Model for making industry 4.0 ubiquitous to improve national productivity requirements of Digital India

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Abstract:

Industry 4.0 offers automated digital solutions, which benefits corporations, governments, society, and individual citizens. Many studies have shown that as technology adoption rises, it has a substantial influence on national productivity, and industry 4.0 is a technological approach to automate India. According to information from various government and corporate reports, Industry 4.0 is still in its budding stage in India. Despite the widespread use of smartphones and the surge in demand for real-time automation services during the COVID-19 pandemic, the benefits of Industry 4.0 in India is not explored and realized. As a result, it is necessary to look into its impact on national productivity. The authors recognized the driver for improving national productivity in India by implementing Industry 4.0 methods. Utilizing ISM-Interpretive structural modeling, the authors proposed a model to increase India's national productivity using industry 4.0-based techniques and its implication are discussed.

Keywords: Industry 4.0, automation in India, futuristic requirements of digital India

Introduction:

Productivity is measured as a ratio of outputs to inputs, but depending on the context, data availability, and input and output measures used, productivity calculations can be interpreted differently at various levels, such as business organisations, society, government, and individual citizens of the country[1,2]. The progress of ICT fosters productivity by allowing people to connect, communicate, transact, and exchange information. It also allows people to increase productivity by automating regular chores, analysing data to get insights, and making better decisions [3, 4].

The Industry 4.0 concept links multiple cyber-physical systems to boost efficiency by automating choices. Industry 4.0 provides new ways to work, learn, and interact with family and friends by encompassing a wide range of modern technologies such as cloud computing, IoT, AI, Big Data science, 3D printing, 5G, drones, and communications to boost productivity in industrial operations using connect-automate-analyze. Data generated from sensors or machines can be saved on cloud servers, and AI analytics combined with mathematical models can run predictive algorithms to boost efficiency and aid in the manufacturing process. Data generated by industry 4.0 services will grow tremendously, necessitating the need to increase the speed requirements for each user or application. Industry 4.0 will usher in a new era, in which robots will be connected remotely to AI based computer systems that can direct machines/robots/humans with minimal human intervention. Thought there might be difficulties in exploiting our possibilities [5,6].

Literature Review

To build the ISM model, literature review is separated into three sections to get insight of industry 4.0 at different levels. Then to build model drivers and measures are extracted. Productive benefits of Industry 4.0 is studied in the first part , then different reports are reviewed to find the current status of industry 4.0 in India and futuristic requirements of digital India. Further, in third part ISM in different domains are reviewed.

In this first part of literature, the productive benefits of industry 4.0 for consumers, government, governance, and society, citizens, government and Industries is studied from different reports [7-18]. Following are the benefits for each one.

Productive benefits of industry 4.0 for citizens
- to provide access to better infrastructure and quality of life
- to create an optimized environment in Personalize spaces
- to help to transform the life experiences

Productive benefits of industry 4.0 for business Organization-Business 4.0
- Smart monitoring and control
- Minization of production waste
- Value addition by allowing for better customization, quality, and value.
- Exceptional levels of automation and decentralized decision-making capabilities.
- Health and safety of plant workers
- Rapid speed, cost reduction, and less time to reach the market
- Safer factoreries to market

Productive benefits of industry 4.0 for government – Government 4.0
- governance and service on demand
- Citizen Participation
- more control on Anti-Corruption activities
- Transparency & Accountability

Productive benefits of industry 4.0 for agricultural- Agriculture 4.0
- Innovative products in agriculture like Agricultural robots, Precision farming.
- Bluetooth “beacons” in agriculture
- Agriculture 4.0 –Real time Agriculture Field activités monitor and control

Productive benefits of industry 4.0 for Education -Education 4.0
- New set of skill o balance social skills, scientific knowledge, technological skills, and training, as well as human-machine interaction skills.
- New set of skill to bring artificial intelligence

- New skill sets to minimize negative environmental and social effects
- Skill sets for Industrial value creation Integrate environmental thinking

Current status of Industry 4.0 in India

According to the "India Industrial Automation Market [9]" highlights the initiatives taken by the Government of India to promote Industry 4.0, such as the establishment of Centres of Excellence (CoE) and the focus on cluster integration. The Indian industrial automation market has witnessed substantial growth, with projections indicating further expansion driven by robotics-enabled automation, artificial intelligence, 5G, and 3D printing. The Digital India campaign has identified key areas for growth, including broadband highways, mobile connectivity, e-governance, and electronics manufacturing. However, the adoption of Industry 4.0 in India is still at an early stage.

3. RESEARCH OBJECTIVES, RESEARCH QUESTIONS

Following are Research objectives of this ISM model designing study.

- To investigate the current status of Industry 4.0 at national level and international level. This is achieved by considering secondary sources like different reports and earlier researcher work.
- To identify the drivers and measures of to make industry 4.0 practices ubiquitous and pervasive in India to improve National productivity of India
- To develop a model to establish the relationship among the drivers national productivity and measures of National Productivity using Industry 4.0 practices.
- To discuss implication of this research with different stakeholders.

Using these objectives following research questions are formed.

R1:-What is a current status of Industry 4.0 at national level and international level?

R2: What are the drivers and measures of to make industry 4.0 practices ubiquitous and pervasive in India to improve National productivity of India?

R3:-What are implications of research on different Stakeholders.

4.0 Identification of driver and measures to develop ISM model

Using a literature research and investigation of present status Industry 4.0 practises in India, the authors determined the variables, i.e. Drivers and Measures of Industry 4.0 in India. The experts were then asked about the interdependence of variables (how does one variable aid the achievement of the others?). After a few days, the experts discussed the contextual linkages to see whether they needed to be changed. A few divergent viewpoints were incorporated into the final ISM model, which was then validated by professionals. The 10 Industry 4.0 Drivers (Input factors) and 5 National Productivity Measures identified by authors and validated by experts.

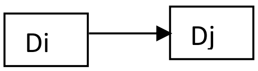
Table 1: Variables for Improvement of National Productivity using Industry 4.0 based practices

Vno.	Levels	Variables for National Productivity using Industry 4.0 based practices	Variable Types
1	L6-NP	Improvement in National Productivity In India	Measures of National productivity
2	L5- Usage in different sectors for productive benefits	Society Productivity 4.0 Improvement	
3		Agriculture Productivity 4.0 Improvement	
4		Government Organization Productivity 4.0	
5		Industrial/Organizational Productivity Improvement 4.0	
6	L4 -Services	AI and ML based decision making in real time for Innovative Services and models	Drivers of Industry 4.0 in India
7		Context based Data capture and storage based services	
8		Services for Smart monitoring, Automation and process control	
9	L3- Transformation	Transformation of physical space into virtual space with security/cyber space	
10		Vendors maturity	
11	L2- Infrastructure	Ubiquity of Cyber physical System	
12		High investment for infrastructure integration into digital ecosystems	
13		Government rule, regulations and policies	
14	L1-Research and vision	Understanding the potential industry 4.0 practices)	
15		Research and Development of Application prototype of industry 4.0	

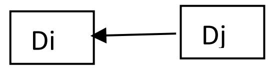
5.0 RESEARCH METHODOLOGY AND MODEL DEVELOPMENT

This system has a significant number of variables (15), and evaluating them is complex. Because analyzing the effect of one variable on other remaining variables is a complicated and time-consuming process, so ISM is utilized. It's an interpretive strategy in which the expert's or group's judgement determines whether and how the variables are linked. Identification of elements, establishment of a contextual relationship, formation of a structural self-interaction matrix (SSIM) of elements are all steps in the ISM technique that are followed to construct a model. Creating a reachability matrix and ensuring that it is transitive; The reach-ability matrix is divided into multiple tiers. Then A directed graph (DIGRAPH) is created and then turned into an ISM by replacing element nodes with statements; and the ISM model is then assessed for conceptual inconsistencies and required revisions are made [21-30]

Matrix of structural self-interaction: Literature review, investigation of study status, and expert opinion are used to identify drivers. Furthermore, because the ISM methodology recommends relying solely on expert opinions in generating contextual linkages, 10 experts from business and academia were referred for determining the nature of contextual relationships and among the NP drivers. The direction of relationship between the variables I and j is denoted by the four symbols below [21-30] V,A,X,O

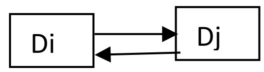


Representing V: Di will help to achieve Dj



Representing A : Dj will be achieved by Di.

Representing O: Di and Dj are unrelated



Representing X: Di and Dj will help to achieve each other.

Following tables shows the interrelationship of drivers among themselves".

Sr. no	Drivers of industry 4.0	Driver	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2
1	Improvement in National Productivity In India		A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	Society Productivity 4.0		A	A	A	A	A	A	A	A	A	A	A	A	X	
3	Agriculture Productivity 4.0		A	A	A	A	A	A	A	A	A	A	A	X		
4	Government Organization		A	A	A	A	A	A	A	A	A	A	X			
5	Industrial/Organizational Productivity Improvement 4.0		A	A	A	A	A	A	A	A	A	A				
6	AI and ML based decision making in real time for Innovative Services and		A	A	A	A	A	A	A	X	X					
7	Context based Data capture and storage based services		A	A	A	A	A	A	A	X						
8	Services for Smart monitoring, Automation and process control		A	A	A	A	A	A	A							
9	Transformation of physical space into virtual space with security/cyber		A	A	A	A	X	X								
10	Vendors maturity		A	A	A	A	X									
11	**Ubiquity of** Cyber physical System		A	A	X	X										
12	High investment for infrastructure integration into digital ecosystems		X	A	X											
13	Government rule, regulations and		A	X												
14	Understanding the potential industry 4.0 practices)		X													
15	Research and Application prototype Development of industry 4.0															
			D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2

Figure 1: SSIM for the driver of industry 4.0 for improvement National Productivity of India

Reachability matrix

Sr. no	Drivers of industry 4.0	Questions	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	Driving power
1	Drivers of industry 4.0 to improve in National	Driver D1 will help to achive	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	Society Productivity 4.0 Improvement	Driver D2 will help to achive	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
3	Agriculture Productivity 4.0 Improvement	Driver D3 will help to achive	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
4	Government Organization Productivity 4.0	Driver D4 will help to achive	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
5	Industrial/Organizational Productivity Improvement 4.0	Driver D5 will help to achive	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
6	AI and ML based decision making in real time for	Driver D6 will help to achive	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8
7	Context based Data capture and storage based services	Driver D7 will help to achive	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8
8	Services for Smart monitoring, Automation and process control	Driver D8 will help to achive	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8
9	Transformation of physical space into virtual space with	Driver D9 will help to achive	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	10
10	Vendors maturity	Driver D10 will help to achive	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	13
11	**Ubiquity of** Cyber physical System	Driver D11 will help to achive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	14
12	High investment for infrastructure integration into	Driver D12 will help to achive	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	13
13	Government rule, regulations and policies	Driver D13 will help to achive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	14
14	Understanding the potential industry 4.0 practices)	Driver D14 will help to achive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
15	Research and Application prototype Development of	Driver D15 will help to achive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
		Dependance power	15	14	14	14	14	10	10	10	7	7	6	6	6	4	2	

Driver	Driving power	Dependance power
D1	1	15
D2	5	14
D3	5	14
D4	5	14
D5	5	14
D6	8	10
D7	8	10
D8	8	10
D9	10	7
D10	13	7
D11	14	6
D12	13	6
D13	14	6
D14	15	4
D15	15	2

Figure 2: Initial reachability matrix

Level Partitioning: After considering transitivity requirements, the final reachability matrix is used for level partitioning. The intersection of these sets is then calculated for all variables [21-30].

Iteration 1: After determining the top level, the identified level's variable(s) are removed from further analysis. The iterative process continues until each variable's levels are determined. This study required six iterations [21-30].

Drivers	Rechability set	Antecedent set	Intersection	Level
1	1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	1	I
2	1,2	2,3,4,5,6,7,9,10,11,12,13,14,15		
3	1,3	2,3,4,5,6,7,9,10,11,12,13,14,15		
4	1,4	2,3,4,5,6,7,9,10,11,12,13,14,15		
5	1,5	2,3,4,5,6,7,9,10,11,12,13,14,15		
6	1,2,3,4,5,6	6,7,8,9,10,11,12,13,14,15		
7	1,2,3,4,5,6,7,8	6,7,8,9,10,11,12,13,14,15		
8	1,2,3,4,5,6,8	6,7,8,9,10,11,12,13,14,15		
9	1,2,3,4,5,6,7,8,9,10	9,10,11,12,13,14,15		
10	1,2,3,4,5,6,7,8,9,10	9,10,11,12,13,14,15		
11	1,2,3,4,5,6,7,8,9,10,11	11,12,13,14,15		
12	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13,14,15		
13	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13,14,15		
14	1,2,3,4,5,6,7,8,9,10,11,12,13,14	14,15		
15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	15		

Figure 2: Iteration 1

Iteration 2: Then next level is determined by observing group of drivers 2,3,4,5 from drivers D6 to D15 and 2,3,4,5 are outcome variables so these variables consider for second iteration though they are not grouped in intersection set of Driver 2,3,4,5 and hers author are not observing the effect of these driver on each other. 2,3,4,5 are the identified in second level and are dropped from further analysis.

Drivers	Rechability set	Antecedent set	Intersection	Level
2	2	2,6,7,9,10,11,12,13,14,15	2	II
3	3	3,6,7,9,10,11,12,13,14,15	3	II
4	4	4,6,7,9,10,11,12,13,14,15	4	II
5	5	5,6,7,8,9,10,11,12,13,14,15	5	II
6	2,3,4,5,6	6,7,8,9,10,11,12,13,14,15		
7	2,3,4,5,6,7,8	6,7,8,9,10,11,12,13,14,15		
8	2,3,4,5,6,8	6,7,8,9,10,11,12,13,14,15		
9	2,3,4,5,6,7,8,9,10	9,10,11,12,13,14,15		
10	2,3,4,5,6,7,8,9,10	9,10,11,12,13,14,15		
11	2,3,4,5,6,7,8,9,10,11	11,12,13,14,15		
12	2,3,4,5,6,7,8,9,10,11,12,13	12,13,14,15		
13	2,3,4,5,6,7,8,9,10,11,12,13	12,13,14,15		
14	2,3,4,5,6,7,8,9,10,11,12,13,14	14,15		
15	2,3,4,5,6,7,8,9,10,11,12,13,14,15	15		

Figure 3:Iteration2

Iteration 3: In these iteration third level variables 6, 7, 8 are identified, and are dropped from further analysis. Same procedure is applied for next level iterations also.

Drivers	Rechability set	Antecedent set	Intersection	Level
6	6,	6,7,8,9,10,11,12,13,14,15	6,8	III
7	6,7,8	6,7,8,9,10,11,12,13,14,15	6,7,8	
8	6, 8	6,7,8,9,10,11,12,13,14,15	6,8	
9	6,7,8,9,10	9,10,11,12,13,14,15		
10	6,7,8,9,10,11	10,11,12,13,14,15		
11	6,7,8,9,10,11	9,10,11,12,13,14,15		
12	6,7,8,9,10,11,12,13	12,13,14,15		
13	6,7,8,9,10,11,12,13	12,13,14,15		
14	6,7,8,9,10,11,12,13,14	12,13,14,15		
15	6,7,8,9,10,11,12,13,14,15	15		

Figure 4:Iteration3

Drivers	Rechability set	Antecedent set	Intersection	Level
9	9,10	9,10,11,12,13,14,15	9,10,	IV
10	9,10,11	10,11,12,13,14,15	9,10,11	
11	9,10,11	9,10,11,12,13,14,15	9,10,11	
12	9,10,11,12,13	12,13,14,15		
13	9,10,11,12,13	12,13,14,15		
14	9,10,11,12,13,14	12,13,14,15		
15	9,10,11,12,13,14,15	15		

Figure 5:Iteration4

Drivers	Rechability set	Antecedent set	Intersection	Level
12	12,13	12,13,14,15	12,13	V
13	12,13	12,13,14,15	12,13	
14	12,13,14	12,13,14,15	12,13,14	
15	12,13,14,15	15	15,16,18	

Drivers	Rechability set	Antecedent set	Intersection	Level
15	15	15	15	VI

Figure 6:Iteration5 and 6

Model building using ISM:

Relationships between various Drivers are depicted after splitting the levels by creating a node for each variable and linking those nodes with arrows in the direction of the self Interaction matrix. The diagraph is checked for transitivity and validated, as outlined in methodology, before being turned into an ISM model [21-30].

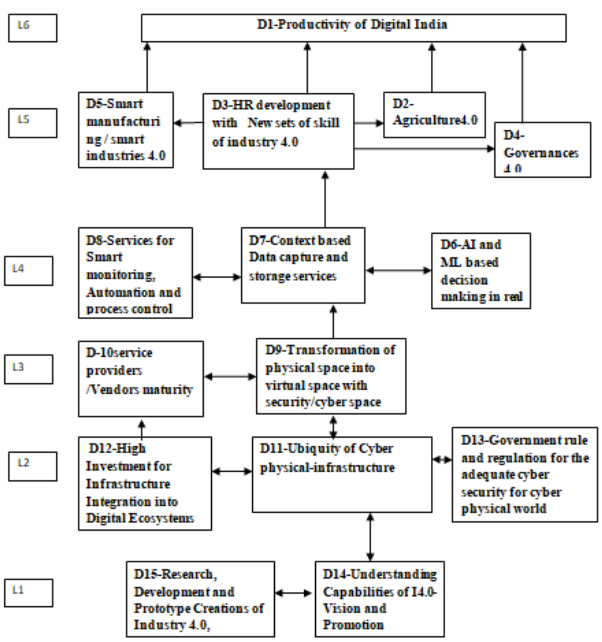


Figure 7: Final ISM Model to Make Industry 4.0 Ubiquitous to improve productivity for futuristic requirements of Digital India

6.0OBSERVATIONS, DISCUSSIONS AND ANALYSIS:

As per the report of industry 4.0 is in nascent stage in India [18-19]. Understanding the potential of industry 4.0 from digital India perspective (vision); Research and prototype Development a very significant and fundamental driver for futuristic requirements of Digital India, as it comes at the L1-level 1 base of the ISM hierarchy. An industry 4.0 practice provides automation and services to access cyber physical system anytime, anywhere at low cost and high quality. So there is need to understand the capabilities of industry 4.0 Practices by government organization to remain connected with citizens, can be used as a medium to deliver important messages and services; for business organization it can become a medium to deliver innovative services and remain competitive; and for society it can act as a medium to remain connected with friends and professionals. This understanding can lead to create supportive government policies for making cyber physical system ubiquitous. Further industry 4.0 infrastructure penetration and Investment need to improve. It should help to determine levels of investment in the economy, which in turn productivity benefits for economic growth, and new skill set creation. Government policies should integrate the impact of these technologies, Ideas and work culture that successful industries are following. But Authors also observed that prototype development and research are leads the industry 4.0 practices.

Industry 4.0 practices provide automation and optimized environment in Personalize spaces with mobility is reliant on linkage variable like AI and ML based decision making in real time for Innovative Services and models; Context based Data capture and storage based services; and Services for Smart monitoring, Automation and process control.

For making industry 4.0 ubiquitous in India depends on penetration of industry 4.0 practices with derived/ observed characteristics as per table 2

Sr.No	Layers	Characteristics
L5	Usage in different sectors (for productive benefits)	Decision making in real time, AI and smart analysis , quality of life , Smart monitoring and control , Revenue Generation, Safety, Comfort, Efficiency, time management, remote access of things(objects) , better infrastructure and quality of life Quality, knowledge at our fingertips Resource utilization, activation and decision making
L4	Services	Real time, context based, transform the life experiences , data transmit, intelligent data storage, M2M communication M2P, cyber physical world interfaces, personalize spaces to create an optimized environment creating competitive advantage-capability provides a dynamic capability to remain connected with a customer base, trends, and real time data updates [23]

L3	Maturity	Standardization, Ubiquitous, Pervasive, , end-to-end digitization of all physical assets with adequate cyber security norms, migration to cyber physical world
L2	Infrastructure development and Penetration	high investment for infrastructure integration into digital ecosystems, Affordability, Availability for cyber physical production system, Internet and energy(power), ,) integration, energy harvesting and self power generators, standardizations, environment friendly, good for human health, miniaturization, embedding, networking, ubiquity, context –awareness
L1	Research and vision	Prototype, rule and regulation for cyber Physical world , Integrate environmental thinking

7.0 MIC MAC Analysis: The goal of MIC-MAC analysis is to determine the driving strength and dependability of variables. Based on driving and dependence power, the variables are divided into four groups. Cluster A: Autonomous variables with low driving force and low dependability. Cluster B: Dependent variables with a low driving power but a high degree of dependence. Cluster C: Linkage factors with a high driving power and a high degree of dependence. Cluster D: Independent variables with a high driving force but little dependence. Improvement in digital India's productivity by driving industry 4.0 with Society Productivity, Agriculture Productivity, Government Organization Productivity, and Industrial/Organizational Productivity are all strong dependent variables, according to this analysis (Figure 8). D6,D7,D8, i.e. D6-AI and ML based decision making in real time, D7-Context based Data capture and storage services, and D8-Services for Smart monitoring, Automation, and Process Control, are strong dependence and driving power variables, according to this analysis. In this study, there are no autonomous variables. D9-D15, are the independent variables in our analysis, and these variables provide a lot of driving power for industry 4.0.

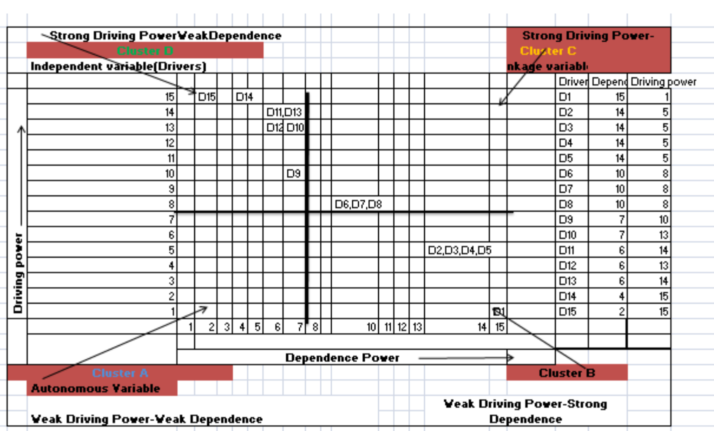


Figure 8: MIC-MAC Analysis

8.0 Conclusion:

Industry 4.0 can provide automated digital solutions for the country's most intriguing problems that affect the economy. In this study, we look at what drives and actions can be taken to make Industry 4.0 a reality for India's future needs. Through automation, analysis, and action, Industry 4.0-based processes can establish efficient trade channels and promote financial inclusion (decision making in real time). The cost-effectiveness of product/process creation, as well as the revamping of current industries from an automation standpoint; are the key drivers for making cyber physical advances prevalent in the field of Industry 4.0. It is necessary to convey technologies to society for the benefit of humanity, as well as to connect with cutting-edge infrastructures. Strengthening knowledge and skills through automation and optimizations is desirable from an HR standpoint. A new skill set that balances social skills, science knowledge, technical abilities, and training, as well as human relation skills and machine related skills, is desperately needed. However, because ICT components like as sensors and devices are needed for deployment, environmental sustainability, resource consumption, and legal regulation are some of industry 4.0's limiting constraints. However, industry 4.0 can be driven by the creation of industrial value through integrated environmental thinking, standardisation, and new skill sets to lessen negative impacts on the environment and social issues. The cooperation of all stakeholders, including Indian MSMEs and SMEs, is critical to making Industry 4.0 a reality in India. Transfer of technologies to industries to aid startups and entrepreneurship, as well as education 4.0 with a new skill set of Industry 4.0 practises, can help to raise it to new heights. With the improvement in productivity, quality, resource consumption, and market share, Industry 4.0 can redesign industrial organisation automation with the process of decreasing maintenance, time and cost, machinery stoppages and downtime, inventory including space, cost, and waste. Overall, the use of artificial intelligence in Industry 4.0 involves not just horizontal factory-to-factory connectivity, but also vertical integration to connect production line hierarchies. As a result of the impact of the Covid 19 outbreak, demand for services based on real-time automation has increased, and the economy has expedited the need for industry 4.0 digital infrastructures.

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