Transitioning from Industry 4.0 to Industry 5.0: A Review and Analysis of Future Research Directions

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Abstract. The next phase of the Industrial Revolution will come soon, even if most companies struggle to digitise their operations via AI, IoT, cloud computing, and other cutting-edge technology. The rapid advancement of Technology and the shifting integration of human processes will usher in Industry 5.0 in day-to-day operations. The study examines and assesses the commercial implications of what is known as Industry 5.0, or the next Industrial Revolution. As a result, the record of success for the Industry 4.0 business transformation is examined, along with its vulnerabilities and dangers. The first outcome is a study of the business environment that identifies current gaps and derives possibilities and threats, along with recommendations for how the company might best transform itself in the context of the next Industrial Revolution. In addition, there is discussion around the strategy of reintegrating human labourers alongside automated operations in the supply chain. This study examines the possible utilisation of Industry 5.0, including supply chain management (SCM), intelligent healthcare, industrial production, and cloud manufacturing. We then discuss some technologies that will enable the implementation of Industry 5.0. These include the Internet of Everything, digital twins, blockchain Technology, collaborative robotics, edge computing, and networks supporting 6G and beyond

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1. Introduction

In previous ages, humans and/or animals have collaborated to develop and create weapons, clothes, cars, and homes. Significant changes in industrial production started in 1974 with the advent of Industry 1.0 [1]. The first three revolutions took more than a century to construct, but the fourth revolution from the third took just forty years. During the 1800s, mechanical manufacturing systems for steam-powered machinery were introduced, and Industry 1.0 started to take form. The expansion of industrial capacity has benefited the economy through assembly line manufacturing. The advent of electric power in 1870 marked the beginning of Industry 2.0.The primary emphasis on mass production and job allocation in Industry 2.0 led to higher productivity in manufacturing enterprises. In 1969, Industry 3.0 emerged with the integration of Information Technology, partial automation, and electronics. In 2011, the idea of future smart manufacturing was introduced, marking the beginning of the advancement of Industry 4.0. The primary goal is to harness developing technology for maximum efficiency and mass manufacturing [2]. The objective of Industry 5.0 is to fuse human experts' inventiveness with accurate, intelligent, and efficient robots [3].

Significant technological advancements in software and hardware have enabled significant environmental changes during the last 20 years. Information, communication, and artificial intelligence (AI) are combined, and many ideas are being cross-pollinated. These modifications bring about the so-called "digital transformation," characterized mainly by convergence and degradation. We are seeing the birth of new and sophisticated technologies due to a convergence phenomenon, wherein initial convergence fosters more convergence.

Sector 5.0 enhances Industry 4.0 by prioritizing research and innovation to transition to a human-centric, sustainable, and resilient sector. The Internet and developing technologies create Industry 4.0, a novel fundamental model change in industrial production [4]. This new paradigm shift takes place at the boundary of established fields. The latest technologies are starting to revolve around the links between many disciplines in a seamless, transdisciplinary way rather than a multi- or inter-disciplinary one. Simultaneously, the distinctions between various disciplines are becoming hazier (among many other things); it is becoming harder to describe the differences between mechanical, electrical, and computer engineering. It is impossible to tell what engineering and the fundamental sciences, even the social sciences, for that matter, are these days. Simply put, we are seeing a phenomenon of disciplines coming together, which calls for a careful examination of the future of engineering education. "We're going to be in trouble in 30 years if we don't change how we teach" [5].

Enterprises require graduates who can handle the changes to compete in an increasingly global and competitive market; this is a problem that the engineers of the twenty-first century must meet. In this new age, engineering graduates need to be able to go from technology to solutions and from operations to solutions. Universities must adopt cross-disciplinary research and teaching to tackle challenges posed by the fourth industrial revolution's megatrends, particularly in South Korea, which is currently at a "stall point" between expansion and stagnation. "Concerning all megatrends, university reform is urgent," he said [6].

1.1 Definitions

Since sector 5.0 is still in its early stages of development, several scholars and practitioners have offered different definitions.Definition 1. Industry 5.0 reestablished the workforce in the factory via the blending of intelligent systems with workflows. Here, humans and robots collaborate to increase productive processes using human intellect and creativity. [7]. Definition 2. Industry 5.0 forces information scientists, practitioners, and philosophers to consider human issues when integrating technology into industrial systems [8]. Definition 3. Industry 5.0 is an advancing evolution from Industry 4.0 and represents the next generation of global direction. By dividing the hyperconnected automated network for production and manufacturing, it strives to provide orthogonal safe exits [9].

1.2 Industrial Revolutions

It is acceptable to differentiate between industrial revolutions in terms of changes influencing production [10]. The technical breakthrough that led to a sharp rise in output is the foundation for distinguishing between a revolution and a development in production process organization. New possibilities brought forth by subsequent technical advancements historically served as the foundation for differentiating between revolutions.

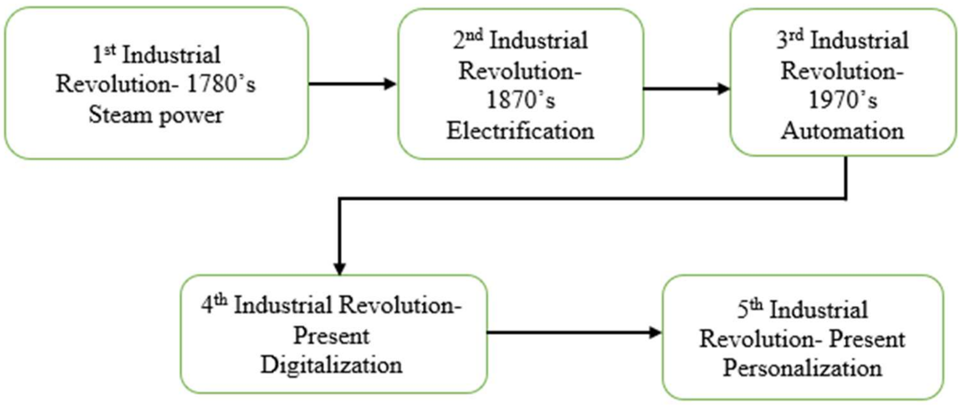

Fig. 1. The effects of the Industrial Revolution

Electrification transfers energy across great distances, separating its source from its destination. Alternatively, it is done via automation, which has allowed robots to do repetitive tasks without human supervision and adapt to changing circumstances. Lastly, Industry 4.0's foundational digitization ensures that information technology will analyze production data in real-time to achieve optimization [11]. On the contrary, personalization is the foundation for differentiating the next revolution, Industry 5.0. The present revolutions will be described in depth among the others.

1.3 What is Industry 5.0?

Industry 5.0 envisions a human-centric, sustainable, and resilient manufacturing system. Flexible and adaptable technology improves system agility and resilience within Industry 5.0. Additionally, it leads to sustainability, respecting the world's constraints, and empowering individuals with talent and diversity. Industry 5.0 was introduced a few years ago, and funding organizations and scholars from numerous universities have discussed it extensively. The for and against transitioning from Industry 4.0 to 5.0 are examined [12], considering industrial uses, supporting technology, and challenges. Industry 5.0 is already affecting business. The European Commission suggested in 2021 that European industry reorient itself in society and promote this idea to define its future success. Industry 5.0 values the well-being of industry technicians above all else and acknowledges that the sector may attain societal targets that surpass job creation and expansion [13]. Since Industry 4.0 prioritizes digitalization and AI-driven technology above social justice and sustainability, Industry 5.0 aims to boost manufacturing flexibility and efficiency. Consequently, Industry 5.0 presents a unique perspective and highlights the significance of innovation and research in helping the manufacturing industry assist people on Earth.

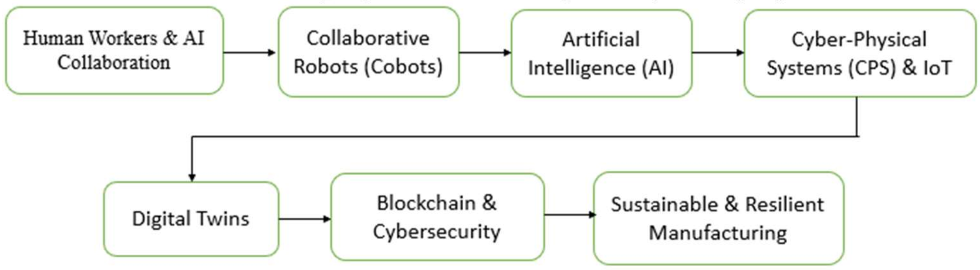

Fig. 2. The flow chart shows Industrial 5.0

1.4 Contributions of this paper

Many publications describe Industry 4.0's enabling technology, applications, and challenges [14]. Discusses Industry 4.0-enabling technologies and the efforts of many governments and regions to create them. In this, the authors outline Operator 4's enabling technologies as the integrated standard for cyber-physical systems and industrial processes. An earlier investigation examined the Industrial Internet's enabling technology, applications, and issues [15]. Another technology that might transform manufacturing is virtual reality. The authors recently released a detailed overview of IoT virtual reality-enabling technologies and usage [16]. Although Industry 5.0 is trendy, we are unaware of any review articles. This inspired us to write the first Industry 5.0 review.

Firstly, we provide a range of terms and definitions from the currently accessible literature to offer a better interpretation of Industry 5.0 from several viewpoints.

- Second, we review some new elements of Industry 5.0 and draw comparisons with earlier industrial assessments. As a result, characteristics of hyper customization, predictive maintenance, cyber-physical cognitive systems, and intelligent additive manufacturing are thoroughly discussed. We also examine the innovative products, services, and standards development teams attributed to Industry 5.0.
- Thirdly, we debate the utmost encouraging implementation we think Industry 5.0 will bring about and make feasible, such as cloud manufacturing, intelligent healthcare, SCM, manufacturing production, and many more.
- In our fourth section, we discuss the pivotal innovations of Industry 5.0, together with edge computing, blockchain, big data analytics (data mining), IoE, collaborative robots, and the soon-to-be 6G systems.

2 Key Advancements in Industry 5.0

The improved version connected with the fourth industrial revolution is known as Industry 5.0. In this part, we discuss Industry 5.0's new features.

2.1 Predictive maintenance

Accurate upkeep of the entire economy is heading toward globalization, which presents several obstacles for various businesses. Predictive maintenance (PdM), an impending transition, is being forced onto the production units. Manufacturers began using cutting-edge inventions, such as Cyber-physical systems (CPS) techniques and highly developed analytical methodologies, which increase production and efficiency [17]. Predictive maintenance is the best option for industrial operations looking to increase transparency. This transition requires sophisticated prediction tools that systematically convert data into information and pinpoint uncertainty so that workers may make well-informed decisions. IoT deployment offers the elemental basis for predictive maintenance using smart devices and sensor networks. Predictive maintenance aims to enhance the self-awareness of equipment and systems. Predictive maintenance relies heavily on clever computational agents equipped with intelligent software to support predictive modeling. Instead of carrying out regular and planned maintenance once an issue arises, PdM assists in undertaking maintenance activities to prevent problems in Industry 5.0 [9].

2.2 Smart additive manufacturing (SAM)

Sustainable manufacturing is the most extensively adopted cost-effective technique for today's manufacturing sectors, enabling businesses to achieve development goals, reduce pollution, and use resources sensibly [18]. Additive manufacturing is a sustainable industrial production method that builds lighter, more durable products layer by layer. Modern industrial and research businesses concentrate on smart manufacturing product rollout. Popular innovative empowering technologies have boosted smart manufacturing growth. These technologies include CPS, AI, IoT, big data,5G, and manufacturing. Smart manufacturing boosts profitability, productivity, and sustainability. In the past decade, SAM has grown into a potential innovative manufacturing approach [19]. Industry 5.0 uses AM, or 3D printing, to make product production more ecologically friendly. In Industry 4.0, additive manufacturing added product functionality to make customers happy. It simplifies transparency, interoperability, automation, and relevant insights. SAM describes how to build a component by adding layers of materials. SAM may reduce material and resource use, enabling pollution-free production. Energy conservation is possible. To maximize Industry 5.0's benefits, integrated automation has paired with SAM to reduce product delivery times and streamline supply chain management.

2.3 Hyper customization

Industry 4.0 connected machines, created innovative supply chains, promoted intelligent products, and separated labor from automation. Industry 5.0 employs hyper customization to address the growing desire for personalization, whereas Industry 4.0 cannot. Hyper customization employs real-time data and cutting-edge technologies like ML, computer vision, AI, and cognitive systems to personalize each user's information, goods, and services. Intelligent robots and humans enable corporations to mass-personalize things. Additional staff members get functional material variants to customize the product depending on customer choice to achieve this. Industry 5.0 wants to make mass products with the utmost affordability and finest accuracy, whereas Industry 4.0 prioritizes large-scale production with minimum waste and high efficiency. Humans, robots, and cognitive systems help companies organize production to meet client needs and market changes. The shift towards an agile supply chain and manufacturing system serves as the foundation for hyper-personalization. Also needed are customer preferences, production team, and human contact. Hyper customization's applicability depends on how cost-effective the resulting goods are [20].

3 Practices in Industry 5.0

The possible utilization of Industry 5.0 is covered in this section.

3.1 Cloud manufacturing

The advent of advanced technologies such as cloud and Edge computing, IoT, virtualization, and cloud manufacturing has the potential to transform the manufacturing industry significantly. International representatives will collaborate in cloud manufacturing to manage a structured and gainful process. In this way, manufacturers may locate their operations nearer to the source of raw materials and in nations where production costs are lower. Here, the cloud manages the plant's machinery control and manufacturing life cycle activities, including scheduling and service composition. IoT sensors may collect and assess data on the functioning condition of manufacturing processes in the cloud. Li et al. [21] and Tao et al. [22] demonstrated the adoption of cloud manufacturing as a client-centric manufacturing approach. Xu et al. [23] discuss the pay-as-you-go business model as a potential business model in cloud manufacturing. Industry 5.0 cloud manufacturing systems will accommodate increasingly complicated engineering, production, and logistical demands. AI/ML technologies and 5G-based telecommunication networks have significantly enhanced cloud manufacturing systems.

3.2 Intelligent healthcare

Today, doctors utilize machine learning algorithms to diagnose patients. Increased diagnosis accuracy saves patients time and money. This is inadequate, given the circumstances. Technology that monitors blood pressure, sugar levels, and other factors and provides tailored treatment with doctors is needed now. This is possible with Industry 5.0. Intelligent wearables like smartwatches and sensing elements can continually save patient health information in the cloud. ML algorithms may identify the patients' illnesses. Smart devices can communicate. These gadgets can alert doctors of the patient's state if required. Cobots, talking robots, may help surgeons. The indicated are just a few means Industry 5.0 may change healthcare. Implant and other customized device manufacture is easier with this revolution. Industry 5.0 allows robots to do medical visits. This lets doctors concentrate on higher-level tasks.

With medical instruction, robots can perform complex operations correctly. Technology like DT lets doctors provide personalized medications. This chapter discusses Industry 5.0's research on healthcare applications. Orthopedics need patient-specific implants, which Industry 5.0 might help produce, according to Haleen et al. [24]. They also discuss how Industry 5.0 might improve surgical accuracy. The authors discuss the potential of Industry 5.0 in medical education. Javaid et al. [26] studied Industry 5.0 technologies that may help COVID-19 patient treatment. They said cobots and other Industry 5.0 technologies might enable non-invasive patient care. They also recommended approaches for physicians to use intelligent robots to diagnose and treat COVID-19 patients, reducing front-line healthcare exposure.

3.3 Supply chain management (SCM)

Disruptive technologies like cobots, 5G, ML, IoT, EC, and others that enable Industry 5.0 and human intelligence and creativity may help organizations meet demand and produce customized items faster. This allows SCM systems to include mass-tailored production, a key view of Industry 5.0. SCM warehouses, inventory locations, assets, and logistics may be digitized utilizing digital twin (DT). DT includes transportation lines, distribution centers, suppliers, contract manufacturers, factories, and clients. DT assists with SCM design, construction, commissioning, and operations. DT mimics real-time supply chain management systems to comprehend IoT sensor data. These data may help ML, big data, etc., predict SCM difficulties. Thus, enterprises should proactively avoid losses and errors throughout SCM phases and help customers get customized items quickly. DT aids businesses in analyzing the intricate balance between capacity, service, inventory, and overall landed cost. Through numerous SCM phases, DT may boost profits and minimize operating expenditures for industries. Some recent DT SCM solutions are discussed in the following section. Defraeye et al. [25] modeled mango fruit thermal dynamics during refrigerated transit using DT. Scientists developed a unique sensing technology to test the fruit pulp temperature model that duplicates fruit. The authors demonstrated that DT could effectively reveal the thermo-behavior of fruits throughout the entire supply chain. The supply chain management (SCM) organization may use these data to locate temperature-dependent fruit losses during shipping and take corrective action. To reduce losses and build a green supply chain, DT may improve logistics and refrigeration.

3.4 Manufacturing/production

It is commonly recognized that robotics and automation transformed industrial paradigms worldwide throughout earlier technological revolutions. Robots have performed dangerous, repetitive, or physically taxing industrial activities, such as lifting and unloading oversized items from warehouses and welding and painting in car plants. Industry 5.0 strives to integrate conceptual computing with human intelligence and capability in cooperative operations as workroom equipment becomes more intelligent and networked. The fifth industrial revolution may influence societal standards and how we see industry and manufacturing. Nahavandi et al. [7] discussed the fifth iteration's realization stage's economic and productivity consequences. This study includes production tracking, machine cognition, multiscale simulation and dynamic modeling, and networked sensor data interoperability, which enable Industry 5.0. In the fifth iteration, cobots are proposed to analyze human intention before task analysis, meaning they should be able to identify when cooperating humans require help. According to the poll, many company leaders still follow Business 4.0, while Industry 5.0 is far off. Human-machine interaction was chosen to create jobs from the fifth generation. Javaid and Haleem discovered essential production indicators for Industry 5.0 [26]. This study examines manufacturing difficulties related to 17 key Fifth Industrial Revolution features. Industry 5.0 in the industrial sector will increase consumer satisfaction and company value, according to the authors. Cary Sherburne suggests textiles utilize sector 5.0. Their qualitative research lays the groundwork for leveraging sector 5.0 characteristics in fiber computing solutions that will reach textile companies soon. The author states that by using industry 5.0 it will result in sustainable growth [48].

4 Related Work

Shlomo and Volotka [27] examined the effects of industrialization on society. They believed that every stage of industrialization had influenced the history of humanity. Examining historical records and data is the best way to predict the future.

Kasinathan et al. [28] proposed a study on developing technologies to utilize emerging technologies to achieve the Sustainable Development Goals (SDGs). The influence of disruptive revolution on product innovation, healthcare betterment, a case study of a global epidemic, and promotional strategies that include the environment, smart cities, and urban areas are inspected in this learning.

Adel [29] intended to look at potential Industry 5.0 implementations. The discussion centered on the definition of Industry 5.0 and the advanced technology required for this industrial revolution. They, too, spoke about the tenders that Industry 5.0 makes possible, together with cloud manufacturing, health maintenance, production lines, and industrial output. Their research incorporates big data, IoT, robotic systems, blockchain, and 6G technologies. They also looked at issues and concerns raised by establishments among robotic arrangements and manufacturing line workers to better grasp those issues and obstacles.

Fatima et al. [30] comprehensively explained how Industry 4.0 and digital transformation projects utilize the IoT. Novelists discuss IoT usage in various productions, development, and challenges while also summarizing technical publications for crucial obstacles, combination analysis, and predictions.

Mourtzis et al. [31] recommend a critical evaluation of the literature to support the idea of industrial 5.0, which promotes industrial harmony, cooperation, changing requirements, and community realism. Their study significantly facilitated the transition from Industry 4.0 to Society 5.0.

Saniuk et al. [32] acknowledged the social and economic expectations on the progress of the 4^{th} industrial revolution within the context of Industry 4.0's resilience, change, and sustainable development. The study results are presented in this article based on surveys of Polish society members and carefully examined literature. Important societal expectations about the future paths of the idea of Industry 4.0 were identified as a result of the study. Three areas of development were prioritized in formulating suggestions for industrial growth: human-centric, feasible, and flexible. The investigation findings would then permit the formation of an investment plan and legislative measures to encourage manufacturing development based on human-centric mechanization of the economic system.

5 Enabling Technologies

The technologies and other supporting technologies are paired with creativity and intellectual skills to benefit firms, increase efficiency, and deliver customized items quickly. Industry 5.0 is a superior production paradigm that emphasizes human-machine interaction through the implementation of these technologies. Intelligent technologies work with humans to maximize productivity and simplify automation for individuals and small businesses. This section briefly describes Industry 5.0 enabling technologies.

5.1 Edge computing (EC)

With the speedy progress of cloud services and the IoT, edge computing (EC) permits data processing at the network edge. EC may be helpful in Industry 5.0 and Industry 4.0. EC meets latency, battery life, response speed, data secrecy, and privacy criteria [27]. EC minimizes transmission overhead and boosts remote application productivity. For crucial

Industry 5.0 events, EC may process information without transmitting it to the public cloud. EC helps with data processing, compute offloading, request delivery, and transfer. The edge must be appropriately built to provide safety and confidentiality with all network functions [33]. EC offers real-time connectivity for Industrial 5.0 applications, including self-directed automobiles and distant medical monitoring. Thanks to EC, Industry 5.0 can access and share industrial sector data using standard hardware and software. Industries try to collect data from local servers to accomplish enormous numbers. All these devices generate a lot of raw data, making analysis challenging. Industry 5.0 may screen statistics since EC minimizes data directed to a central server. EC in Industry 5.0 facilitates early machine problem detection through preventative analytics, enabling individuals to make informed decisions.

5.2 Digital twins

An electronic duplicate of a real-world structure or article is known as a digital twin (DT). Digital twins (DT) enable the digital representation of real-world infrastructure such as wind farms, productions, aircraft engines, structures, and smart cities [34]. Although the concept of digital transformation has been around since 2002, it is only with the expansion of the Internet of Things that it has just begun to get momentum. The IoT condensed the price of DT, making it accessible and cheap for many trades [35]. Connected devices in the actual world may transmit data to their virtual equivalents via the Internet of Things, allowing for more accurate modeling. By creating a real-time digital model of items and systems using DT, we can study, track, and prevent issues before they happen. Rapid AI, ML, and significant data analytics developments have helped DT improve system performance while cutting maintenance expenses.

5.3 Cobots collaborative robots

Recent advances in computerization and automation make human-robot collaboration increasingly important. Due to rapid advances in artificial intelligence (AI) and innovative technology, all computing-powered devices have gotten more advanced, ushering in cobots. Collaborative robots make human abilities easier to automate for individuals and small businesses since they work with humans. Professors Edward Colgate invented cobots in 1996 [36]. The first cobots were passive and motorless, although they possessed brakes. Traditional industrial robots that can work with humans without enclosures are distinct from cobots. Since they have sensors and can sense unexpected impact, cobots may halt on their individual when human workers spot inappropriate items in their route. Compared to industrial robots, this makes them relatively safe [37].

5.4 Internet of Everything

IoE means interconnected information, methods, people, and objects. The IoE presents numerous opportunities that could potentially aid Industry 5.0 applications [38]. Industry 5.0's IoE innovations may provide new features, better user experiences, and commercial and national benefits. In Industry 5.0, IoE data is used to tailor experiences and boost consumer loyalty. Industry 5.0's IoE adoption may reduce operating costs by eliminating communication channel bottlenecks and delays. Industry 5.0 struggles with logistics and supply chain efficiency. The use of IoE can significantly reduce supply chain waste and improve production efficiency. Due to the IoE's fast expansion, humans communicate information wirelessly, usually via wireless sensors. Patient sensors are used in the Internet of Medical Things. These sensors detect patient irregularities and notify doctors and nurses. The information collected will guide physicians' actions.

5.5 Big data analytics

Recently, big data has drawn commercial and academic attention. It has plenty of information from many sources. Big Data technologies, including data fusion, AI, ML, and social networking, are widely utilized in various data analysis techniques. Big Data analytics commonly impacts Industry 5.0. Understanding customer behavior with Big Data Analytics may assist enterprises in improving product pricing, manufacturing efficiency, and overhead costs in Industry 5.0 [39]. Understanding human behavior, social relationships, and user behavior is complex. Based on customer satisfaction, big data analytics may help Facebook, Twitter, and LinkedIn market items and increase income. Industry 5.0 ecosystem resolution involves data infusion and intelligent production automation. Industry 5.0 apps may hire big data analytics to foresee important events and make real-time choices to increase competitiveness. Big Data Analytics allows zero-fail mass customization utilizing current resources in Industry 5.0. Real-time analytical data exchanged with data centers and innovative technology lets businesses generate and manage vast amounts of data. Industry 5.0 must enhance processes, which often need production cycle data. We eliminate non-essentials by using Big Data Analytics to increase forecasting and delve into new opportunities.

5.6 Blockchain

Blockchain technology may boost Industry 5.0 value. One of Industry 5.0's biggest challenges is centralized control of many heterogeneous networked devices. Distributed trust facilitated by blockchain may create decentralized management systems [40]. Blockchains protect peer-to-peer interactions and create an immutable ledger [41]. Industry 5.0 implementations are enhancing operational transparency and big event responsibility through the use of immutable ledgers, which are crucial for the dispute resolution mechanism [42]. Smart contracts might automate Industry 5.0 service-oriented tasks and security enforcement services like authentication. A distributed and segmented blockchain method may improve transaction and data security [43]. Blockchain may simplify data gathering and transfer. Industry 5.0 may employ blockchain to build digital IDs for individuals and corporations to enhance subscription management. Every industrial operation requiring civic network access control and stakeholder authentication needs it. Suitable connections, belongings, goods, and services may be added to these digital identities. Blockchain technology allows original work cataloging, archiving, and IP rights registration [44]. Smart contracts and blockchains may automate contracting by automating multi-party agreements.

5.7 6G and beyond

Industry 5.0 may profit from 6G's value-added services. Building radio infrastructure with millions of sensors, gear, and robots is hard. Smart infrastructure's rapid development and integration with 4G and 5G networks will meet unmet bandwidth needs. Industry 5.0 may have low latency, high-quality services, extensive IoT infrastructure, and AI after 6G [45]. Industry 5.0 applications on 6G networks benefit from AI-powered mobile EC, spectrum management, and smart mobility [46]. In Industry 5.0, 6G networks struggle with mobility and handover. Large, multi-layer, dynamic 6G networks will have frequent handovers [47]. Mobility predictions and connection handovers may be optimized using AI. Industry 5.0

applications face a significant challenge in terms of high data rates [48]. Quantum and free-space optical communication has the potential to address 6G issues. Industry 5.0 energy management is problematic owing to the increased number of connected smart devices and energy use. 6G networks enhance energy management with better energy harvesting and usage.

6 Conclusion

Revolutions and technological breakthroughs are happening at an ever-increasing rate; thus, businesses need to have clear growth goals and a mindset for change. The firm has to be prepared for the future and equipped to handle unforeseen circumstances. We conducted a survey-based lesson on the auxiliary technologies and their potential applications in Industry 5.0 tasks. To begin this effort, we defined a few terms related to Industry 5.0 from the lookouts of the academic and industry communities. We discussed potential Industry 5.0 applications, including cloud manufacturing and SCM. We then discussed the key technologies that enable Industry 5.0.

To sum up, Industry 5.0 is a concept that continuously balances workspace and machine and human efficiency. Industry 5.0 is expected to enhance industrial manufacturing and customer satisfaction through the implementation of new applications and auxiliary technologies. We also discussed certain obstacles and unresolved glitches that need to be addressed soon to implement Industry 5.0 fully. These included workforce training, human-robot cohabitation in an industrial context, privacy, scalability, and security.

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