Advanced Manufacturing is a new initiative in China. China is still transitioning to Industry 3.0, which is the use of industrial automation, electronics, and IT. Only 60% of Chinese companies use industrial automation software and only 25% of Chinese SMEs have adopted internet.[17]
- China was a low-cost goods manufacturing destination with cheap labor geared towards the export market. However, as the country became more prosperous, wages nearly quadrupled during 2004-2014, bringing the low-cost tag under attack. To close this gap, China has launched two policy plans to carry out a new round of industrial revolution: **Made in China 2025** and **Internet Plus.**

Made in China 2025

- In May 2015, China launched **Made in China 2025** (MIC 2025), a ten-year plan to revolutionize its manufacturing industry with Advanced Manufacturing technologies, including 3D printing and robotics.
- One of the main goals of MIC 2025 is to address the current issues of labor production costs. MIC 2025 implements goals to boost labor productivity by increasing the use of robots and upgrading the entire industrial value chain. A 7.5% annual growth of labor productivity is projected until 2020, and from then on, an annual 6.5% productivity growth. This would require a reversal of China's long-term productivity slow-down from almost 9.5% during 2007-2012 to an estimated 6.7% for 2015.[18]

Internet Plus

- To reboot its economy through advanced digitization China launched a secondary plan, called Internet Plus (IP) in 2015. IP's action plan aims to integrate the Internet with traditional industries. The plan will integrate mobile Internet, cloud computing, big data and the Internet of Things with modern manufacturing to encourage the healthy development of e-commerce, industrial networks, Internet banking, and to help Internet companies increase their international presence.[19]
- The goals of IP also include increasing R&D funding and increasing internet connectivity throughout the country. As part of Internet Plus, China plans to bolster its research and development spending to a total of 2.5% of gross domestic product through 2020. This

represents an increase of 0.4%, as such spending accounted for 2.1% of GDP from 2011 to 2015.[20]

- The action plan maps development targets and supportive measures for key sectors which the government hopes can establish new industrial modes by integrating with the Internet, including mass entrepreneurship and innovation, manufacturing, agriculture, energy, finance, public services, logistics, e-commerce, traffic, biology and artificial intelligence.
- To achieve these initiatives within the IP plan, there is a list of 65 corresponding development tasks and a specified leading ministry responsible for completing each task. The IP initiatives are supposed to be completed by 2025.

Integrating Industry Academia and Government Coordination

- China has recognized that a lack of coordination between the industry, academic, and government will only slow progress towards implementing Advanced Manufacturing. To solve this problem, MIIT has brought 14 state-run associations from different sectors together and created a voluntary quality management standard for automated and intelligent manufacturing.

Key Takeaways for India

- India could implement a similar initiative to improve policy coordination across different government agencies, universities, and manufacturing companies.
- China's MIC 2025 plan has been criticized for being too general in its objectives. For example, the priorities for increased *New advanced information technology* are the same priorities for upgrading its semiconductor industry. India needs to take care in its own plan that it is not repackaging similar goals for each objective.
- Another critique of the MIC 2025 plan and the IP plan is their lack of robust data on employment, skills and other labor market issues. Much of China's current employment data is unreliable. India should ensure it has accurate data on its employment and manufacturing numbers to ensure its objectives are accurate and realistic

The United States: Success through Federal Intervention and Industrial Coordination

Background

- The United States has long led innovation in Advanced Manufacturing. Recently, however, capability gaps in the U.S. have led to the loss of substantial economic benefits. In 2009, the United States ranked eighth among industrialized nations for R&D intensity (defined as national R&D as a share of GDP).[21]

- After the Great Recession, the United States began to realize the numerous fault lines in its economic weaknesses and the importance of redirecting adequate investment toward research and development and overhauling its policies and initiatives to bolster its manufacturing.

Key Policy Interventions

- The current key push in the recent U.S. Advanced Manufacturing renaissance comes mostly from federal coordination and comprehensive national innovation initiatives. The Obama administration turned the page in February 2012 and released its ***National Strategic Plan for Advanced Manufacturing***,[22] complete with five major objectives designed to accelerate the U.S. transition to Advanced Manufacturing technology.[23]

Major Institutional Partners

- In 2012, the U.S. federal government launched Manufacturing USA as a collaboration initiative that has pivotally "revitalized America's industrial commons and help[ed] ensure U.S. leadership across a range of advanced-manufacturing process and product technologies."[24] Now, at least four Institutes of Manufacturing Innovation (IMIs) within the Manufacturing USA network address Advanced Manufacturing-related technologies and processes.[25]
- The Manufacturing Extension Partnership (MEP) provides training, technical assistance, and other services to America's SME manufacturers. MEP centers operate in all 50 states (and Puerto Rico), managing 588 service locations with more than 1,200 field staff serving as trusted business advisors and technical experts ready and able to assist SMEs.
- Coordination between Manufacturing USA and America's SME manufacturers occurs through the Manufacturing Extension Project (MEP), which serves as a vital connection to diffuse new manufacturing technologies.[26] Estimates find that for every dollar of federal investment, the MEP generates $19 in new sales growth and $21 in new client investment. This translates into $2.2 billion in new sales annually.
- The United States' community college system also serves a critical role in preparing America's current and future workforce. Accenture recently estimates that 80 percent of America's manufacturing workers lack essential skills needed to unlock the potential of smart manufacturing,[27] casting a long shadow on the future of U.S. Advanced Manufacturing.

Case Study: Tesla Gigafactory[28]

- This state of the art manufacturing plant in Nevada is a collaborative effort between Tesla and Panasonic. Tesla invested significant resources to apply Panasonic's battery production technology on a large scale for specialized battery needs. When fully functional,

the plant is expected to produce more batteries than the global production total in 2013. The original partnership announcement[29] highlights collaborative R&D projects, and the combination of the two companies' competitive advantages to lower production costs for batteries.

- During the staggered construction phases, the plant imports batteries and components from Panasonic's factories in Japan to assemble products. This project is estimated to cost nearly $5 billion, with the aim to create a globally disruptive manufacturing plant. The key advantages being applied are an Advanced Manufacturing process and cutting edge technology to deliver cost savings of 30% over current manufacturing costs.

Case Study: Local Motors-DARPA Collaboration[30]

- This collaboration between the Department of Energy's Oak Ridge National laboratories and the Local Motors Corporation in 2014 pioneered full scale prototyping and design for the auto industry. The entire production process took less than six weeks from the start of the project to completed car. Local Motors is using this technology to significantly reduce the design time required for launching new product lines.
- Oak Ridge National Laboratories is a government funded institutions dedicated to advancing key manufacturing areas, dictated by policy, through partnerships with private companies. This winning combination allows a government directed tool for collaboration between companies with some of the brightest minds in the public sector.[31]

Key Takeaways for India

- Central government financial and technical assistance for increasing private and public collaboration in the areas of research and development for Advanced Manufacturing is fertile ground for meeting India's 2025 goals.

Germany: Collaboration and Innovation at All Levels of Manufacturing

Background

- Since 2006 the German government has been pursuing **High-Tech Strategy 2020** geared toward the coordination of research and innovation initiatives. The current overarching strategy focuses on five priority areas: health/food, climate/energy, mobility, security, and communication.
- High-Tech Strategy 2020 is composed of strategic initiatives through which the Industry-Science Research Alliance addresses concrete medium-term goals relating to scientific and technological development over a period of ten to 15 years. One such strategic initiative is "***Industrie* 4.0**", which was launched in January 2011.[32]
- A two-pronged approach was pursued: 1) the widespread adoption of basic technologies

and experience to Advanced Manufacturing, and 2) research and development of innovative solutions. At the same time, actors from industry professional associations joined together with research, business, and civil society communities to ensure coherent implementation. The cooperative exchange of technological and social innovations has been crucial to this process.[33]

- Six years later, 92 percent of visible exports are industrial goods and industry accounts for more than 22 percent of the German economy. On a global scale, German companies are the biggest exporters in fields such as green technology (products in environmental and climate protection fields) and renewable energy. Its gross-domestic product to exports ratio is 41.5 percent. In Europe's largest economy, industry still accounts for one in five jobs.[34]

Key Policy Interventions

- The Vocational Training Act of 1969, and amended in the labor reforms of 2005, introduced a tight-knit alliance between the Federal Government, the federal states, and SMEs with the aim of providing the country's unemployed youth with training in occupations, and certifications of their skillsets, that were recognized nation-wide.[35]

Major Institutional Partners

- Germany's success has been frequently credited to its **federal vocational training program**—the costs of which were subsidized and regulated by the state. The curriculum of the vocational system is governed through a process involving labor and employers' associations, and the government. The system is characterized by an emphasis on training workers broadly, beyond training them to work at a job site. Students divide their time between onsite training with an employer and theoretical coursework outside of their apprenticeship site aimed at the development of innovative thinking at all levels of manufacturing.[36]
- The **Fraunhofer-Gesellschaft** is an independent non-governmental organization which provides high-quality, short-term affordable applied research. Established in 1949 with just three employees, it is now Europe's largest application-based research organization, and a vital element in Germany's industrial and scientific landscape. Its operating budget is US$2.2 billion--approximately 30 percent of which is obtained through public sector funding and 70 percent through contract research earnings.[37] Applied research, carried out at partner universities, is funded to almost 100% by public grants. Industrial R&D, up to prototype level, is largely financed by private enterprise. Much of its 24,500 staff are scientists and engineers with advanced degrees. Its clients include policymakers, industry, and the service sector. Its focus areas include communication, health, energy, environment, and security. Together, Fraunhofer's 69 institutes and research units specialize in more than 250 research areas, and each is tied to a university with similar research interests.[38]

Case Study: Beckoff Automation

- Beckoff works with more than 75 distributors and 3,350 staff worldwide.[39] Headquartered in Verl, Germany, the company brought in $660 billion in 2015—an increase of 17 percent from the previous year. While subsidiaries in North America and Southern Europe are performing well, exports accounted—largely to Asia—for 65 percent of 2015 sales.[40]
- The company's strategy: produce machine tools and equipment the Chinese use to make luxury consumer goods. This niche market has kept the firm at the cutting edge of global trends in manufacturing; designing and making its product (ie, refusing to outsource) means the company can maintain quality control and respond quickly to changes in demand.

Case Study: Miele

- Headquartered in Gutersloh, and represented in 47 countries by company-owned sales organizations and in about 50 additional countries via importers, Miele experienced a sales volume of 3.71 billion euros last year--a 6.4 percent increase in its home market. Its eight plants produce over a million home appliances a year.
- By relying solely on family money and partnering with other SME firms, the company has been able to avoid debt and attract skilled labor from the vocational system.[41] As a partner of the vocational system, companies like Miele are the foundation of why German unemployment remains low.

Key Takeaways for India

- In Germany, many SMEs have thrived as of late with a simple strategy: producing machine tools and equipment the Chinese use to make luxury consumer goods. Targeting niche markets has kept these firms at the cutting edge of global trends in manufacturing; designing and making its product (i.e., refusing to outsource) means the company can maintain quality control and respond quickly to changes in demand.
- While the German government worked to reform the labor market, companies were simultaneously investing in vocational training for their employees. Similarly, the vocational system theoretically trains students to understand the larger systems in which they will work; no position in the labor force is too menial to be thinking critically about new innovations, strategies, or markets. The task of enabling manufacturing environment requires the input and commitment of individuals at macro and micro levels alike.

Japan: Fostering SMEs by Linking Local Enterprises into National and Regional Government Policies

Background

- As a "late-comer" to industrialization and modern scientific and technological development, Japan pursued intense efforts to catch up to the advanced countries during the post-World War II period and these efforts were underpinned by a close co-operation between the government and industry.[42] In April 2016, Japan published the new fifth plan for fiscal year 2016 to 2020.[43] As the economy matures, however, the Japanese economy has been stagnating for almost two decades. Both the manufacturing industry's share of the GDP and the manufacturing industry's share of employment had gradually declined throughout 2000s.
- Japan has the highest proportion of SMEs among the industrialized countries, accounting for more than 99% of total enterprises.[44] Historically, Japanese SMEs has often been concentrated in specific regions and formed regional clusters.[45]
- An important feature triggering local initiatives in Japan is a unitary national government system with control over regional development which enables them to pursue active and consistent centrally directed regional programs aimed at equalizing and balancing development.[46] As a result, there has been a strong interest by Japanese local governments in linking local enterprises, mostly small and medium sized ones, into national and regional government policies, and generating local approaches to research, technology development, diffusion and innovation.

Key Policy Interventions

- Following the passage of the Science and Technology Basic Law in 1995, local government has been responsible for formulating and implementing policies regarding the promotion of science and technology (S&T) corresponding to national policies' in accordance with the characteristics of their jurisdictions, and each of the three successive Science and Technology Basic Plans implemented since 1996 have contained a section outlining objectives for the regional level.[47]
- Currently, Sagamihara, Kitakyushu and many more city government have various ongoing projects in the city, focusing on support for supporting SME's to engage and enable new advanced manufacturing capabilities.[48]

Major Institutional Partners

- The Ministry of Economy, Trade and Industry (METI), the Knowledge Cluster Initiative of the Ministry of Education, Culture, Sports and Science and Technology (MEXT), and local governments play a major role in developing innovation regional policies.
- The role of Regional Bureaus of METI can be summarized as follows: (1) launching 20

Industrial Cluster Projects (up to 2005), (2) developing specific businesses, (3) promoting the reforms in corporate management and the creation of start-up companies, and (4) developing and refining the plans.[49] While METI is concerned with industry level, MEXT more focuses on universities and public research institutes.

Case Study: Polytechnic Colleges

- Japan faced a significant challenge of changes in industrial structure driven by technological innovation and the progressive shift of company activities overseas. This trend has accelerated the urgency of training human resources capable of supporting business developments in high value-added sectors and new areas of industry.[50] In addition, it remains vital for Japan to foster human resources to support the industrial base as companies are increasingly shifting their production overseas, and the number of young people interested in acquiring skills is decreasing.
- To cope with these circumstances, the Japanese Ministry of Health, Labour, and Welfare (MHLW) has taken steps to train people who underpin the advanced Monozukuri (Japanese Manufacturing Style) to serve as the foundation of Japan's industry. The Human Resources Development Promotion Law of 1985 stipulates that the national and prefectural governments should provide vocational training for workers wishing to change their jobs, and other persons needing special assistance for the development and enhancement of their vocational abilities.[51]
- In Article 15-6 of the Human Resources Development Promotion Act, the state and prefectures are obliged to provide public vocational training programs for unemployed workers, employed workers, and graduates. The Polytechnic Colleges were made to combine practice and study by effectively linking theory with skills and technology in accordance with developments in technical innovation and changes in the industrial structure, so that advanced technical engineers can be trained who are capable of handling cutting-edge skills and technology through their mastery of basic manufacturing technology.[52]

Key Takeaways for India

- India, according to its Ministry of Micro, Small and Medium Enterprises, had 13 million SMEs in 2008, equivalent to 80% of all the country's businesses (Ghatak 2010).[53] SMEs play a major role in the creation of employment opportunities in Japan and have provided job opportunities especially for women and elderly who have been excluded from economic activities.[54]
- Despite the proportion of youth population aged below 35 of about 70 percent, India is seriously handicapped with a very weak and narrow knowledge base.[55] The existing technical education system in India should employ the available huge human resource potential to align with a high-demand advanced manufacturing pathway.

South Korea: Renovating the Domestic Manufacturing Sector by Refining Manufacturing Cycles and Creating Exemplary ICT Convergence Models

Background

- In three decades, South Korea achieved what it took more than a century for the Western industrial countries to accomplish because of rigorous efforts concentrated on R&D and innovation. Korea's spectacular transformation resulted from a systematic economic and trade development policy that included incentives for technological innovation and the development of domestic intellectual property assets.
- Korea has employed the outward-looking development strategy (export-drive) of the government drove domestic industries out to international market, putting the manufacturing firms under fierce competition.
- In 2014, the Korean government announced the Advanced Manufacturing policy called "**Manufacturing Innovation 3.0**," which aims to raise $972 million in US dollars and set up 10,000 smart factories by 2020 to facilitate convergence between software and hardware technologies. In addition, experts said that Korean industries have been able to meet the increasing demand for R&D and innovation because their investments have been backed up by well-trained human resources.

Key Policy Interventions

- The Ministry of Science, ICT and Future Planning of the Republic of Korea has implemented its 5-year roadmap for smart manufacturing R&D since 2015 with the purpose to reform the country's domestic manufacturing sector, thus enhancing Korea's technological competitiveness among developed nations. Korea also paid significant attention to promoting collaborations between different technical fields to innovate manufacturing, facilitate technological convergence and create market demand. Korea's 5-year roadmap is expected to lead to greater productivity, less energy costs and shorter product development periods.
- Innopolis Foundation was established in 2005 by special law to contribute to the innovation of national technology and development of national economy by facilitating the R&D in universities and research institutes in the Daedeok area.[56] Recently, Daejeon city applied for the National Project (Official title: Korea's National Project on International Science Business Belt; referred to as "ISBB"), which is funded by Korean Ministry of Education, Science and Technology for the years 2012-2017 (total budget $ 4.5 billion).[57]
- Located in the middle of South Korea, Daedeok Innopolis was originally planned as Daedeok Science Town (DST). It was constructed in the early 1970s by the Korean state as part of a strategy to foster its heavy and chemical industry. As public sector R&D was crucial for advancing technology and upgrading industries, the DST research complex was built with the investment of $3.16 billion over the past 3 decades to better respond to the

economic demands of the nation. In 2002, for the further development of technology commercialization based on R&D, the Korean government re-designated the first National Special R&D Zone by encompassing DST, Daedeok Techno-Valley (DTV), and Industrial Complex.

Major Institutional Partners

- The central government, mainly the Korean Ministry of Education, Science and Technology, was the major institutional player at the initial stage. From the middle stage, the Daejeon Metropolitan City has become a major player. The central and local governments have collaborated in building a strong basis for innovation over three consecutive five-year long phases to transform industrial complexes into innovative clusters to nurture competitive clusters, which will in turn transform the Korean economy into an innovation-led one.[58]

Case Study: IoT for Public Safety LTE

- Korea has rapidly become a forerunner in Public Safety LTE (PS-LTE), and the Korean government is strongly mandating the rollout of a PS-LTE network. The government also plans to build an LTE-Railroad network, the world's first LTE-based network for railroad and subway operational support and an LTE-Maritime (LTE-M) network for coastal communications and navigational coordination.
- In the coming future, such networks will need to accommodate the Internet of Things. Sensors such as smoke alarms, motion detectors, wearables for emergency personnel and other devices will all be connected to the network.

Case Study: Hyundai Motor[59]

- Established in 1967, Hyundai Motor Company is committed to becoming a lifetime partner in automobiles and beyond. The company leads the Hyundai Motor Group, an innovative business structure capable of circulating resources from molten iron to finished cars. Hyundai Motor has eight manufacturing bases and seven design & technical centers worldwide and in 2015 sold 4.96 million vehicles globally.[60]
- Since 2015, the group has been focusing on helping automobile-related companies transforming their factories into smart factories. As part of supporting the government's project to build leading clusters of smart factories, the group is turning about 100 small and mid-sized partners in the Sihwa Industrial Complex in Banwol into smart factories.
- The group is supporting 200 companies (100 automobile-related companies and 100 other companies) so that they can transform their factories into smart factories from 2015 to 2019 in partnership with the Gwangju Creative Economy and Innovation Center in the Gwangju area.

Key Takeaways for India

- Future industrial policies in India will be focused on developing industrial clusters because these clusters can unite the advantages of innovation and employment generation for smaller firms with scale and cost advantages of larger organizations.[61] This industrial policy could interact with a strategy to foster Advanced Manufacturing, thereby gathering all the actors of innovation around key markets and technologies to foster the emergence of collaborative innovation projects.

Taiwan: A Model for Innovation Across the Manufacturing Industry

Background

- Taiwan continues to develop its Advanced Manufacturing industry. Taiwan is the world's fifth largest exporter of machine tools and components and has averaged $4 billion in exports annually over the last three years.[62] Taiwan is known for its computer-related products, wireless equipment, and flat panel displays. It is also an IT global supply leader in original equipment manufacturing and original design manufacturing.

Key Policy Interventions

- In October 2014, Taiwan's government approved its **Industry Upgrading and Transformation Action Plan**, with the goal of "pursuing green, knowledgeable, and culture and creativity transformations" to annually increase the manufacturing industry's production and export values. [63] The plan's four main strategies include "raising product levels and product added value," "setting up complete industry supply chain systems," "establishing systems solutions project competency," and "accelerating the development of emerging industries." [64]

Four Intelligent Industries Plan

- In 2010, Taiwan launched the **Four Intelligent Industries** plan, which focused on implementing cloud computing, electric vehicles, green architecture, and patent commercialization. By 2013, Taiwan's cloud industry had an output valued at TWD 427.6 billion and had created at least 32,000 jobs. Taiwan has also focused on smartphone development, with a goal of achieving an output value of TWD 1.28 trillion and 150,000 new jobs by 2015.[65]

Case Study: Encouraging Collaboration and Innovation in Advanced Manufacturing

- Since its founding in 1973, the Industrial Technology Research Institute (ITRI) has been conducting research and supporting Taiwan's economic growth by cultivating more than

140 CEOs and nurturing over 240 innovative companies, including the multinational companies of UMC and TSMC.[66] It is the largest research institute in Taiwan.

- ITRI holds more than 17,000 patents and is considered an industry expert in many research fields. ITRI mainly focuses on basic R&D for various applied technology. Research projects are conducted in conjunction with small and medium enterprises. The results of the research are then transferred to the SMEs for further development and eventual manufacture for industry. ITRI has invested US$2 billion in its Open Lab/Incubator program, which helped company start-offs get off the ground.[67]
- ITRI has an operating budget of US$510 million. It receives approximately 50% of its funding from the government. The remainder is provided by the 30,000 private sector enterprises that issue ITRI consulting, training, research and service contracts and lease its technology.[68] It has a research-oriented workforce of 5,800 employees with advanced degrees
- ITRI has an international division to seek out partner for the benefits of Taiwanese industries. ITRI has signed research alliances with leading US companies such as IBM, Microsoft, SRI International, and leading US universities like Berkeley, MIT, and Stanford University.[69]

Key Takeaways for India

- Implement an organization like the ITRI to increase R&D for various technologies within India. This organization would encourage research projects, collaboration with other countries, labor training, and entrepreneurship.

Mexico: Focused on Advantageous Growth through Free-Trade and Regional Trade Agreements

Background

- In 1994, at the time of the signing of the North American Free Trade Agreement (NAFTA), Mexico was widely regarded as having an economy suited only for a non-complex assembly of low-mix, low design and minimally engineered content products.[70] Surprisingly, Advanced Manufacturing operations were nonexistent for the most part.
- Two decades later, that mischaracterization is far from reality. Since the creation of NAFTA, Mexico has ascended rapidly up the global value chain, with the presence of Advanced Manufacturing in Mexico increasingly more common than not.
- Manufacturing in Mexico remains primarily export focused, and results mostly from the shift away from import substitution, started with the maquiladora policy launched in 1965.[71] The policy attracted FDI by allowing producers and investors tax-free raw material and intermediate input imports that they can then process/assemble and then re-export tax-free under the provisions provided by NAFTA.

- In 2010, Mexico's manufacturing sector exports reached almost 244 billion dollars, which represents nearly 48 percent of Latin America's total exports.[72] In 2011, three industries accounted for more than 70 percent of Mexican trade: electrical and electronic equipment, vehicles and machinery.[73]

Key Policy Interventions

- Numerous policy interventions have contributed to Mexico's success[74]:
    - Today's Mexico has greatly benefited from infrastructure investments dedicated to road improvements, rail expansion, and aviation infrastructure enhancements.
    - Present day Mexico has invested in vocational training centers and universities, and is currently graduating 230,000 engineers a year.
    - Mexico has made recent and difficult efforts to crackdown on cartels, resulting in a dramatic reduction in crimes rates in the last two to three years.

Major Institutional Partners

- Mexico has emerged as a global automotive manufacturing powerhouse[75]-- it is the seventh largest vehicle manufacturer and the sixth largest auto parts manufacturer currently.[76] 93 out of the top global 100 automotive parts manufacturers operate in Mexico.[77] Complex technical operations and production processes are increasingly becoming the norm in Mexico, primarily because of the automotive (and other similar industrial) sectors.

Case Study: Pallets and Crates International

- Pallets and Crates International (PCI) is a leading Mexican provider of bespoke engineered, low-cost wooden, manufactured, and recycled crates and pallets, serving industries in the El Paso – Ciudad Juarez Borderplex and companies in the city of Chihuahua. PCI's annual production sits at approximately 2,000,000 units, selling this volume across more than 150 different model lines.[78]
- PCI utilizes an advanced computer-aided-design (CAD) system to produce pallets, wood skids and crates. Using CAD ensures that PCI's products meet the precise needs of its customers and are delivered at an affordable price.[79]
- To match its customers' operational expansions, PCI continually invests in new equipment to adapt and innovate their CAD system. In addition to its technologic innovations, PCI consistently troubleshoots its systems with an eye to further streamline the process of delivering quality pallets with Advanced Manufacturing.[80]

Case Study: Visual Merchandising Inc.

- Visual Merchandising Inc. is a Broomfield, Colorado-based company that produces

polyurethane mannequins, with most of the product made in its Ciudad Juarez, Mexico plant.[81] With its focus on making a customer design experience as user-friendly as its mannequins, Visual Merchandising, Inc. has successfully grown into one of North America's largest source of truly custom mannequins. Recently, the Ciudad Juarez, Mexico plant recently manufactured and delivered 35,000 polyurethane mannequins to its U.S. affiliate,[82] Fusion Specialities,[83] for Nike.[84]

- The company holds onto patents for Advanced Manufacturing "rotational molding processes, magnetic fittings, and easy to use, non-marring flanges," with aspirations to rotate and hone its creative processes constantly. VMI's production of the life-sized figures used a rotational mold process in polyurethane--instead of the industry standard fiberglass--because of the superior durability of the former material.[85]
- In 2014, VMI expanded its facility and contracted an additional fifty employees--beyond its original four hundred and eighty workers.[86] Rich Moran, the company's executive vice president of operations, explained that "the present expansion is due to a growth in demand for VMI product. An increase in floor space at our Mexican manufacturing facility . . . enable[d] us to ramp up production in response, as well as to improve efficiencies by re-laying our factory work flow."[87]

Key Takeaways for India

- The Mexico of today has literally hundreds and hundreds of high-tech plants in industry clusters around major metropolitan areas, populated with highly trained and qualified professionals,[88] primarily due to several key policy interventions (modernizing the customs and imports processes, invigorating the vocational college system, etc.). These targeted strategies were derived primarily from the unique situation that resulted from Mexico's signing and implementation of NAFTA.

Kazakhstan: Creating Special Economic Zones for Advanced Manufacturing as a Driver for Economic Growth

Background

- Kazakhstan, geographically the largest of the former Soviet republics, excluding Russia, possesses substantial fossil fuel reserves and other minerals and metals, such as uranium, copper, and zinc. It also has a large agricultural sector featuring livestock and grain. The government realizes that its economy suffers from an overreliance on oil and extractive industries and has embarked on an ambitious diversification program, aimed at developing targeted sectors like transport, pharmaceuticals, telecommunications, petrochemicals and food processing.

Key Policy Interventions

- Kazakhstan's State Program of Industrial-Innovative Development for 2010-2014 and for 2015-2019 has been developed by the long-term priorities of the strategy "**Kazakhstan 2050**" in the implementation of the key direction "acceleration of diversification of the economy"[89].
- According to promulgated legislations, state support measures are as follows:
  Lending by financial institutions; Guaranteed state contract; Provision of engineering and communication infrastructure; Providing qualified human resources; Support products in the domestic market; Attraction of foreign investments; Development and promotion of export of domestic products[90].
- The government provides grants for innovation on R&D, training of technical staff abroad, support to produce high-tech products at the initial stage of development, patenting in foreign countries, commercialization of technologies, attracting highly qualified foreign experts, and the introduction the lean technology. Projects applying for grants must meet the priorities identified by the Government of Kazakhstan.[91]

Case Study: Special Economic Zones

- The SEZ Park of Innovative Technologies was established in 2003 by the Decree of the President and is valid until January 1, 2028. The SEZ was established to create of highly effective, including high-tech and competitive productions, development of new types of products, investment attraction[92].
- SEZ provides tax benefits, customs benefits, special conditions for attracting foreign labor force, access to utilities and transport infrastructure. In SEZ, Property Tax - 0% (1,5% outside SEZ), Corporate Income Tax - 0% (20%), Social Tax - 0% (11%), VAT - 0% (11%)[93].
- In 2015, the Autonomic Cluster Fund Act was introduced. The Autonomic Cluster Fund "Park of Innovative Technologies" (ACF "PIT") has the status of a non-profit organization and is the management body of the SEZ "Park of Innovative Technologies." It consolidates the scientific and technical base of leading universities and research institutes, as well as companies participating in the SEZ creating an innovative environment for innovation to be occur.
- By the Autonomic Cluster Fund Act, any natural resource extracting company is obliged to pay 1% of the total annual income for the development of innovation. The implementation of these requirements of the law is carried out by Innovation Cluster Tech Garden. The building of the Kazakhstan's International University of IT is being built on the SEZ. The Trust Fund is the highest management body headed by the President of the Republic. It determines the strategic directions of development of the Cluster and SEZ.
- Because of ongoing reforms, the share of innovation-active enterprises has increased from 4.3% (2010) to 8.1% (2015). The expenses of enterprises for technological innovations have increased threefold, and the volume of innovative products has increased threefold as well (2015). According to the "Innovation" Factor of the Global Competitiveness Index of

the World Economic Forum, Kazakhstan improved the rating by 18 positions and took 84th place (2014). In the factor for "Technological Readiness," Kazakhstan increased 25 positions (57th place)[94].

Key Takeaways for India

- Since India has several small size SEZ (416) with three level bureaucratized management system, it is reasonable to determine a wide area SEZ focusing on developing Advanced Manufacturing with flexible management system.
- Special Economic Zones (SEZ) acts as a driver of economic growth with tax free regime, special conditions for investors. The unique law regulates all processing and authority including labor relations within the SEZ. SEZ works closely with business communities, which would demand and push trends. Academia would generate ideas based on business' demands for further commercialization. The branch of the IT University has been relocated to SEZ to make academia more closely tied to the AM process. Housing for workers and scientists is also being built on the SEZ territory.
- The management company (e.g. Autonomous Cluster Fund) has wide authority which aims only in developing IT and Advanced Manufacturing and supports startups in the areas of Advanced Manufacturing.

IV: Recommendations for Implementing Advanced Manufacturing in India

Manufacturing Infrastructure

#1. Determine Special Economic Zones (SEZ) for developing Advanced Manufacturing that is managed by one management company which operates under the uniquely enacted law.

- **Summary:** The Government of India should develop and enact a bill that regulates a new cluster (SEZ, Management company, Trust Fund) to create flexible management system of Special Economic Zones (SEZ) with special conditions for investors and its unique labor relations system. The SEZ program should be integrated with the "Make in India" initiative so that it can be a major engine for economic growth in general and for manufacture development in India.
- **Vision for Application in India**
    - Enacting a new regulation would allow India to consider establishing or expanding the existing SEZ to gather all successful IT companies working on Advanced Manufacturing and set up a management company, as exemplified by Kazakhstan.
    - The activity of the autonomous cluster fund should be based on the following principles: integration of science; education and manufacture; the priority of financing the projects of participants, in the spheres of Advanced Manufacture;

development of fundamental and applied research; and stimulating the commercialization of technologies in priority sectors of the economy.

- **Potential Funding**
    - Funding of the SEZ, the Autonomous Cluster Fund and its activities can be done via establishing a Trust Fund. The Trust Fund's assets could be formed at the expense of voluntary property contributions and donations, as well as through the execution of public contracts (a separate budget program might be created). Besides accumulating and allocating funds, the trust fund can be a strategic structure to ensure that goals are being achieved and funds are not diverted.

#2: Implement a SBIR policy as a federal program of grants and loans to support high tech value added SMEs

- **Summary:** This policy programs uses national government goals to support small and medium enterprises. The SBIR program creates national grants to fund small businesses to develop technology that is a national priority. These priorities are set by federal scientists to further national economic and defense goals.
- **International Examples**
    - **The United States:** The SBIR program was started in 1982 with four goals: to stimulate technological innovation; to use small business to meet Federal research and development needs; to foster and encourage participation by minority and disadvantaged persons in technological innovation; and to increase private sector commercialization innovations derived from Federal research and development. For example, PA-14-171: HHS STTR PA-14-171 is being sponsored by the Health and Human services department to support marketable developments in mental health services.
- **Vision for Application in India**
    - Application in India could be developed in conjunction with local governments. An ideal application would involve companies creating technology requests that would then be distributed by universities and state organizations. The rewards or grants could be financed by multiple businesses within an industry, or they could be offered on an exclusive basis. This could be done via an NGO or through state facilitated offerings.
- **Potential Funding**
    - The best potential partners for this proposal are business executives, state leaders, and university or military support.

#3: Utilize investments on infrastructure as a motivation for the development of Advanced Manufacturing.

- **Summary:** As India becomes one of the most important economies in the world, many investments will be needed. One of these investments is the expansion and improvements of the nation's infrastructure. This necessity can also open doors to a cascade effect that can help other sectors develop including manufacturing.
- **An Example from Home**
    - **India:** In the case of railways, as indicated in the General Electric case study, the government stimulated the implementation of Advanced Manufacturing. GE was a pioneer in building a manufacturing plant that produces items in accordance with its contract with the Indian government. Without the government contract, GE may have been more hesitant to adopt Advanced Manufacturing practices in India.
- **Vision for Application in India**
    - In the case of India's railroad system, the government considers it a priority to further expand and modernize the system. In 2015, the mammoth Indian Railways transported 8.3 billion passengers, operating more than 21,000 trains on a network of more than 66,000 kilometers. With the expected economic growth of the country, Indian Railways services will need to grow to manage the demand. Thus, opening multiple opportunities to combine infrastructure investment with development and expansion of Advanced Manufacturing to will help to manage the infrastructure demand.
- **Potential Funding**
    - Indian Railways alone will receive an investment from the Ministry of Railways of over US$130 billion between 2016-2021. Other sectors will also need investments, thus attracting more companies seeking expansion. The government can require companies to develop Advanced Manufacturing practices to compete for contracts.

Technology Provisions

#4. Develop a comprehensive broadband infrastructure to accelerate the impact of ICT in India.

- **Summary:** A comprehensive broadband infrastructure should be developed to create a conducive network which has the capacity of promoting higher-volume and higher-quality data exchange in comparison to current network providers in India. A new broadband infrastructure would bring about reliability, better quality of service and synchronization with universally available bandwidth. Broadband tends to bring social benefits by reducing the digital divide and act as a GDP multiplier.
- **International Examples**
    - **Germany** was one of the leading countries in promoting the development of a broadband Internet Infrastructure. Germany viewed that it should be expanded on a massive scale.

  - **China** spent US$ 320 billion in 2015-2020 on a Government-funded infrastructure project to bring broadband coverage and penetration to OECD levels.
  - **The United States** developed a Connect America Fund-II to further strengthen broadband infrastructure. The investments reached US$ 70-75 billion per year.
- **Vision for Application in India**
  - Although India is amongst the largest telecom markets in the world, the country is currently at an early stage of broadband growth with approximately 150 million subscribers, around 2 percent penetration rate.
  - The Indian Government should review and draft new telecom policy focusing on strengthening Broadband, thus promoting state-of-the-art technologies such as IoT or M2M communications under Industrie 4.0.
  - India should consider the following steps: apply Public-Private Partnership models or innovative models such as the deferred payment Hybrid Annuity Model; carefully conduct needs test to ensure sound program results in different regions, such as in the rural or urban areas; set ambitious goals concerning increasing the number of broadband subscribers in the next 5 years; develop policies to facilitate the ease, efficiency and sustainability of broadband networks (reduce regulatory barriers, enhance private sector investment); examine the current availability and performance of traffic capacity; and conduct public comments and views.
- **Potential Funding**
  - In 2016, India received US$ 55.7 billion FDI thanks to the reform measures initiated by the Government. The Government should conduct feasibility studies and allocate the budget for project implementation under the Broadband or ICT spectrum for financing universal broadband access.

Skilled Manpower Development

#5. Secure the talent pipeline to successfully prepare students for Advanced Manufacturing employment.

- **Summary:** The Indian government should provide ample assistance to the state governments to restructure the training necessary for Advanced Manufacturing, with an emphasis on bolstering the programming that occurs around crucial transitions—i.e. the transitions of students from secondary to post-secondary education, as well as from post-secondary education to employment.
  - Not only should Advanced Manufacturing concepts and readiness training be introduced early into the curriculum, but India should strive to create "[a] series of connected education and training programs and student support services that enable individuals to secure a job or advance in the [advanced] manufacturing industry sector. [Such pathways] focus on easing and facilitating student transition from

high school to community college; from pre-college courses to credit postsecondary programs; and from community college to university or employment."[95]

- Similarly, federal education funding should be administered at a state-level, earmarked specifically for programs that enable post-secondary schools to hire additional career counselors, administrative staff, and instructors to develop and implement industry certification and local job market bridge-to-practice programs, especially in Advanced Manufacturing.[96]

- **International Examples**
  - **The United States:** San Antonio manufacturers recently partnered with the Alamo Colleges, a community college system, to focus on the workforce of the future by introducing high school juniors and seniors to manufacturing careers and higher education by completing an industry-driven curriculum in manufacturing skills. The program incorporates classroom instruction with hands-on learning in a state-of-the-art facility, and allows participating students to graduate from high school with up to 35 college credits, a National Career Readiness Certificate and the Production Technician Certification from the Manufacturing Skill Standards Council. Local manufacturers provided significant input into the program design and curriculum and local industry groups offer paid job internships. San Antonio manufacturers recruit graduates for job opportunities in manufacturing production operations and facilities maintenance.
  - **Italy:** ELIS ICT Academy is Italy's oldest Cisco Networking Academy partner. In 2010, ELIS opened its Vocational Master's Training program, which revolutionizes the transition from school to the workplace through a unique relationship with company partners. As part of the Vocational Master's Training program, ELIS's partners sponsor individual loans to more than 25 students each year. Students will be asked to return the cost after 2 to 3 years of working. Over 12 months, students take Networking Academy courses and have a chance to earn their Cisco CCNA certification.
- **Vision for Application in India**
  - This plan is ripe for implementation in India. According to some measures, more than 3200 polytechnics and equivalent technical institutions are in operation, many of which exhibit the potential for growth.[97] Similarly, recent estimates report that "more than 540 community colleges [exist] in [more than 22 states] registered under the IGNOU Community College Scheme."[98]
  - Providing the skill training to millions of youth could occur through these institutional facilities and/or by formally establishing extension centers in collaboration with state governments, employers (public-private partnerships), or

other non-government organizations.

- **Potential Funding**
  - Gaining momentum to implement this recommendation might begin with federal grant funding earmarked for designing and implementing such crucial transition programs in institutions across the various Indian states.

 # 6. Establish a research institution that would help SMEs conduct low-cost research, connect with partners, and receive training.

- **Summary**: India should initiate and organize a research organization whose mission would be to advance applied Advanced Manufacturing research, innovation, and collaboration in the image of the Fraunhofer-Gesellschaft in Germany (see page 9) and the Industrial Technology Research Institute in Taiwan (see page 12). The organization would strengthen technology advances by conducting research projects with SMEs, supporting research that may turn into separate spin-off companies, seeking out partnerships with leading technological multinational companies and universities, and incentivizing entrepreneurs to create low-cost solutions. This recommendation ties together low-cost applied research, innovation, and academic-industry collaboration--key aspects of Advanced Manufacturing at the micro-level. It aims to ensure that the costs of technological change and innovation are not barriers to the adoption of Advanced Manufacturing techniques.
- **Vision for Application in India**
  - Anyone from society at large, to multinational corporations, SMEs, and government will benefit from this low-cost applied research initiative. Like the examples above, this organization would receive funding from the Indian government, grants, and private sources.

V. A Roadmap Forward for India

Government Roadmap

India's government bodies have to actively work to facilitate the development of Advanced Manufacturing, both at the state and the national level. States need to work to create an environment that supports information sharing, collaborative initiatives, and innovation. This should be done through government investment funds, policy support, and state sponsored institutions. The following list includes additional recommendations as a way forward for India.

- Establish an institute, replete with executive power and independent financial authority, to create paradigms for new manufacturing processes which are useful to the industry
- Ensure the central government can support and direct designated[99] state governments to create similar institutes to support technology pilots and to support training and retraining or personnel.
- Implement tax breaks and other policies to support technological innovations and create

additional incentives for companies to evolve on their own.

- Collaborate and build networks with nations that exemplify best practices as highlighted in this report.
- Establish industrial zones in which unionization is not allowed; these zones should work with training institutes to provide qualified labor.
- Ensure state governments support national initiatives wherever possible.
- Create a team of industry experts to ensure efficient and timely implementation of national initiatives.
- Work to implement public sector (ministry and education) technology to new companies or existing industries.
- Develop a training curriculum in conjunction with industry partners to meet the advancing training requirements of each industry.

Industry Roadmap

Industry members must actively push Advanced Manufacturing, internally and externally. Industry players will receive the bulk of the benefits from the adoption of Advanced Manufacturing, as their survival is at stake. They should work with any available government resources and lobby for additional government based support.

- Establish training institutes and ensure those institutes remain a priority, even if the states do not carry their weight in establishing and nurturing them.
- Create a corpus to support Advanced Manufacturing.
- Collaborate to create a plan for the industry, including what the industry needs from the state and national governments.
- Ensure support of small scale industries and educate the industry on how this partnership benefits everyone.
- Maintain Advanced Manufacturing as a critical priority.
- Collaborate effectively to maximize resource usage.

Conclusion

India has a unique opportunity to leap to the front of a new wave of manufacturing. This is a make or break opportunity for Indian manufacturing. Global advances in manufacturing will render traditional manufacturing obsolete. In time, 69% of Indian manufacturing jobs will be lost to automation and advances in Advanced Manufacturing.[100] India must act now to ensure it is creating an ecosystem ripe for the success of Advanced Manufacturing to propel its economy forward.

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competitive. The Institute for Advanced Composites Manufacturing Innovation (IACMI) is accelerating development and adoption of cutting-edge manufacturing technologies for low-cost, energy-efficient manufacturing of advanced polymer composites for vehicles, wind turbines, and compressed gas storage. And the newest IMI, the Clean Energy Smart Manufacturing Innovation Institute, currently being stood up by the Smart Manufacturing Leadership Coalition in collaboration with the U.S. Department of Energy, will focus primarily on innovations such as smart sensors, data analytics, and controls in manufacturing that can dramatically reduce energy expenses in Advanced Manufacturing. *Id.* at 28.

[26] *Id. supra* note 5, at 29.

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