Artificial Intelligence (AI) and Its Applications in Indian Manufacturing: A Review

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Abstract Artificial intelligence (AI) is globally acknowledged as innovative technology. Today, many corporations and individuals are making an effort to harness the capabilities of AI in almost all sectors viz. healthcare, education, manufacturing, smart cities, agriculture, etc. The concept of ‘Smart Factories’ and ‘Industry 4.0’ has prompted many global enterprises to use automation and intelligent robots to improve manufacturing and enhance the quality of the finished product and overall productivity. Indeed, artificial intelligence is a vital tool to augment manufacturing by facilitating the R&D, enhancing the quality, reducing the errors, and maintaining the supply chain by projecting demand forecasting and simulation of outcomes to foster higher margins in stiff competition. However, the requirement is to build an industry that should be compliant with such disruptive changes and a workforce compatible enough to create a collaborative environment for both men and technology to work productively. Thus to conduct this study, several keywords and their combinations were used and explored using Google Scholar. The relevant articles, papers, and journals obtained were examined, and data pertinent to the study were collected, examined, and aggregated. Furthermore, specific changes in the current policies and the working parameter were also suggested. In this paper, the scope of artificial intelligence and its applications in today’s manufacturing sector of India is discussed. Here, the Indian manufacturing sector’s present status is focused primarily, the limitations are identified and how they can be dealt with.

Keywords Artificial intelligence (AI) · Industry 4.0 · Smart manufacturing
1 Introduction

Artificial intelligence (AI) is a science with cognitive abilities. It has revolutionized the world with applications enabling high-level cognitive processes like thinking, perceiving, learning, problem-solving, and decision making. With additional advantages, such as data collection, segregation, and analysis, artificial intelligence presents numerous opportunities to supplement and augment human intelligence to enrich the way people live and work [1, 2]. On the other hand, Industry 4.0 is the subject matter of recent times, driven by the combination of big data, high computing capacity, artificial intelligence, and analytics to digitize and revolutionize the manufacturing sector in the world [3, 4]. The strategic readiness for Industry 4.0 in India can be observed, but the concept is far from practical implementation. Hence, the focus will be on the current limitations of the manufacturing industry, the dearth of competent workforce and the required steps to be taken to create technology-compliant jobs concerning a developed sophisticated industry harnessing the AI technologies shall be identified which eventually contribute further to the idea of Industry 4.0 [5, 6]. Nevertheless, we need to know what artificial intelligence or Industry 4.0 is all about and how it can transform the ongoing industrial scenario.

The concept of artificial intelligence was developed in 1956 by computer scientist John McCarthy and Marvin Minsky, Allen Newell, Herbert Simon, and Arthur Samuel. Since this concept was so ahead of its time, it took extensive research and two winters to become today. However, the use of AI grew extensively in the late 1990s and the early twenty-first century, owing to an immense increase in computational power and an emphasis on problem-solving, which was aided by researchers who developed mathematical methods and scientific standards to improve ties between AI and other fields viz. mathematics, statistics, and economics [7, 8]. Today, AI is being employed for tasks ranging from very commonly used search engines like Google, etc. to high-profile usage like smart manufacturing, medical diagnoses, autonomous vehicles, etc. Modern-day AI technologies can be categorized depending upon their strength, cognitive abilities, and the existing technology in the application currently.

The term ‘Industrie 4.0’ or I4.0 or I4 originated in 2011. It was a German government initiative that primarily focused upon the computerization of manufacturing. Industry 4.0 is a new phase in the Industrial Revolution that focuses heavily on interconnectivity, machine learning, automation, and real-time data. This particularly involves the usage of cyber-physical systems (CPS), the industrial internet of things (IIoT), Radio Frequency Identification (RFID), cloud computing, cognitive computing, and artificial intelligence for improved communication and monitoring that analyses and diagnoses issues without the need of human intervention. This is a revamped approach inspired by new advancements to achieve results that were not possible earlier due to technological constraints. Hence, it has also been labeled the ‘Fourth Industrial Revolution’ [3, 9, 10]. Smart factories, forming the heart of Industry 4.0, are geared up and equipped to take the information and communication technology to execute a much higher level of automation and digitization of production lines and an equal evolution of the supply chain. This eventually means machines
will be using self-configuration and self-optimization to accomplish complex tasks to deliver better cost efficiencies and superior quality goods and services [11, 12].

India has seen considerable economic growth since the advent of liberalization in 1991. Many trade barriers were removed, and the scenario changed drastically as the Indian market opened up. This resulted in tremendous growth in the service sector of India over the last few decades. However, the manufacturing sectors are still stuck with technology, equipment, and processes from the Industry 2.0 era viz. manual inputs, lack of ICT integration, etc. [6, 13]. Although in the recent past, the flagship initiatives by Prime Minister such as Skill India, Make in India, and Digital India, did attempt to transform the manufacturing to India. However, lack of primary factors such as proper technological infrastructure, optimum technical and soft skills, and AI research restrictions up to certain institutions and organizations pose a tough challenge [1]. In current COVID-19 pandemic, innovative technologies like AI, 3D printing, Multi-agent system, biosensors, telemedicine, seems helpful to track this virus [14–19]. In these days, supply of essential medical equipments like medical equipments and ventilators parts is required and technologies are available to fulfill this requirement [20, 21].

In this paper, the impact of AI and its contemporary applications in the manufacturing sector, especially India, and its socio-cultural impacts and the shift of paradigm of knowledge and technology are considered. The paper is organized as follows: further reading focuses on the literature collected from various papers and journals, which is processed so as to obtain the results and conclusions. This review is delved into the details of the existing conditions and the requirements at this stage. The Methodology follows this; the discussions and findings throwing the light on the ongoing developments of technologies, current drawbacks, and the relevant steps needed to be taken; the conclusions are based upon the literature review and discussions with a mention of the current limitations and future scope implications.

2 Literature Review

While AI and its corresponding resultant technologies such as Machine Learning (ML) have already been utilized in manufacturing in recent times; however, it is evident that such technologies demand considerable capital and an optimum human resource to work collaboratively in an environment. AI used in manufacturing is a discipline that dedicatedly focuses on developing, validating, and deploying various machine learning algorithms for all the industrial applications with a sustainable performance [2]. Such manufacturing, known as smart manufacturing, integrates autonomous sensing, data-intensive modeling, a collaboration of computing platforms and communication technology, simulation, and control. Besides, the combination of the Internet of Things (IoT) and AI are also beneficial as IoT generates massive information from which the user data is sensed out by the AI, turning it into predictive findings. This helps any company reduce downtime and cost, maximize productivity, improve quality, and streamline operations. Overall, the company’s
asset operating efficiency is maximized by systematic analysis of machines, prediction of outages, handling of repairs, and automation of equipment maintenance [8]. Thus, smart manufacturing harnesses the concepts of cyber-physical systems, IoT, cloud computing, AI, and data science and is principally based upon the concepts of advanced manufacturing processes, predictive engineering, resource sharing, and sustainability alongside data and materials. This will make manufacturing the fourth industrial revolution hallmark, i.e., Industry 4.0, if implemented efficiently [12].

The concept of Industry 4.0 is predominantly novel to developing economies, and it needs an in-depth understanding and practice in business. As compared to other Asian countries such as Malaysia and China, India is comparatively slow in adopting modern information technologies due to which the industrial automation level in the manufacturing sector is comparatively low. Most of India’s manufacturing sectors are still stuck with technology, equipment, and processes from the Industry 2.0 phase, even when the service sector has witnessed tremendous growth. Overall, the adoption of Industry 4.0 concepts is still in the nascent stage in Indian manufacturing from the managerial viewpoints [5, 6]. Another important aspect is capital expenditure, which the organizations have to incur for developing the infrastructure in compliance with Industry 4.0. Emerging technologies also carry a noteworthy threat for investments as there can be a potential for financial losses with no recovery [13]. Hence, the most important challenge for the Indian industry is to upgrade the manufacturing value chain to cover the gaps in critical technologies.

In the present times, the integration of Information and Communication Technologies (ICTs) and Cyber-Physical Systems (CPS) along with Advanced Manufacturing Technologies (AMTs) such as increased automation, additive manufacturing, big data, and advanced analytics has scaled up the technological excellence which has a mention in the design of smart manufacturing for Industry 4.0 [13]. The IT systems that store and process the knowledge that enhance the complete technological process are referred to as knowledge management systems. This knowledge management can be benefitted by processing the big incoming data collected from IoT devices. However, the existing systems may not be able to handle real-time data and the knowledge management requirements of Industry 4.0. That is device and process automation, guided vehicles, and a huge number of devices needed to be monitored and controlled, etc. cannot be met by the current communication systems as it needs very high bandwidth, ultra-low latency, and hence high data rates [8, 9]. Lights-out manufacturing often referred to as dark manufacturing, is one of its kind that does not require any human intervention. As the name suggests, such manufacturing is completely machine-based, and any human necessities such as lighting or HVAC are not required in the first place. In lights-out manufacturing, machines are completely self-sufficient in carrying out tasks without any human supervision. The designing of such a special factory floor does require items having significant capital expenditure. However, such factories reduce a significant operational expense in the long run, the only ones being related to the upkeep and maintenance of the machines. Moreover, human error is completely nullified, and this also results in significant energy savings.
3 Methodology

In a developing area, there is more conceptual work being reported initially, after which policy documents are made, and then the quantitative work is done accordingly. Thus, most of the papers are subjective research being reported. In this section, the way literature review is conducted is discussed briefly. According to the research requirements, relevant data from various websites and different research papers were collected, examined, and aggregated. This was initiated by a brief introduction of the AI technology and Industry 4.0, the information collected from various websites and was put concisely. This was followed by a detailed study of research papers and journals and a collection of clear-cut information corresponding to the research requirements. The existing scenario, including the technology and infrastructure, was noted after a thorough examination of papers and journals. Different aspects of implementations made by different countries and their strategies were also explored. The limitations in India’s AI development and challenges being faced while implementing the technology with the existing technological infrastructure were identified and were worked upon. Furthermore, specific changes in the current policies and the working parameter were also suggested.

4 Findings and Discussion

AI is a cognitive science with some productive research activities in fields such as image processing, natural language processing, machine learning, etc. Although, Machine Learning and AI were perceived to be techniques that might not yield an appealing return on investment even when worked with consistently. However, the current AI applications used in Industry 4.0 are far more systematic, which focuses majorly on developing and deploying various machine learning algorithms for sustainable performance [2]. On the other hand, manufacturing has witnessed a transformation in the context of machine-based technology, which has led to automation in the sector. Various manufacturing abilities such as Computer Numerical Control (CNC), Direct Numerical Control (DNC), automated guided vehicles (AGV), robotics, Flexible Manufacturing Systems (FMS), automated material handling systems (AMHS), automated storage and retrieval systems, etc. along with Computer-Aided Design (CAD) is being used and can be utilized according to the quantum of the work. Lately, the Internet of Things, i.e., the networking of computers, smartphones, appliances, machines, and a host of other elements, has taken manufacturing to another new level. Even though AI struggled in its early day due to the rudimentary technology available, yet in recent times, we see far more robust AI networks, infrastructure, and algorithms than those in the past [8, 13]. The research in AI has a history of constant sequential development. In western countries, particularly the USA, the investment in AI dates back to the Cold War era when the government employed machine intelligence to auto-translate Russian documents.
This phase of research experienced many hurdles, and there were periods when the research was abandoned temporarily, commonly referred to as AI winters. Nevertheless, AI research thrived and has found its way into different applications and standalone technologies [1].

In the context of the relationship of AI with the industry, we see various countries around the world engaging in it. With Germany devising the initiative of Industry 4.0, the United States launching the Advanced Manufacturing Partnership, and United Kingdom laying out the UK Industry 2050; we also see Asian nations such as Japan, South Korea, and China working their way out to reap the best of the technology to execute the fourth industrial revolution successfully [7]. The manufacturing sector is considered the backbone of India’s economy since its contribution to India’s GDP is 17%. Thus, keeping aside the large enterprises owning some of the world-class facilities, the majority of India’s manufacturing is driven by Small and Medium Enterprises (SMEs), which employs approximately 101.25 million people, even when its contribution to the GDP is mere 8.72% [13]. In the wake of recent times, it is necessary to pay attention to empower such SMEs so that they can deliver quality products and can manufacture while conforming to the global standards by systematically organizing and implementing a combination of Information and Communication Technologies (ICT) and Cyber-Physical Systems (CPS) in advanced manufacturing technologies. Probably due to the effect of international collaboration and competition, India has already witnessed the utilization of such technologies in the fast-moving automotive, electronics, and pharmaceuticals sector. Then again, a considerable number of enterprises majorly SMEs do not even possess an established ICT structure. A basic structure exists due to the affordability of mobile and communication technologies, which are utilized mostly for telephonic and email conversations and, to some extent, for costing and accounting [13].

Some reasons behind this technological backwardness include lack of skills and training among people concerning these technologies, lack of resources to install basic structure as most enterprises work in rural areas, and a proper investment with a promising return. For instance, the automotive sector involves such a huge investment and has the deployment of advanced manufacturing technologies. However, most of them have outsourced some of their work to vendors who are majorly SMEs. The SMEs’ competitiveness increases, which probably needs an overhaul of the whole manufacturing chain [1, 13]. Given the quantum of population, unemployment is a major issue in countries like India. This issue can also be attributed to the technological transition and lack of relevant skills among the people in recent times, probably due to the bias towards traditional methods of manufacturing [13]. To address this, the Government of India (GoI) recently have made specific changes in its policies to accommodate new technologies in manufacturing, and emphasis has been made on learning new skills [6]. However, there is no concrete development seen in this direction due to the lack of proper implementation of these policies.

The flagship initiatives of GoI are likely to get affected by the recent advancements of AI. The initiatives such as Skill India, Digital India, and Make in India possess enough potential to create, develop and harness the latest technology by imparting the knowledge of ICTs, CPS, neural networks, etc. in order to develop
a capable infrastructure which can reap the benefits of the new technology in the manufacturing sector. In addition to this, the cloud computing infrastructure capable of storing vast amounts of data and processing the massive amount of computing power required by AI largely resides in servers beyond India’s borders. Therefore, the absence of a large native-install base on-demand cloud-computing infrastructure in India puts the most recent advances in AI out of government-funded research labs’ reach. Furthermore, many industries cannot risk storing their data outside India, accessed by algorithms over which the Indian government has little direct control. Without this critical infrastructure, the adoption of AI technology becomes more expensive for the private sector. There also exists a long history of public funding in computing infrastructure as well as AI across the globe. However, there has been a shift towards private sector funding in the past two decades due to the advent of the internet economy. Consequently, Indian policymakers’ focus should be more towards creating an organizational structure with facilities to build such technological giants, which must take lessons from both public-sector and private-sector models [1]. Besides the government, sector companies and academia can also be brought to gain the past two decades due to work towards creating a stable indigenous AI platform. In the recent past, many people from academia shifted to the industry as major IT companies recruited people to fast track private-sector AI. The factor that AI research may get concentrated on a few private corporations that have to ability to pay the most is something to be regulated, else many areas of social and national importance may suffer for want of talent [1, 6].

5 Industry 4.0 in India-Implementations and Shortcomings

The Government of India (GoI), in its National Manufacturing Policy 2011, has given a considerable emphasis on the usage of advanced technology by providing incentives and encouraging enterprises, particularly SMEs, to use green technology. In addition, the National Education Policy 2019 marks the presence of disruptive technologies like AI and has urged for learning, research, and monitoring the same with a deliberate focus upon skilling and re-skilling as per the socio-economic impact of AI. However, there is still a need to cater to some very important factors to lay down a strong foundation for an indigenous AI program. The most crucial factor in this direction, which demands the attention of GoI at the utmost priority, is to establish a capable and robust computing infrastructure with servers that can provide a massive amount of computing power required by AI and can store vast amounts of data. This can either be done by complete public funding or through a Public-Private Partnership (PPP). This approach will keep the government-funded research labs more updated on the recent advances in the technology and thus encourage them to put more productive efforts towards AI. Furthermore, industries that cannot risk storing their data outside India can rely upon a centralized native-install base upon which the government manages, directly or indirectly. However, a strict and robust privacy policy should also be designed and implemented. Data security is indeed a
major concern in the current scenario and an environment of stiff competition; it is also very necessary to enforce data security norms effectively so that the data does not get manipulated by one party against the other or by the government itself, unless or until there is any unlawful activity.

The National Education Policy 2019 encourages the youth towards the learning of technologies like AI, so as to be more technology-compliant. Therefore, the flagship program Skill India should be molded accordingly to accommodate such curricular changes that contribute to the development of AI and Machine Learning skills among the young talent. The existing workforce can be re-skilled accordingly to make them compatible to work in the changing scenario. It is obvious that the young talent being more robust and adaptive to change can acclimatize to the new technology and is also more susceptible to adjust to any further advancement in the technology of the future. However, there is also a need to re-skill the existing workforce with considerable experience in the field with little or no knowledge of the technology to curb the rate of attrition. This is where the industry, academia, and the government have to come together with a plan to develop a curriculum necessary for re-skilling. The course thus generated should be technically feasible and economically viable, as not to create a burden upon the learner or on his finances. As mentioned earlier, there is a strong need to equip SMEs with the latest technologies to par with international conformations and standards. The National Manufacturing Policy 2011 does incentivize enterprises to use new and green technologies and tend to leverage the earlier existing incentives of the GoI to benefit enterprises already using these technologies. The flagship program, Digital India, can play a vital role in digitization, networking, and the optimum usage of AI-powered platforms. The SME sector needs to be organized and properly networked efficiently and innovatively to harness low-cost manufacturing. India’s strong telecommunications backbone does manage the country’s business landscape, but other factors such as civil infrastructure viz. roads, railways, seaports, airports, etc., and an uninterrupted electric supply should also be taken care of.

6 Research Limitations and Future Scope Implications

This study identifies a limited application of AI in the Indian manufacturing sector as the same is highly unorganized, and the requirements of trained human resources and capital investment. The technological R&D and commercialization cycle is also not very common. A high initial cost of the complete framework with the increased cost of overall production still prompts a lot of Small and Medium Enterprises (SMEs) to refrain or hesitate in taking a step towards next-gen manufacturing. The report’s findings are based upon the detailed study of the research papers, journals, and a few policies of GoI, and no survey or field observation has been conducted for the same. Also, the conclusion’s achievement parameters are based upon the statistics and data available in the reviewed literature. Therefore, different outcomes are possible,
subject to some other criteria upon which these parameters can be judged. Similarly, there exists much scope for future research and development as the emerging industrial environment and technologies are undergoing constant developments. AI in context with Industry 4.0 is a concept which possesses a considerable scope of evolution in the future as the industrial environment is also experiencing a new shift in processes currently, from static chains to a more flexible and efficient idea of production. Consequently, the technology development pertaining to this shift can also play an important role in contributing to the current and future developments further efficiently.

### 7 Investigation in Indian Scenario

In India, the concept of Industry 4.0 has indeed driven the industry stalwarts to adopt new and innovative technologies, so as to lay the foundation of the smart factories. The Government of India has recently initiated Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH) and is formulating the National Policy of Advanced Manufacturing to enhance the implementation of Industry 4.0 in the current manufacturing sector. The applications of machine learning, machine vision, and the Internet of Things (IoT) are actively being employed in certain sectors, where such smart machines enhance the quality of work or the manufactured product, thereby reducing the cost and the probability of errors. Moreover, additive manufacturing (3D-printing) have been readily adopted and possess enough potential to revolutionize the manufacturing industry in the near future. However, additional factors such as a high installation cost and expensive maintenance of such innovative technologies have been holding it back from large-scale adoption.

### 8 Conclusion

The advanced technology and its applications in the Indian scenario are yet to be harnessed to its full extent. In a similar pattern, the educational system is to be upgraded to add these technologies’ potential benefits on a wider basis. India has had experienced a revolution in the IT and telecommunications sectors in the past. Although it would be too quick to say AI may enjoy the same fate, one can be hopeful about the technological transformations occurring. Furthermore, the idea of 5G technologies in the future can enhance the overall efficiency and productivity. 5G technologies in communication will result in high network reliability and support the extreme density of IoT devices needed to satisfy industry-specific needs. Other developments include the lights-out manufacturing, which, along with smart and dynamic technologies, can generate and regulate a very decent production with negligible human intervention. Such manufacturing can be useful in areas having high production rates with tight deadlines and having no chance of human error. This may also
result in a considerable reduction in cost and time required to complete the finished product. In conclusion, the concept of AI is evolving, and the same will be reflected in the industry in the longer run. The requirement, however, is to develop the knowledge at par with the times.

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