Challenges and Significance of Digital Technologies in India: A Rapid Systematic Review based on Industrial Manufacturing Sector

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Abstract: Digital manufacturing has been recognized as a viable aspect of innovation for lowering manufacturing costs and development cycles while also shifting resources toward quality goods, the need for personalization, and rapid market demand. With the emergence of digital manufacturing, the world is in the early stages of a new epoch and is perfectly poised to confront conventional methods of product design and manufacturing. This review paper provides a comprehensive overview of the evolution of digital manufacturing, the significant role of information technology such as the Internet of Things (IoT), Additive manufacturing, Computer aided technologies and the complexities associated with digital manufacturing implementation in India. Initially, this paper provides a historical overview of distinct industrial revolutions before delving into existing research on digitalization in industrial manufacturing. It then delves into the technologies and critical features built into digital manufacturing systems, as well as their significance in India. Lastly, the influential problems and diversified complexities impeding the implementation of digital manufacturing in the context of India's manufacturing sector were explored, which will be beneficial for future directions.

Keywords: Digital technologies, Industrial manufacturing sector, Industrial revolution, Digital manufacturing.

1. INTRODUCTION:

Digital transfiguration is an era wherein entities, the public, employees, and universities are transformed, and neoteric business practices and frameworks are established. Digital transformation typically is a basic utilization of the web in manufacturing, marketing, design, and promotion for enhancing the capabilities of organizations and ameliorating their processes. Digital technologies mainly involve advancements regarding cloud computing, robotics systems, big data, artificial intelligence, cyber security, smartphones, the internet of things, virtualization, automation, sensor technologies, advanced robotic mechanisms, etc. which are intensely employed in heterogeneous fields of social life and economics [1]. Digitalization refers to the augmented exploitation of imperative digital technologies, their integration, and intra-fertilization in the organization’s inbound, outbound activities and products [2]. Digitalization can lead to fundamental variations, particularly, in how organizations establish and gain value. In common terms, digitalization is mainly viewed as the augmented generation, investigation, and exploitation of information systematically, for boosting the organization’s internal efficacy and expanding the organization by adding value for consumers via the migration from analog to digital formats. It is regarded as the fourth industrial revolution or industry 4.0. Digital technologies modify the way operations and processes are completed. Organizations and industries are significantly forced to employ, or risk being blotted out. Digitalization is chiefly transforming the way industries operate and is releasing comprehensive opportunities for adding value or creating value in industries. It establishes superior advantages to a broad level of industries and is gaining terrific interest from enterprises globally.

Today, digitalization is influencing almost all sectors associated with human activities. Among diverse existing sectors, the industrial manufacturing sector is one of the predominant sectors that is connected with human lives [3]. Therefore, this survey work aims to explore the impact of digitalization or digital technologies on the industrial manufacturing domain by analyzing its scope and challenges for implementing it in the Indian industrial manufacturing realm.

Digital information created a greater impact in the manufacturing field that includes certain enhancements in sustainability, revenue, efficiency, throughput, quality, and safety that minimizes the costs in the marketplace. The main advantages of using digitization in the manufacturing industry are that it prevents accidents, safety issues, and workplace injuries. This improves the quality of the output, minimizes the product's rework and warranty work, and, finally, maximizes customer satisfaction. The utilization of digital transformation in real-time manufacturing data allows for to capture of information instantaneously and analysis to make quick real-time decisions. Therefore, predictive analytics techniques are also used to enhance the products and execution in the manufacturing industry. This normalizes the execution process and prevents failures in certain aspects of the manufacturing business.

1.1 Paper Organization:

The paper is organized as follows: Section 1 provides an overview of digital technologies and background, the purpose of the study. Section 2 describes the historical background of manufacturing. Section 3 explores the existing studies on digital technologies in India based on the industrial manufacturing sector. Section 4 discusses the methods integrated with digital manufacturing. It describes the diverse approaches pertinent to data handling, connectivity, visualization, computing, and manufacturing. Section 5 discusses the issues and impediments encountered in digital manufacturing systems. Section 6 presents the chief characteristics of digital manufacturing systems like security problems, system integration, interoperability, etc. Section 7 provides the prominence and scope of digital manufacturing. Finally, section 8 concludes the survey.

1.2 Contributions of Survey:

The chief contributions of this survey include:

- Exploration of the impact of digital technologies on the industrial manufacturing sector.
- Analyzation of distinct generations of the industrial revolution.
- Exploration of existing works on digital technologies and industrial manufacturing for analyzing their prominence, challenges, and developments.
- Investigation of techniques integrated with digital manufacturing.

1.3 Significance of the Study:

This review work aids in understanding the impact of digital technologies on the Indian industrial manufacturing domain. It further assists the readers in gaining knowledge regarding the existing digital technologies, their benefits, and their challenges. It also provides information on the developments made in this domain and future ameliorations required for achieving better innovations in this realm.

2. MANUFACTURING HISTORICAL BACKGROUND:

Although the industrial revolution transpired about 300 years ago, it has left an intense effect on people's lives and businesses. Undoubtedly, the factories developed during the industrial revolution are accountable for generating capitalism. Prior to this age, many households received their income through farming and primarily lived in rural, small communities. The advent of industries made people work for companies situated in urban regions and working for these companies provided a better living compared to farming.

During the industrial revolution, production efficacy improved with inventions like the steam engine. Steam engines drastically diminished the time required for product manufacturing. Extremely efficient production consequently diminished the product prices owing to reduced labor expenses, creating the marketing paths to a neoteric level of consumers. The industrial revolution is also instrumental in enhancing employment opportunities. The widespread expansion of factories demanded additional employees and managers for operating them, thereby increasing the overall wages and job opportunities. As many large companies and factories are situated near the urban regions, populations relocated to cities seeking employment, often startling the existing housing supply. Further, this resulted in substantial ameliorations with regard to city planning. Augmented innovation also resulted in an avalanche of education and motivation, leading to various breathtaking inventions that are employed to date. These inventions include anesthesia, calculator, lightbulb, X-ray, the sewing machine, etc. Owing to the industrial revolution's developments, the nation witnessed the preliminary incandescent bulb, combustion engine, and assembly line employed in manufacturing. The industrial revolution has ameliorated the living standards of people and diverse technologies available and developed for their use.

2.1 Fourth Industrial Revolution:

This revolution is dependent on cyber-physical systems. It connects IoT with manufacturing methods for facilitating systems to analyze, share information and utilize it for guiding intelligent actions. Additionally, it incorporates contemporary technologies like augmented reality, artificial intelligence, robotics, additive manufacturing, advanced materials, and other imperative cognitive technologies. The fourth industrial revolution entails computer-produced product design and three-dimensional printing that can generate solid objects through generating successive material layers. This revolution, when compared to past industrial revolutions, is evolving briskly at an exponential manner instead of at a linear pace. It brings together the developments of networks, machines, and facilities that were derived from previous industrial revolutions. It also intends to consolidate the developments in ICT introduced by the communication revolution and internet, automating the industrial operation with embedded systems, real-time control, and monitoring [4]. Furthermore, this revolution is affecting virtually every sector in every part of the world. The depth and breadth of these variations foretell the transfiguration of whole systems of governance, management, and production. This revolution supports achieving connected industries with globally interlinked value chains connecting consumers, business partners, global suppliers, etc. Furthermore, systems belonging to this revolution are self-aware and they offer a complete understanding of the industry, facilitating faster decisions.

The cardinal benefits of this revolution [4] include:

- Enables devices, people, sensors, and machines to communicate and connect with one another.
- Aids in creating a cyber-physical network that enables networks to instantly and seamlessly share information when required in real-time.
- Makes supply chain management global and businesses competitive.
- Develops autonomous systems capable of making simple decisions without human intervention in real-time.

- Companies can provide highly customized products that are profitable and useful for expanding the business.
- Predictive analytics and augmented technological integration boost the efficacy and thereby assist in saving costs.

The chief features of the afore-discussed industrial revolutions are presented in Table 1.

Table 1. Characteristics of all generations of the industrial revolution

Period of industrial revolutions	Energy source	Chief developed industries	Chief technical achievement	Transport means
First: 1760-1900	Coal	Steel, textile	Steam engine	Train
Second: 1900-1960	Electricity, oil	Auto, metallurgy, machine building	ICE	Car, train
Third: 1960-2000	Natural gas, nuclear energy	Chemistry, auto	Robots, computers	Plane, car
Fourth: 2000-present	Green energies	High tech industries	Genetic engineering, 3D printer, internet	Ultra-fast train, electric vehicles

3. LITERATURE SURVEY:

In [5], the integration of digital technologies and lean manufacturing tools, considering the industrial domain perspectives in the digital age was discussed. From interactions of these tools with augmented reality, cloud virtual simulation, and big data analytics, multi-range circular diagrams indicated the cardinal contributions of Kanban 4.0, Kaizen 4.0, steam mapping, overall productive maintenance, and Poka-Yoke 4.0. Additionally, five lean 4.0 attributes were recognized, indicating the assimilation between stakeholders, processes, and devices; automation, and waste minimization. In [6], industry 4.0 technologies exploited in Italy and technological advancements achieved were explored. An investigation was conducted using qualitative comments and data from Italian manufacturing industries. Results revealed that while these digital technologies provided no contribution to any prominent amelioration with regard to environmental sustainability, remaining strategies like lean strategy, design-to-cost, servitization, machinery-electronic tool-and database fusion, and supply chain fusion were enabled via the exploitation of industry 4.0 methods. In [7], blockchain-empowered product lifecycle handling and achieving sustainable manufacturing were discussed. This work declared that from the viewpoint of production process, blockchain might be devised as facilitator for driving current manufacturing data systems, and from the viewpoint of product management, blockchain could be a useful tool for handling the life cycle of a product and establishing a database for sharing product data and making deals allowing non-secure manufacturers to interchange requirements and capabilities freely.

In [8], a lean manufacturing model using value stream mapping was presented for the plastic bags production unit. It comprised mapping the present procedure of industry and assessing the same for identifying wastes and constraining processes. Depending on seven lean manufacturing wastes, solutions were suggested for eliminating the identified wastes. A prospective state map depending on recommended solutions was created. Further, both current and future state map was simulated and examined for distinct attributes like production lead duration and processing time for assessing the total gain attained through utilizing stream mapping. Simulation outputs clearly ascertained the efficacy of this model for diverse small-scale manufacturing firms. The work [9] underscored the prominence of digital technologies for logistics and supply chains. It examined the miscellaneous challenges and trends in assisting digital supply chain performance and investigated the managerial and implementation hurdles of establishing a neoteric integrated paradigm. Findings of this work illustrated that digitalization of procurement and supply chain procedures could yield diverse benefits including increased flexibility, better decisions, higher transparency, lower inventory and warehousing costs, efficient delivery, ameliorated asset usage, and greater uptime and reduced amount of loading miles required for transportation. Furthermore, the work revealed that improved notification mechanisms and analytics could offer valuable insights and greater accuracy and facilitate the smoother realization of their improvements. The work [10] discussed the impact of industry 4.0 and digital technology on supply chain threat analytics. This study discovered that digital technologies during the proactive phase enhanced capacity flexibility and demand responsiveness, thereby establishing a positive effect on diminutions in threat mitigation. Furthermore, it declared that the reduced lead times owing to manufacturing strengthened the effect of digitalization with regard to inventory control augmentation. The work [11] reviewed the implementation of industry 4.0 in the manufacturing industry of New Zealand. This work suggested a neoteric model involving concept awareness, readiness, planning, pilot project, investigation, and digitalization phases for attaining massive benefits of industry 4.0 and receiving guidance for realizing industry 4.0 in manufacturing firms at diverse levels. The study [12] described the concepts, envisioned benefits, and dimensions of digital society and industry 4.0. It declared that by effectively adopting industry 4.0, the industries could substantially boost their competitiveness, reduce risks and enhance value creation. It further mentioned that the chief envisaged benefits included rapid delivery times, reduced operation cycle times, rapid time to market of contemporary services and products, ameliorated quality, and service/product customization. It also recommended the necessity for appropriate human competencies and robust leadership for the successful implementation of industry 4.0.

The work [13] concentrated on the stages featuring the additive manufacturing procedure, wherein a segment for aircraft companies could be produced. Furthermore, a digital twin was also proposed via the adoption of blockchain panaceas. This work presented a conceptual solution for organizing and securing the information generated via an end-to-end manufacturing procedure within the aircraft organization. From the viewpoint of management, blockchain offered the potential to revolutionize and transform complete industrial sectors. Particularly in the aviation domain, it assists in reducing the effects on process traceability, supply chain, compliance guarantee, authenticity control, and service or product quality for ensuring the safety of all installed components on each airplane. This work effectively illustrated the efficacy of blockchain and the digital twin for performance amelioration of the manufacturing realm. The work [14] examined China's current manufacturing state, its dimension, problems, and structure. It concluded that the forthcoming Chinese economy would experience severe issues while making substantial compromises during the period of the trade war. The study [15] discussed digital twin-oriented manufacturing, service, and product design using big data. It explored the imperative frameworks and application techniques of digital twin-oriented manufacturing, service, and product design. Findings recommended the necessity for further research on the practical implementation of effective digital technologies useful for the manufacturing realm. The work [16] discussed the scope of additive manufacturing (AM) in industry 4.0. The work revealed that AM aids in saving costs and time and is crucial for process efficacy. Furthermore, this study declared that AM is helpful in lowering the complexity, enabling brisk prototyping and extremely decentralized production procedures. Furthermore, it stated that this AM would be supportive of developing future smart factories involving all procedures interlinked with the internet of things, integrating individualization and greater flexibility with regard to manufacturing procedures. In [17], a conceptual model for empowering production laborers with digitally assisted knowledge processes was presented. This work discussed four imperative digital advancements with regard to knowledge processes, particularly in knowledge-profound production environments. These advancements included knowledge discovery via self-learning workplaces, worker-centered knowledge sharing, knowledge acquisition via mobile learning, and digitally enhanced knowledge transfer. These advancements were capable of assisting one particular facet of workers' knowledge management procedures. This work greatly contributed to production research by discussing recent trends in modern manufacturing settings and by aligning evolving digital technologies for assisting workers and ameliorating productivity, efficacy, and job satisfaction. It also provided recommendations regarding the development of innovative panaceas for production settings that assist workers in achieving flexible productions via the exploitation of digital approaches. The work [18] proposed a comprehensive model that integrated imperative evolving trends of digitalization and servitization in manufacturing. It quantified and defined their impact and contribution to the manufacturing firm's performance. It declared that digitalization offered a valuable mechanism for unlocking the servitization benefits and ameliorating the manufacturing organization's performance. The findings of this work revealed that digitalization positively mediated the association between firm performance and servitization. Moreover, it indicated that the mediating impact of digitalization contributed to discrimination of indirect and direct influences of servitization on manufacturing organizations' performance. In [19], the impact of local manufacturing on customer welfare, competitive dynamics, and market structure was investigated. This work provided a neoteric viewpoint on the basic trade-off between the instantaneous accessibility of products produced by and in the vicinity of a customer and the efficacy gains of achieving desirable economies through manufacturing standard products. Furthermore, AM was analyzed from the standpoint of the standard theories of spatial competition and user innovation. This work suggested the wide scope for the amelioration of customer welfare looming from local manufacturing by customer producers. The work [20] discussed the digital manufacturing system, and its present implementation condition and examined the gap between the forecasted future digital manufacturing and the present digital manufacturing system. The diverse technologies linked with it in addition to their contribution to the manufacturing domain were also discussed. The work then explored the implementation challenges, future prospects, and opportunities for digital manufacturing systems. In [21], a conceptual model for digital technologies like base technologies and front-end technologies was presented. Here, base technologies involved four cardinal elements namely big data, data analytics, cloud services, and IoT while the front-end technologies considered smart working, smart supply chain, smart products, and smart manufacturing. This work also explained how these digital technologies are interrelated and implemented. Findings explicitly revealed that industry 4.0 was related to a methodical utilization of front-end technologies, wherein smart manufacturing played a pivotal role.

Eventually, the technologies utilized to emphasize the existing research in the manufacturing industry are Artificial Intelligence (AI), Quantum Computing, Industrial IoT, Augmented Reality, Robotics, Cloud Computing (CC), and much more. The advancements in these technologies in the manufacturing sector provide an efficient outcome and increase production. This transforms the interaction between the machinery and workers more smoothly, eventually for faster and safer manufacturing.

4. TECHNIQUES INTEGRATED WITH DIGITAL MANUFACTURING:

Digital manufacturing is a subset of Industry 4.0, which entails the integration of production processes with IoT technology. The necessity for short processing times, combined with an increasing demand for more customer-oriented different products, has resulted in the subsequent era of manufacturing information technology (IT) systems. Albeit still being used or practiced, the conventional approach of industrial production dedicated assembly lines cannot cope with changes in the market such as increased customer demand for the product, product changes such as the launch of a new item in the line, and equipment malfunctions such as machine failure in a cost-effective or timely way. Over the last decade, the advancement of data systems has played an important part in the implementation of novel information technologies within the framework of manufacturing techniques [22]. Digital manufacturing is the synchronous creation of product and production process interpretations using a computer-based system that incorporates modeling, 3D visual analytics, big data, and collaboration tools. Design for manufacturability (DFM), computer-integrated manufacturing (CIM), lean manufacturing, and flexible manufacturing are industrial production approaches that emphasize the importance of cohesive processes and product development. Because of the latest innovations in sectors such as additive manufacturing, human-machine interaction, AI (Artificial Intelligence), robotics, and digitization, as well as a proliferation in data and innovative abilities, digital manufacturing is also breaking the manufacturing facade. Furthermore, rapid technological and scientific advances, market dynamics, and rising demand for personalized products resulted in the digitalization of computer-integrated production [23].

4.1. Computer-Aided Technologies:

Computer-Aided Design (CAD) is one of the innovations that have productivity increases, allowing for a quicker pace of product in the marketplace, and has significantly minimized the time associated with product advancement. Planning and execution of production decide the production processes and chain of events required to financially and commercially generate a given part [24]. In order to accomplish this, computer-aided process planning (CAPP) systems have been utilized to generate simultaneous process strategies and are deemed as essential aspects of the Computer Integrated Manufacturing (CIM) surroundings [25]. Computer-aided engineering (CAE) systems are also utilized to simplify the process of hardware development and testing during product innovation and to accomplish better understanding [26]. The innovation of the CAD system ascertained the idea of computer-aided manufacturing (CAM). The incorporation of computer numerical control also empowered a clear correlation between the three-dimensional (3D) CAD model and its manufacturing. Furthermore, the assimilation of Total Quality Management (TQM), Just in Time (JIT) manufacturing, Concurrent Engineering (CE), Lean Manufacturing (LM), and engineering science with CIM resulted in a manufacturing revolution. Moreover, the existing research such as blockchain technology, lean manufacturing model, neotric model, big data, additive manufacturing technology, conceptual modeling, comprehensive model, and much more has been utilized on digital technologies reliant on the industrial manufacturing domain. Further, the base technologies are also used in the research with cardinal elements such as big data, data analytics, cloud services, and IoT due to the consideration of front-end technologies working on smart manufacturing systems.

4.2. Simulation:

Modeling factories in a digital reality to optimize machine configurations for preexisting assembly plants without assessing in the physical universe will save both money and time in assessing the manufacturing operation. Since the 1980s, simulation software products have included visualization capabilities, such as motion graphics and graphical user interaction features, because they offer the significant benefit of examining and statistically analyzing what-if circumstances, thereby minimizing the overall cost and time needed for making choices based on system behavior. Furthermore, simulation has been incorporated into the digital manufacturing system in recent years, which has aided in the analysis of system failures, manufacturing time, manpower, and power required for the complete manufacturing, as well as the preparedness of budgeting, profitability analysis, and bill of materials prior to actually progressing into the actual production process [27, 28].

4.3. Virtual Reality:

Virtual reality (VR) technology, an enhanced version of simulation technology, allows users to interact with computer-generated videos and images that simulate real-world activities [29]. VR has been utilized in smart factories to teach new engineers and specialized grads who are not adequately prepared to cope with manufacturing processes. Using virtual reality, they are presented with the production process, mechanization processes, problem resolution, and maintenance systems, which have proven to be of better value than academic knowledge. It also aids in reducing the expense of developing and evaluating any product by visualizing the layout without physically constructing it, as well as visualizing and trialing products in a simulated space for end users, up additional possibilities for mass customization, restoration, and rapid product development [30-34].

4.4. 3D Printing (Additive Manufacturing):

3D printing, also referred to as virtual device fabrication or additive manufacturing (AM), is an innovative technique for creating real items from a simple geometric depiction that opens up new possibilities for digital manufacturing technology. To produce an object straight from a CAD model, 3D printing employs layer-by-layer material deposition [35]. 3D printing is altering the way industries operate, prompting some experts to call the rise of 3D printers the "second Industrial Revolution ". AM technology is adaptable for personalization, functional prototypes, mass production of spare components, and on-site production, which saves both money and time on industrial machinery replacement parts and materials [36]. The primary strength of AM in digital manufacturing is that it enables regression testing of any components or item through 3D scanning and enables realignment in layout and rapid procreation for validation and testing.

4.5. Cloud Technology:

Cloud-based design and manufacturing (CBDM), also referred to as a personalized service-oriented interrelated product framework is a rapidly evolving technique that will fundamentally change cloud-based design and manufacturing by leveraging cyber-physical systems (CPS), IoT, and big data. CPS integrates simulation entities to the physical realm and its ongoing processes by implementing information management solutions that are directly accessible via the internet, and it is essential in the planning and creation of future CBDM systems, which must account for system security, data protection, proprietary information, and confidentiality. IoT enables potential CBDM systems to boost manufacturing digitization, supply-chain management, help support, and diagnostics, and big data will play a significant role in assisting developers to deduce definitive customer requirements from available data to enhance and create models [37]. Cloud technology will have an impact on how corporations operate their processes, from ERP) and financial planning to data processing and workforce training. Furthermore, cloud computing will be crucial for enabling and democratizing automated manufacturing production practices such as 3D printing, generative design, and the Industrial IoT.

4.6. IoT & IioT:
IoT is utilized in widely accepted domestic applications such as connected homes, public transit, supply chain, healthcare, farming, human pets, and fleet tracking applications, whereas IIoT is concentrated on the Manufacturing application of IoT, which connects every tangible thing with each other via the internet [38]. In industries, the IIoT integrates real objects such as sensors, actuators, and the entire process control and monitoring system to the cloud server, allowing each object to engage and cooperate to achieve common objectives [39]. These communications among components aid in production scheduling, proactive maintenance, and failure tracking, enhanced human-machine interaction, and smart control systems for optimizing resources, equipment, and components. IIoT also enables customers to view virtual lectures on products, procedures, and industrial plants for information and marketing objectives [40].

5. PROBLEMS AND CHALLENGES FACED IN DIGITAL MANUFACTURING:
Digital Manufacturing is a vital domain as it adds value to manufacturing returns and structures by incorporating technological innovations in the manufacturing industry and offerings. High capital expenditure rates and a lack of sufficient abilities and knowledge in the workforce appear to be the major vulnerabilities impeding the incorporation of digital manufacturing systems in India.

5.1. Employment Disruptions:
Employment disruptions are outlined as conflicts in employment carried about by the emergence of new innovations and digitization. Current manufacturing employment is at risk of being robotized, resulting the reduction of the human workforce [41]. The residual skilled workers will include additional information and having to learn technicalities, as well as more quick and difficult-to-plan tasks.

5.2. High Implementation Cost:
The capital cost that organizations must accrue to establish the smart manufacturing system in their organizations is referred to as high implementation cost. While small and medium-sized organizations that were early adopters gained competitiveness, it remains correct that numerous of these smaller companies have little or no financial capital and financial backing of larger competitors [42]. There is also the issue of tying new investment to potential earnings. Many companies are concerned about the initial cost, but the cost of not adopting may be greater or even fatal. Organizations can improve iterative proposals that concentrate on a vital area, such as leisure time, with strategies to broaden the framework as the outcomes pay for themselves via higher production by using a cloud-based application and cost-effective devices. However, new and emerging innovations, such as IoT, always pose a significant risk to organizational investments due to the possibility of investment deficits and no investment recoupment [43].

5.3. Organizational and Process Changes:
The term "organizational and process changes" refers to the procedural changes that will be brought about by the introduction of CPS and digital manufacturing. Following the incorporation of digital manufacturing technologies, organizational functions will alter, resulting in a decentralized organizational structure [44]. With the assistance of massive IoT software and solutions, which are valuable across industry sectors, major challenges pertaining to the incorporation of both internal and external, directional, diverse, and closed systems as many organizations regard these as major concerns [45].

5.4. Lack of Skill sets:
Many attempts are being made to utilize sophisticated data analytics, artificial intelligence, machine learning, digital twins, and digitization as industries expand their modern manufacturing technological capabilities. With the organization's incorporation of digital manufacturing technologies, employees' understanding, qualifications, and abilities will be crucial to the achievement of a truly innovative organization [46]. Lack of knowledge in these and related areas can stymie advancement if non-tech organizations move to digital manufacturing technology. To address this, organizations must prioritize the progress of qualified manpower through effective human resource management. Effective system and rollout of IoT solutions necessitate extensive primary understanding, which is lacking in many technical and non-technical programs [47].

5.5. Lack of Data Management System:
Database management systems are information systems that store and restore data, enhance concerted response, obtain sources of information, excavate records for hidden data, seize and use data, and optimize the data management process. Information management systems can benefit from incorporating IoT and processing big data generated from IoT systems [48], but real-time data might not be treated by existing technologies. To shift from operational to more tactical and precise activities, strong technical skills are needed. Data analysts who analyze big data and generate valuation through maximization and predicting will be in high demand [49].

5.6. Security and Privacy Issues:
On the digital service, there is a massive amount of data flows, which creates cyber risks and data privacy concerns. Virtual work on a web server or phases requires delegates to be familiar with digital protection [50]. Many organizations that recognize the value of digitalization and understand its future and present benefits were also concerned about data security. The majority of these processes are cloud-based and run online, with Wi-Fi or wireless sync and Ethernet to integrate legacy analog equipment to the floor. Organizations continue to face significant challenges with data security risks associated with confirmation, authorization,

data confidentiality, access control, applications, networks, and information [50]. These IoT security problems, however, do pose a risk, but they can be ameliorated to reduce the hazards of digitalization.

5.7. Lack of Clear Comprehension about IoT:

When implementing IoT in a business venture, organizations must possess a clear understanding of the complexities of IoT integration, such as value creation, distribution, and abduction. If organizations are contemplating a business strategy based on IoT applications, they must evaluate the disparities appropriately in order to benefit [51–53]. Multiple IoT applications and related technologies are currently in the initial stages of development, and as a result, there is ambiguity in the prospective economic earnings that could be deduced from IoT deployment. Hence, the adoption of IoT is perceived as a critical challenge faced by most organizations [47].

5.8. Regulatory Compliance Issues:

Regulatory compliance alludes to the goals that the organization seeks to achieve in its efforts to ensure that they are aware of and comply with relevant laws, agreements, and standards [54]. Organizations must establish stringent standards for IT protection, functioning with machines, and hours worked [55].

5.9. Legal & Contractual Uncertainty:

Because of the competitive pressures, the digital revolution presents a threat to the legal system. When implementing a digital transformation strategy, data privacy laws, AI obligations, and standardization should all be considered [56]. The simulated affiliation does not possess a legal existence and thus cannot be differentiated as a legally independent component. Each simulated affiliation that utilizes information and communication technology (ICT) must guarantee that when transferring info on the internet, they do so in a secure manner, do not violate security protocols, and that the agreements concluded are legitimate and actionable.

6. CHARACTERISTICS OF DIGITAL MANUFACTURING:

The concept of digital manufacturing is the consequence of the convergence of digital technology, computer network technology, and manufacturing techniques, as well as the inevitable outcome of the digitization process in industrial companies, manufacturing, and production systems. Digital manufacturing combines industrial production with advancing IT processes such as artificial intelligence and VR technology, enabling real-time monitoring of the entire manufacturing line via sensors. This reduces costs, improves quality, shortens the manufacturing development process, and streamlines the procedure all the way to e-commerce and the supply chain. Additionally, the classification of characteristics will aid in comparing and distinguishing other approaches such as Industry 4.0, cyber-physical automation systems, intelligent systems, industrial automation, and advanced manufacturing, which are often used interchangeably with digital manufacturing.

6.1 Security Issues:

The incorporation of an interconnected network framework in a production system for providing data between production or machining parts to ultimate consumers is referred to as digital manufacturing. This necessitates network connectivity, which is provided primarily via the internet. Sharing information over the internet necessitates security of data and information at different points throughout the process, including a unique identification and end-to-end data encryption [57]. As a result, every network node must be secured from exterior threats and data misapplication. The most critical consideration to make when developing network infrastructure such as digital manufacturing systems is ensuring the system's and the overall process's security.

6.2 System Integration:

The incorporation of advanced technologies with current systems is another characteristic of the digital manufacturing system [58]. The incompatibility of current devices with smart technologies induces a number of issues when implementing digital manufacturing innovations. Old equipment governed by some communication channels may be obsolete, and new systems may use a different procedure. An improved communication system is also required for machine-to-machine communication and system connectedness. To endorse more network connections together at the same moment, a recent manufacturing system needs IPv6 connectivity. These are the problems that could occur when upgrading modern digital production equipment and machines [59]. One of the key impediments related to the deployment of IoT technology to generate a CPS of IoT ecologies is ensuring consistent amalgamation and interoperability between various technological innovations and communications networks.

6.3 Modularity:

Modularity is a system characteristic that allows a device to be disintegrated into parts that can be put together to create different layouts [60]. Composability is the characteristic of a system that allows it to be formed from its subunits [61]. Since these two characteristics perceive a component getting constructed from sub-components and modularity resulting in a different configuration, composability may be regarded as a component of modularity.

6.4 Interoperability:

Interoperability refers to the capability of various systems to individually comprehend and access each other's features [62], allowing system units to transfer and share data. Interoperability in Industry 4.0 is divided into four categories operational, systematical, technical, and semantic. CPS and Industry 4.0 are linked by operational interoperability, which is concerned with the conceptual framework of Industry 4.0. Systematic interoperability is concerned with norms, rules, fundamental methods, and concepts. Technical interoperability defines platforms and tools for technical and ICT contexts, as well as associated technology. Semantic interoperability is concerned with the transfer of data between various levels of organizations and individuals [63]. Interoperability, on the other hand, may be difficult to attain if communications and norms are not perfectly aligned. Discrepancies in network bandwidth, operational frequency, mode of communication, device abilities, and so on restrict the system's interoperability.

6.5 Safety in Human-Robot Collaboration:

Human-Robot collaboration is specified by the International Federation of Robotics as the robot's capability to collaborate with the workforce in an industrial context to fulfill complex operations [64]. The essential things should be concerned with workplace safety and health of the employees on the job site; any highly unsafe atmosphere should be prevented and required workplace safety and health must be retained. The primary focus ought to be on minimizing any kinds of mechanical, electrical, thermal, noise, vibration, radiation, material/substance, and workplace environment risks in the sector when incorporating the CPS system or industrial robotic technology [65].

6.6 Multilingualism:

Digital manufacturing systems should be capable of dealing with multilingual processes, interpreting any instructions provided in human language into device code, and instructing the machine to perform the required function [66]. To make the term "digital manufacturing" more reasonable and to incorporate AI and sophisticated technology in a production system, it must be capable of receiving instructions directly from the provider, either verbally or in writing.

6.7 Return of Investment in New Technology:

When implementing a new technological advancement in a current manufacturing process, the cost estimation and investment return are thoroughly examined [58]. The capital investment necessary to implement advanced technologies is weighed against yield loss during an upgrade, and the duration needed to regain the investment's return with the current framework impacts the adoption of newer technology.

7. SIGNIFICANCE OF DIGITAL MANUFACTURING IN INDIA:

With the recurring coronavirus pandemic, the world is facing two simultaneous transformations, including the formation of an alternative distribution chain and the development of new, cutting-edge production processes known as digital manufacturing. In addition, the pandemic has accelerated India's transition to digital manufacturing. Organizations that previously considered it an alternative now perceive it as a core aspect. In the meantime, those companies in India that have already begun the digital manufacturing journey, primarily Indian and foreign global corporations, have ramped up their integration. The transition falls in line with India's preparations to benefit from the worldwide divergence from China, However, India appears to lack the remaining 50% of the equipment needed for a properly developed digital manufacturing industry: physical components such as sensors, 3-D printers, and, most notably, cloud platforms. Furthermore, in a country like India, where job creation is critical, smart manufacturing is a sensitive topic. However, digitalization is already in use, and larger corporations typically require a progressive and phased robotic technology strategy. As of now, digital manufacturing in India continues to operate on a small scale alongside global technological endeavors. To be fully effective, it must be ramped up and fully implemented by small and medium-sized organizations that are poised to take off. The manufacturing industry in India will implement automation and digital manufacturing techniques much quickly as customers' demands, quality attributes, and safety and environmental legislation alter. Furthermore, the emergence of Fifth Generation (5G) technology has the potential to not only accelerate the IT infrastructure industry but also be a game changer in the world of digital manufacturing. As the country enters the revolutionary change, digital manufacturing will offer it a groundbreaking, even futuristic, advanced manufacturing platform and will help to establish a brand-new environment that will place it on par with its international peers.

8. CONCLUSIONS AND FUTURE DIRECTIONS:

With the advent of IoT and IIoT, digital manufacturing systems have become increasingly crucial in the adoption of improved manufacturing techniques in the present manufacturing era. The integration of digitization innovations and production systems enabled the maker to respond promptly to a user's request by gaining data, transforming it, modeling and prototyping the feature as well as layout, and eventually owning up to the production task of the production process. Digital manufacturing technology boosts productivity and effectiveness while also having a significant influence on the global economy. IoT and CPS intelligent technologies have now arisen as a universal concept capable of radically transforming any sector equipped with sensing, recognition, remote control, and industrial automation functionalities. Various studies have shown that digital manufacturing techniques in the industries, among many other things, provide high production rates, cost control, and consumer demands. The issue with the interoperability of their current systems and equipment with modern technology is the most difficult factor for a digital manufacturing system. Nonetheless, digital manufacturing must be expanded to fill the void between product planning (element setup and requisite production processes) and real manufacturing and production tasks within the organization. For the effective implementation of digital manufacturing technology, affiliated technologies such as AI, CPS, big data processing, augmented reality, VR, IoT, robotics engineering, and so on must be fully established in the industrial sector. These techniques, however, have not been discovered to be widespread in the existing manufacturing circumstance, and there is a massive disparity between the theoretical digital manufacturing system and the present manufacturing technology. New research areas such as organized supply chain and advanced manufacturing control, data gathering from production models and data enhancement for the utilization of efficient and effective devices, and optimized maintenance planning should be discovered in conjunction with the adoption of digital manufacturing systems.

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