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Industry 4.0 in India: A Comparative Study

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ABSTRACT

The purpose of this paper is to shed light on the current status of Industry 4.0 policies in India and provide holistic policy recommendations in the transition towards Industry 4.0. The study was conducted based on the content-centric review of written policy documents like policy memoranda (memos), green papers and white papers, policy briefs, policy reports, opinion pieces, and newspaper and academic publications on Industry 4.0. India lacks infrastructure, regulatory framework, architectural reference model, incentives, skills, and standard roadmap towards Industry 4.0. The current policy status and policy recommendations presented in this study can serve as a great asset for academicians, policymakers, and practitioners to prepare a holistic roadmap for Industry 4.0 policy implementation. The study is first to assess India's current policy status and compare with Germany towards Industry 4.0. Besides, it is expected to assist government policymakers in formulating tangible policy outputs and strategic roadmaps.

Keywords: Industry 4.0, Comparative, Policy Analysis, Industry 4.0 Roadmap

Ⅰ. Introduction

Manufacturing based economy forms the base and backbone of every economy of a country. Countries like Japan, Germany, China, and the United States of America have successfully dominated the world economy with their robust manufacturing output contributing equally to the country's economy and the world. Over the years manufacturing sector has changed and is drastically moving towards the next level of engineering efficiency, maintenance efficiency, energy efficiency, information efficiency, service efficiency, and operational efficiency. Such drastic changes are possible due to the advancement of technology and the adoption of new technologies in the manufacturing process. With the ever-changing and ever-increasing use of digital technologies, all organizations' functions are undergoing a sea change in the way it functions both internally and externally (Rajnai and Kocsis, 2018; Sony and Naik, 2019). In such a scenario, countries and companies worldwide are transitioning towards the next level

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of automation. They are adopting innovation policies, regulations, education policy, and industrial development policy to ensure the country's economic growth. There are a growing phenomenon and a lot of debate among academicians, policymakers, and practitioners regarding the next industrial revolution wave called the fourth industrial revolution. It is said that no company will escape the effects of the fourth industrial revolution, and those industries that dominate once are likely to fail if they don't change now (WEF, 2019).

Adopting industry 4.0 technologies is expected to increase the production system efficiencies, cost reduction, engineering efficiency, performance efficiency, energy efficiency, maintenance efficiency, service efficiency, and improve the lead time, thus increasing the revenue for the organization. This technology will significantly impact manufacturing organizations, especially in automobile, railways, steel, chemicals, pharmaceuticals, defense manufacturing, and financial services sectors in India. However, the question is that can India continue to remain low-cost manpower to protect the future of India's manufacturing competitiveness? And is India ready to leapfrog towards Industry 4.0? The reality is India cannot stay idle and rely on low-cost manpower. The Industry 4.0 is bound to influence the economy of a developing country like India as the country's strong base is on the low-cost manufacturing of products and services (Kamble et al., 2018; Lutra and Mangla, 2018). Of late, Govt. of India has initiated "Make in India," "Digital India" to improve the current GDP from 16% to 25% by 2022 in the manufacturing sector (CII, 2021). Further, India has strong domestic market and abundant opportunity to improve upon in many areas and cannot afford to miss or ignore (Wagire et al., 2020). Hence, it is important for India to devise Industry 4.0 technology policies to reach towards the target. In this regard, this study is highly important for policymakers, practitioners, and industry leaders to leapfrog towards Industry 4.0.

Meanwhile, all the leading countries are promoting the adoption of Industry 4.0 technologies and are embarking on major initiatives to promote smart manufacturing. It is said that the implementation of Industry 4.0 technologies will lead to the increase of the GDP by 1 percent per year and create 390,000 jobs in Germany (GMIS, 2019). On the other hand, it is bound to influence and impact the economy of a developing country like India as the country's strong base is on low-cost manufacturing of products and services (Kamble et al., 2018; Lutra and Mangla, 2018). Hence, Industry 4.0 is unavoidable from both developed and developing countries perspective.

The main purpose of this study is to critically examine the current status and policies on Industry 4.0 in India and shed light on the identified policy tool gaps. It also gives a detailed understanding of the existing policies between Germany and India in various policy tools. Besides the introduction, the methodology is described, followed by a comparative analysis and the current status of adoption in India. The third section focuses on policy gap analysis and findings. Finally, it ends with proposed suggestions and recommendations for future implementation.

Ⅱ. Methodology

We used a qualitative approach for collecting and synthesizing information related to the Industry 4.0 policies. We evaluated written policy documents like Policy Memoranda (memos), Green papers and white papers, policy briefs, policy reports, opinion pieces from government websites like Department of Heavy Industries, government of India; newspaper, and aca-

demic publications on Industry 4.0 from prominent ones. These documents were analyzed and examined based on their relevance with focus areas on Industry 4.0 policy in India. Further, we kept in mind the key words-Industry 4.0, Industry 4.0 policy, Industry 4.0 in India for screening and filtering the literature in google scholar and journal websites. Those policy documents, green papers, white papers, newspapers and policy briefs having replication were excluded in the process.

Ⅲ. Brief Insights on Industry 4.0 policies

3.1. Industry 4.0

The fourth industrial revolution, also called "Industry 4.0," originated in Germany at Hannover fair in 2011. This concept has become a buzzword and discussion in many academic forum and other eminent industrial forums. The German government and policy makers, practitioners, academicians, industry leaders, and scientists came together in Hannover fair and discussed the issues related to the country's manufacturing scenario. Based on the discussion, a new policy initiative called "High -Tech Strategy 2020" was initially rolled out to transform the existing German manufacturing sectors with the use of digital technologies such as cyber-physical system, sensors, internet of things, 3D printing, and cloud computing (Hermann et al., 2016). Industry 4.0 is termed as fourth industrial revolution that focuses on end-to- digitalization of existing systems and processes (Hajoary and Akhilesh, 2020; Kang et al., 2016; Pereira and Romero, 2017). On the other hand, it is also popularly termed as smart manufacturing to describe the use of information and automation technologies like sensors, IoT, artificial intelligence, cloud computing, virtual reality, additive manufacturing, advanced robotics, cybersecurity, and simulation (Avedillo et al., 2015; Hajoary, 2021; Mittal et al., 2018; Oesterreich and Teuteberg, 2016; Yin et al., 2018). Further, it is also referred to as the digitalization of the physical systems into the digital ecosystem (PwC, 2016). According to McKinsey and Company (2015), "Industry 4.0 is the confluence of digital technologies that are going to change the manufacturing industry drastically." However, there is no universally accepted definition and standard widely accepted by researchers, practitioners, and policymakers (Caiado et al., 2020; Lasi et al., 2014).

3.2. Industry 4.0 Policies

Countries across the globe are spearheading new policies, schemes, and agendas to ramify their manufacturing sector in the context of industry 4.0. Likewise, India is also focusing on developing advanced manufacturing capability and investing in high-tech infrastructure, skill development, and technology innovation to keep in mind the future implications of Industry 4.0. The concept of Industry 4.0 has become a buzz word with a lot of people from government organizations, industries, and practitioners discussing its future implications, challenges, and opportunities and are focusing on creating a policy, standards, schemes, and agendas for implementation in their own country and organizations (Schumacher, 2019). In such a scenario, digitalization has become a pre-condition for organizations to move towards the next automation level. According to da Silveira Junior et al. (2018), technology policy is "an extended vision to the future in a chosen field composed of collective knowledge and imagination of brightest change agents in that field." However,

Motorola has announced two types of policy roadmaps named "emerging technology roadmap" and "product technology" policy roadmap (Willyard and McCleses, 1987). Emerging technology is concerned with budding technologies over a period, while product technology is concerned with changes in its product components over time.

Ever since the inception of the concept of Industry 4.0, many countries have started to establish associations, forums, coalitions to accelerate the adoption of Industry 4.0 technologies and practices. The German government along with representatives from industry and academia have initiated a policy initiative "The Platform Industrie 4.0" for digital transformation of the manufacturing ecosystem of the country (FMEAE, 2021; Schumacher et al., 2016). The main objective of this initiative is to promote the digital transformation and engage in strengthening the competitiveness of the country. Similarly, France has initiated "Alliance pour l'Industrie du Futur" with focus on use of digital technologies in production process and transform the manufacturing ecosystem of the country. On the other hand, china has initiated ten years national manufacturing plan "Made in China 2025" for transforming the manufacturing ecosystem of the country with the use of advanced ICT technologies (NMSAC, 2015). Meanwhile, South Korea has also initiated "Manufacturing Innovation 3.0" with the objective to convert 10,000 SMEs into smart factory with the use of IT, IoT, cyber physical system (Moon et al., 2018). Further, USA too has initiated "Advanced Manufacturing Partnership" to invest in advanced manufacturing technologies like IoT, cloud computing, additive manufacturing, cyber physical system to transform the existing manufacturing ecosystem of the country (Kuo et al., 2019). In the same way, India too have initiated a "SAMRATH Udyog Bharat 4.0" with a focus to create and facilitate Industry 4.0 technologies in every MNC, large, and small-scale manufacturing industries in India by 2025 (Samrath Udyog, 2021).

SAMARTH Udyog Bharat 4.0 is a policy initiative undertaken by the Department of Heavy Industries and Ministry of Heavy Industries and Public Enterprise, Government of India, with a vision to transform and build a healthy ecosystem for the propagation of technological innovation in Industry 4.0 technologies (Samarth Udyog Bharat 4.0, 2019). This initiative intends to transform Indian manufacturing sectors by providing a platform for innovation and adoption of industry 4.0 technologies such as Cyber-physical systems, Internet of things, additive manufacturing, simulation, cybersecurity, artificial intelligence, virtual reality, robotics, cloud computing, and analytics. The above initiative comes from the global transition towards the next industrial revolution, also called the fourth industrial revolution. Of late, it is expected to spearhead the adoption and innovation of indigenous products in the country as per the needs of the local market. According to the Department of Heavy Industries, as part of the initiative a common engineering facility centers (CEFC) are being created in five different places across the country to promote innovation and awareness about Industry 4.0 technologies. These five centers act as a nodal center and center of excellence in setting up start-up incubation centers, research and development, training and development, skill certifications, testbeds, awareness, prototyping, simulation, and testing services, consulting services, and site integration services in the country.

In this study, we have compared the Industry 4.0 polices of Germany and India to bring coherent analysis on the developed and developing economy approach on Industry 4.0. The main idea behind this comparative analysis is to bring in early adopter and

<Table 1> Initiatives Undertaken by the Government of India

Name of the CEFC (Common Engineering Facility Centre)	Focus Areas & Objectives
Centre for Industry 4.0 lab Pune (C4I4)	- Accelerate and drive adoption of Industry 4.0 technologies among SMEs and MSMEs in India - Promote training and development with relevant skill sets - Start up incubation support and development of standards for Industry 4.0
IITD-AIA Foundation for Smart Manufacturing at IIT Delhi	- support innovation and awareness building measures - Cyber physical system development - demo cum experience and consulting services - Training and developing, skill certifications - Research and development on Industry 4.0 technologies
Industry 4.0 India at IISc Factory R&D platform	- Sustainable manufacturing - Smart manufacturing - Data analytics - Additive manufacturing
Smart Manufacturing Demo & Development Cell at CMTI Bangalore	- to establish a demo cum development center (Machine tool centric) as pilot project for implementation - Showcase industry 4.0 tools and concepts - Support companies for adopting smart production systems in their organization - Develop smart practices towards industry 4.0
DHI Centre of Excellence in Advanced Manufacturing Technology at IIT Kharagpur	- development of IoT for supply chain management, predictive maintenance and inventory optimization - Development of 3D simulation model for material flow behavior - Proof of concept development for IoT based services, CNC machine tools, test beds etc.

late adopter focus areas and gaps on Industry 4.0 polices and provide a policy recommendation for India. Meanwhile, Germany is the early adopter and leader in adoption of Industry 4.0 technologies and practices, while India is trying to leapfrog with range of initiatives undertaken by the government. In this regard, it is relevant to analyze the existing polices of both the countries to bring out better rational gaps and provide recommendations for developing country like India.

The government of India fully funds the above five dedicated centers of excellence in association with private organizations like TCS and CII (Confederation of Indian Industry). These centers of excellence work on developing and deploying almost all the key technologies of Industry 4.0 in the Indian context.

Ⅳ. Comparison of "SAMRATH Udyog Bharat 4.0" and "Industry 4.0"

The two policies, i.e., SAMRATH Udyog Bharat 4.0 and Industry 4.0, focuses on transforming the manufacturing sector using advanced technologies. However, the core of Industry 4.0 is Cyber-physical systems, IoT, and intelligent manufacturing, thus integrating the entire value chain of an organization.

<Table 2> Summary of comparison of SAMRATH Udyog Bharat 4.0" and "Industry 4.0"

Country	Germany	India
Date of Origin	2013	2018
Name of the Policy	Industrie 4.0	SAMRATH Udyog Bharat 4.0
Stationary Bodies	Federal Ministry for Economic Affairs and Energy, Federal Ministry of Education and Research	Ministry of Heavy Industries & Public Enterprise, Department of Heavy Industry
Focus areas	CPS, IoT, Intelligent manufacturing	CPS, collaborative robots, Sensors, Actuators & controllers, Augmented reality, Analytics, Digital twin, Remote maintenance, Wireless instrumentation, Rapid prototyping, Advance simulation
Current GDP (2018-19)	$3.846 trillion	$1.901 trillion
Strengths	Well established manufacturing brands, global products, fourth largest economy in the world	Fastest growing economy & high population dividend, Services sector, fifth largest economy in the world
Implementation Period	10-15 years	Not Specified
Implementing phases	Not specified	Not specified
Pilot Plan	Not specified	Not specified
Standardization	Yes	Not yet
Reference architecture model	RAMI 4.0	Not yet
Collaboration	European Union	Educational Institutions & R&D centers
Market Leader	Siemens	Not yet
Schemes	Platform 4.0, 2030 vision for Industrie 4.0	Enhancement of Competitiveness in Indian Capital Goods Sector

However, SAMRATH Udyog Bharat 4.0 will create and facilitate Industry 4.0 technologies in every MNC, large, medium, and small-scale manufacturing industries in India. Germany has a strong manufacturing base, and it contributes more than 40 percent to the country's GDP and currently stands the fourth-largest economy in the world. Meanwhile, the Indian manufacturing sector contributes 16 percent to its GDP and stands the world's fifth largest economy presently.

The major similarities lie with focus areas as both the countries are focusing on Industry 4.0 technologies such as CPS, IoT, AI, advanced robots, additive manufacturing, and cloud computing to transform their manufacturing ecosystem of the country. In addition, both the countries have invested substantial amount for Industry 4.0 implementation and joined hands with industry and academia partners.

As part of the Industrie 4.0 initiative, Germany has introduced a platform 4.0 scheme to spearhead Industry 4.0 implementation plans in various sectors of the economy on a 10-15-year implementation period. It has also developed standardization and certification programs on various Industry 4.0 technologies to streamline the digitalization process across various industries. Germany introduced an architectural reference model, "RAMI 4.0," for industries looking to adopt digital technologies in their

own organization to create awareness. On the other hand, India recently initiated a slew of measures to encourage and create awareness in adopting newer sets of technologies to increase the manufacturing output from the current 16 percent to 25 percent by the year 2020. Such initiative aligns with the overall "Make in India" initiative undertaken by the government of India. Make in India usually focuses on improving foreign direct investment (FDI) and in-house production in all the 25 sectors of the economy, keeping in mind using advanced technologies. The government of India has set an ambitious plan to reach a 5 trillion economy by the year 2024. However, such plans will be successful only if there is a proper mechanism to transform the country's manufacturing ecosystem as it forms the base for growth in almost every economy.

Ⅴ. Current Status of India on Industry 4.0 adoption

The Industry 4.0 market is expected to reach $214 billion globally by the year 2023 (AIMA and KPMG, 2018). Countries such as United States, Germany, China, Japan, South Korea, and European countries like Sweden, Denmark, Netherlands are investing heavily in Industry 4.0 technologies and are leading ahead in terms of adoption and innovation. Of late, India started a long-term initiative to change the manufacturing ecosystem of the country by introducing "Make in India" and "SAMRATH Udyog Bharat 4.0" (Smart Advanced Manufacturing and Rapid Transformation Hub) (MCIDPI, 2018). These two initiatives are expected to transform the manufacturing ecosystem and bring about a drastic change in the adoption of digital technologies as India's government sets an ambitious target to increase the GDP from the manufacturing sector from the current 16 percent to 25 percent by the year 2022. Several initiatives and policy reforms, such as GST (Goods and services tax), Digital India, Startup India, and Invest in India, are implemented by the government in a phased manner. However, a significant portion of Indian manufacturing sectors are still in the post-electrification phase and have limited access to new technologies, especially SMEs and MSMEs. To keep informed, prominent world bodies like World Economic Forum and IMD started a world ranking system among 141 countries to rank countries in their competitiveness in major areas (Brits and Cabolis, 2019). These rankings are widely accepted and well known worldwide to find out the current status and performance of their country in major factors towards Industry 4.0. In this regard, I have adopted this ranking framework to bring out India's ranking in terms of global competitiveness in Industry 4.0.

The below <Table 3> provides the ranking of the current status of selected countries in terms of the global competitive index. The global competitive index talks about the national competitiveness on twelve parameters that drive a country's economy. It compiles the attributes and qualities in terms of economy and growth leading towards the fourth industrial revolution. The main parameters used to assess the competitiveness are based on enabling environment, human capital, markets, and innovation ecosystem of a country. However, the above four parameters are further broken down into twelve pillars that will help policymakers track hold of a country's performance in terms of various economic factors in the long run. Singapore is currently ranked 1st, followed by the U.S.A and Hong Kong, whereas India is currently ranked 68th among 141 countries in the world. India trials 40 places below China with

<Table 3> The Global Competitiveness Index 4.0 2019 (Author's Own Compilation)

Overall Rank	Country	Institutions	Infrastructure	ICT Adoption	Microeconomic environment	Health	Skills	Product Market	Labour Market	Financial System	Market Size	Business Sophistication	Innovation Capability
1	Singapore	2	1	5	38	1	19	2	1	2	27	14	13
2	U.S.A	20	13	27	37	55	9	8	4	3	2	1	2
3	Hong Kong	5	3	3	1	1	20	1	7	1	28	15	26
5	Switzerland	6	4	17	1	5	1	25	2	4	39	22	3
6	Japan	19	5	6	42	1	28	6	16	12	4	17	7
7	Germany	18	8	36	1	31	5	9	14	25	5	5	1
9	U.K	11	11	31	1	33	11	21	9	7	8	9	8
13	South Korea	26	6	1	1	8	27	59	51	18	14	25	6
28	China	58	36	18	39	40	64	54	72	29	1	36	24
68	India	59	70	120	43	110	107	101	103	40	3	69	35

14 points difference. However, India fairs well in terms of the market size (3^{rd}) and innovation capability(35^{th}) well ahead of other emerging economies. India still lacks ICT adoption (120^{th}), Health (110^{th}), Skills (107^{th}). India should increase the use of digital technologies in society and governance while improving public health facilities. It also needs to improve on skill development on the latest technologies and labor market conditions.

Ⅵ. Gap Analysis on Industry 4.0 Policy Tools

A gap analysis was performed on 20 main policy tools on nine key Industry 4.0 technologies to identify policy formulation and implementation status. The main reason behind filling the matrix between policy tools and technologies is to bring the current status of the Industry 4.0 policies with the technologies in India. These nine technologies are the key Industry 4.0 technologies, and the matrix provides the glimpses of the as-it-is state of the Industry 4.0 policy tools with respect to Industry 4.0 technologies in India. Hence, this gives us a comprehensive and clear picture of Industry 4.0 in India. <Table 4> summarizes and brings out a clear picture of current gaps in various policy tools. The analysis was based on the report obtained from various written policy documents like Policy Memoranda (memos), Green papers and white papers, policy briefs, policy reports, opinion pieces, newspaper, and academic publications on Industry 4.0. A National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) and Technology Innovation Hubs (TIHs) was initiated in five years with an initial investment of $36.6 million to provide strong R&D and knowledge development activities in the country (SERB, 2019). This program is implemented by the Department of Science and Technology (DST), Government of India (SERB, 2019). To harness the potential of Industry 4.0 technologies, i.e., Cyber-Physical System, IoT, Virtual Reality, Cloud Computing, Additive Manufacturing, Big Data Analytics, Advanced Robotics, Cyber

<Table 4> Gap Analysis on Policy Tools for Industry 4.0 Technologies

Policy Tools	Technologies								
	CPS	IoT	VR	CC	AM	BDA	AR	CS	AI
R&D	√	√		√	√	√	√	√	√
Collaboration	√	√			√	√	√	√	
Investment	√	√	√	√	√	√	√	√	√
Pilot Program	√	√		√	√				
Test Beds					√				
Assessment Method/Measurement									
Standards & Norms									
Awareness Program	√	√	√	√	√	√	√	√	√
Education	√	√				√	√	√	
Training		√		√	√	√		√	√
Legal Framework									
Incentives									
Infrastructure									
Safety & Security Framework								√	
Reference Architecture									
Regulatory Framework		√						√	
Business Environment	√	√	√	√	√	√	√	√	√
Marketing		√			√	√			
National Strategy	√	√		√		√	√		√
Start Up Strategy	√	√	√	√	√	√	√	√	√

Note: CPS- Cyber-Physical System, IoT- Internet of Things, VR- Virtual Reality, CC-Cloud Computing, AM-Additive Manufacturing, BDA-Big Data Analytics, AR-Advanced Robotics, CS-Cyber Security, AI-Artificial Intelligence

Security and Artificial Intelligence, the union cabinet approved an investment of $737.49 million to be implemented across public sector units, educational institutions and R&D centers for training, product development, innovation, and commercialization (PTI, 2019).

There is still a lot to be done in terms of implementing testbeds, training on CPS, legal framework, and incentives to the companies working in Industry 4.0 technologies. Meanwhile, India lacks in providing an assessment framework to assess its implementation status and undertake benchmark study for the same. For example, Germany undertakes assessment studies to understand the status and provide a prescriptive, comparative, and descriptive roadmap for SMEs and MSMEs. Meanwhile, Reference Architecture for Industry 4.0 implementation provides a comprehensive guideline and best practices for organizations to refer to and adopt technologies. The government must concentrate first on setting up a standardization and regulatory framework for Industry 4.0 technologies as it is a primary necessity to streamline the business environment with a long-term policy for the country.

Ⅶ. Findings and Way Forward

This study assesses the status of implementation, objectives, focus areas, and investment level in Industry 4.0 policies in the country. It sheds light on twenty policy tools adapted from Rothwell and Zegveld (1984) and nine key technologies adapted from KPMG (2018) and their status in the Indian context. The majority of the policies aim to transform the manufacturing ecosystem by ensuring sustainable growth with the use of advanced technologies. Nevertheless, both countries have similar focus areas, but the level of investment level is higher in Germany's case. Germany focuses on improving efficiency and productivity with the use of digital technologies. It has a strong foundation with Industry 4.0 reference architecture and state-of-the-art facilities and infrastructures.

Meanwhile, India with the initiative like "SAMRATH Udyog Bharat 4.0" and "Make in India" can produce tangible qualitative and quantitative outputs in the coming years. To ensure equal representation, networking, and exchange of information among all the stakeholders, a standard and regulatory framework is required in India. This will ensure smooth information flow and equal rights, data security, data autonomy, and reflect the interest of all individuals. The initiatives must raise awareness on Industry 4.0 across all the domains in all the country's states about its benefits and challenges of implementation. However, India lacks a global competitive index and is currently ranked at 68th among 141 countries globally. It needs to improve ICT adoption, skill sets, training, regulatory framework, IT integration, education, infrastructure, and labor market.

Moreover, India stands strong in terms of innovation capability among other countries in the world. The government must provide incentives to organizations to move towards Industry 4.0 and close the gap faced with best in class by leapfrogging towards the next level of automation. In addition, it must also recognize domestic products and globalize them with other countries by helping them in exporting. To ensure rapid development and adoption of Industry 4.0 technologies, the government must focus on improving and devising policies for following priority areas-

1. Develop an open and standard Industry 4.0 reference architecture that applies to all companies for standardization, development, integration, and operation of technologies relevant to Industry 4.0.
2. Develop a standard AI based policy for widespread adoption
3. In order to ensure standardization, a national wide regulatory framework must be introduced keeping in mind at the stakeholders on board
4. Create a robust digital infrastructure and make it accessible equally to all the participants in the ecosystem of Industry 4.0
5. Focus on R&D initiatives on key technologies to strengthen product innovation
6. Most of the major national Industry 4.0 relies on public funding, while joint funding along with private players can also leverage the initiative
7. Most of the Industry 4.0 tends to concentrate on technology innovation, infrastructure creation with very little attention on skills and training, hence the country must focus on building required skill sets based on latest technologies
8. Collaborate with major players and adopt some of the best practices across the globe towards adoption of Industry 4.0

9. Strengthen data protection and privacy law towards Industry 4.0
10. Maximize funding and provide platform incentives for adoption and innovation of Industry 4.0 technologies
11. To continuously monitor the implementation and adoption, it is advised to establish a benchmarking or performance management system in all the projects.
12. To respond to the changes due to automation and digitalization, a concrete and workable action plans are needed to monitor its impact on work, society, labour and provide a practical solution for the same

Apart from the above recommendations for the government, the manufacturing companies, business owners and practitioners must devise a policy roadmap for widespread implementation of Industry 4.0 technologies such as IoT, AI, big data analytics, cloud computing, virtual reality, advanced robotics and cybersecurity. In addition, the managers must focus on reskilling and upskilling of employees with the above technologies and create test beds for innovation and training. Further, the companies must assess the Industry 4.0 maturity and readiness in order to know the current status of the organization and bring out level of abstraction towards widespread implementation.

Ⅷ. Theoretical and Practical Implications

This research provides a theoretical and practical implications on the Industry 4.0 policies of Germany and India and contributes to existing literature on Industry 4.0 policy. The study is the first to assess the current status of Industry 4.0 polices between Germany and India. This cross-national study between developed and developing economy provides rich understanding on Industry 4.0 polices and initiatives undertaken by the government to reach towards Industry 4.0. In practice, it provides policymakers, industry leaders, practitioners, and government officials much need information and suggestions to take corrective policy steps on the gaps identified. Further, to the best of my knowledge, this study uniquely contributes to the Industry 4.0 policy research as it emphasized the current policies particularly in developing country perspective. In summary, this research made significant findings on gaps such as lack of infrastructure, regulatory framework, architectural reference model, incentives, skills, and standard roadmap towards Industry 4.0 in India and the similarities between India and Germany.

Ⅸ. Conclusion

This study reveals the status of strategies and policies undertaken by the government of India on Industry 4.0. It also proposes a strategic policy roadmap in the transition towards Industry 4.0. A cross-comparative analysis was done to bring out insights on policy initiatives of Germany and India. Based on the comparative analysis, both the countries focus on Cyber-Physical System, the Internet of Things, Advanced Robotics, Cloud computing, Additive Manufacturing, and Big Data Analytics as their main priority to transform their manufacturing ecosystem. Germany tends to align most of its policies in strengthening manufacturing ecosystems using advanced technologies, thus increasing their productivity, and minimizing production costs. Meanwhile, it is not clear on the part of India in

terms of productivity and output. However, both countries have long-term investment plans for the same. The manufacturing sector in Germany is stronger than India as it contributes more than 40 percent to its GDP, while in India, it contributes only 16 percent to its GDP. Germany has already developed an Industry 4.0 reference architectural model and regulatory framework for its users, while India still has no such regulatory framework and architecture. Market Size, Innovation capability, and capital, India fairs well ahead of other emerging economies. However, India still lacks ICT adoption, health, infrastructure, and regulatory framework. There is still no clarity in terms of Industry 4.0 norms and regulations for SMEs and MSMEs to adopt Industry 4.0 technologies. Lack of infrastructure, incentives, reference architecture, training, and education will hinder the pace of transition towards Industry 4.0. Hence this study provides a theoretical analysis of Industry 4.0 policy status in India and provides a holistic insight into the transition towards Industry 4.0. However, this study is confined to the Indian perspective and is limited to a strategic roadmap developed based on the existing literature and merely a holistic view of common steps that are dynamic based on the economic, political, and social scenario.

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