INDUSTRY 5.0: ANALYSIS, APPLICATIONS AND PROGNOSIS

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ABSTRACT
Industries are the major forces behind economic growth. However, the industries and its workers are directly impacted by changes brought about by the technological revolutions.
Industry 4.0, is here for the last one decade and is still growing in attention and acceptance throughout the world. It integrates the real world with its "virtual twins." Industry 4.0 has revamped the production systems by improving the operational effectiveness and developed novel business models, products and services. Industry 4.0 focuses on increasing the productivity and sustainability of industrial processes and emphasizes on both, viz digitalization and digitization of systems which may further lead to improvements. Many countries have invested significantly to harness its benefits and a substantial amount of research has been carried out into creating and implementing Industry 4.0 technologies.

A new industrial paradigm called Industry 5.0 emerged very shortly after Industry 4.0, sparking discussions regarding the new paradigm's purpose and justifications for its use. Industry 4.0 is less focused on humans and more on machines and systems. As a result, various countries have initiated to design and develop the human-centric aspect of technologies, systems, and services, known as Industry 5.0. It is a shift in paradigm that will place less emphasis on technology and will impact and influence societal transformation. Industry 4.0 is driven by technology whereas Industry 5.0 is driven by value. Human welfare, sustainability and resilience will be the area of focus of Industry 5.0. It is conceived as an expansion of Industry 4.0 with a social and environmental component. The coexistence of two Industrial Revolutions viz 4.0 and 5.0, raises issues, which calls for debates and explanations.

This paper aims to discuss Industry 5.0, analyze its potential opportunities and applications, explain the various technologies enabling it, focus on inherent challenges in its implementation, and discuss its prospects.
Keywords: Industrial Revolution, Industry 5.0, COBOTS, Human Machine Collaboration

Organization of the paper
Section 1 provides a brief discussion on the Industrial Revolution and its progression from Industry 1.0 to Industry 5.0. It defines Industry 5.0 from the viewpoint of different authors and highlights its attributes. Section 2 defines and introduces Industry 5.0 with a detailed literature review on its concepts and ideas. Applications of Industry 5.0 and its social implications are highlighted in section 3. Section 4 focuses on the technologies that are the driving force behind Industry 5.0. In section 5, challenges of Industry 5.0 are discussed. The conclusion is provided by section 6, which summarizes the entire research paper and highlights the future course toward the implementation of Industry 5.0.

Introduction
Disruptive technical innovations have historically been the main drivers of industrial revolutions, altering manufacturing paradigms and the methods for meeting consumer demand.

By enabling machines to produce items using newly devised methods and techniques, Industry 1.0, which occurred in the eighteenth century, significantly altered the industrial systems. The switch from manual to steam- or water-powered industrial equipment characterized the 1st Industrial Revolution. Due to the arrival of

Industry 1.0, the economy transitioned from being dominated by handicrafts to one dominated by machinery, influencing sectors including mining, textile, agriculture, glass, and others. (Longo, Padovano, & Umbrella, 2020).

Between the years 1871 to 1914, the industrial sector observed a successive transition in the form of Industry 2.0, which promoted the rapid circulation of innovative ideas. The Second Industrial Revolution was made possible by electricity, which renovated industries into cutting-edge manufacturing, which resulted in greater productivity and substantial fiscal expansion.

Automation of computers and memory programmed controls in the 1970s of the 20th centuries, the digital revolution i.e., Industry 3.0 began. With the advent of communication technologies and field-level computers, production became increasingly automated. The usage of integrated circuit chips, digital logic, mass production, and related technologies—including digital cellular phones, computers, and internet—are the focal points of this particular phase (Pathak, Kothari, Vinoba, & Tyagi, 2021), (He, Ma, Zeadally, Kumar, & Liang, 2017).

The digital revolution has enabled the conversion of technology to digital form. The blend of physical assets and cutting-edge technologies like AI, IoT, robots, 3D printing, cloud computing etc. is known as "Industry 4.0". Organizations that have implemented Industry 4.0 are adaptable and ready to make data-driven decisions (Leone, 2020).

As companies adopted Industry 4.0, it became apparent that it relied more on digitalization and AI enabled technologies to increase the production flexibility and efficiency than it did on the fundamental ideas of sustainability and social justice. This resulted in the 5th IR and thus Industry 5.0 emerged. The idea of Industry 5.0 is put up as an addition to the current Industry 4.0 to achieve technological and industrial goals without compromising socioeconomic and environmental performance.

Literature review characterizing Industry 5.0:

Industry 4.0 primarily focuses on a shift in the industrial paradigm that is driven by technology; society and human factors have received less emphasis. The potential job loss and lack of job security brought by the rising use of autonomous systems is one worry associated with this industrial revolution (Doyle-Kent & Kopacek, 2019). The technological transition must therefore be made sustainably and in accordance with the goals of socioeconomic development (Nahavandi, 2019). Considerations to people and the society throughout the industrial changeover gave rise to “Industry 5.0”, which (Rada, 2015) introduced in 2015 to advance the idea of "Industrial Upcycling." Studies are done to differentiate the goals, objectives, and techniques of “Industry 5.0” as a novel phase of the engineering transition. Keidanren, the most significant business organization in Japan, proposed "Society 5.0" to track the effects of this paradigm shift. This concept aims to protect societal, environmental, and economic benefits while exploiting technological breakthroughs (Fummi, 2021). It tries to reverse the revolutionary solutions for the betterment of human life. Over the past few years, Industry 5.0 has focused a great deal of attention on human-robot collaboration with a focus on the human’s role in the digital revolution. Additionally, several studies examine the role of humans in logistics from a variety of angles, including ethical, technical, Sociological, operational, safety, etc.; this is the primary research field for this new IR.

In fact, there are several speculations regarding the "Age of Augmentation," in which the human and the machine can coexist and collaborate, prior to this formal launch of Industry 5.0. (Longo, Padovano & Umbrella, 2020). (Letto, Ancillai, Sabatini, Carayannis, & Gregori, 2022), believes that "Industry 5.0" brought sturdy, ecologically friendly, and human-centric ideas to the industrial revolution. It will transform production processes worldwide by eliminating repetitive tasks from human labor.

“Industry 5.0” technologies are being adopted more widely, but this will not reduce the value of people; on the contrary, it will encourage the dual amalgamation of human and machine intelligence in a cooperative setting (Bednar & Welch, 2020). The borders between the real world and the virtual one will be removed by industry 5.0., even though it is unclear exactly what it will do or how it will affect business (Scanlon, 2018). Collaboration between people and intelligent systems like robots will increase in “Industry 5.0”, especially in the industrial sector. In this level, all boring, repetitive jobs are taken over by machines, freeing up humans to focus on their creative side while taking on more responsibility and supervising systems to improve overall production quality. This will be made possible by the desire for more complex human-machine interfaces through stronger integration, increased robot automation, and the power and ingenuity of human minds (Shelzer, 2017).

Applications of Industry 5.0:
Industry 5.0 offers advantages to the employees and workers as well as the society. Deployment of this sector promotes resource-use technologies that are sustainable and ethical. It encourages human decision-making and benefits from enabling technology that helps transform many different sectors. Some of the major applications are:

Smart Hospitals:
One of the major applications of "Industry 5.0" is a real-time, smart hospital. It is vital for enhancing medical practitioners' quality of life. By using smart healthcare technology, doctors may examine infected individuals remotely and provide useful information for better medication, for instance as in the COVID-19 pandemic (Longo, Padovano, & Umbrella, 2020), (Wu, Nguyen, Chorppath, & Fitzek, 2017). Machine learning (ML) applications make use of genetic data, natural language processing, and medical imaging. Disease detection noted that Industry 5.0 makes it possible to produce the customized smart implant correctly in accordance with changing client demands focus (Nahavandi, 2019 & Lutz, Memmert, Raabe, Dornberger, & Donath, 2020), Artificial intelligence technologies are being used in the medical industry to measure a variety of things, including levels of glucose. The standard procedure for implant creation has evolved, and it can now be used to update a variety of tools and medical equipment.

Manufacturing Industry:
"Industry 5.0" is a brand-new manufacturing model that focuses on human-machine communication. The main objective of "Industry 5.0" is to maximize human creativity and more accurate machinery's ability to work together. It creates procedures for resource recycling and reuse to make the production sustainable (Aslam, Aimin, Li, & Rehman, 2020 & Alhassan, Zhang, Shen, & Xu, 2020). Manufacturing needs to have less negative environmental effects, too. Utilizing additive manufacturing, personalization must be increased to reduce waste and maximize resource efficiency. By releasing human workers of boring tasks, Industry 5.0 is revolutionizing industrial processes everywhere.

According to (Ghobakhloo, Fathi, Iranmanesh, Maroufkhani, & Morales, 2021) manufacturers can place production facilities in areas that have low manufacturing costs and close to sources of inexpensive raw materials. Control of plant machinery and activities related to the production lifecycle will be handled by cloud manufacturing. The manufacturing sector tries to boost production efficiency, value addition, and market share by incorporating service components into the production process. The virtualized platform, which is used cost-effectively, manages the manufacturing services. Distributed and networked production resources are used in cloud manufacturing (Deepa, 2009)

Supply Chain Management:
Supply chain 5.0, according to (Nguyen, Ebrahim, & Stylianou, 2018), emphasizes the value of cooperation between humans and COBOTS and other intelligent robots. Customers' demands for Industry 5.0 hyper-customization demands a blend of human creativity and machine proficiency. Robots are needed for supply chain management in high manufacture quantities of standard procedures, adding this to every product. This presents a hurdle since robots need the right instructions (Wang , Wang, Li, Alazab, & Song, 2020).

According to (Babamiri, Bahari, & Salimi , 2019), customizing and personalizing products don't always involve human interaction. However, it also ensures the flawless operation of the supply chain from beginning to end, including the selection of raw materials after taking into account the specific customization and modification requirements of each customer.

The goal of Industry 5.0 is to integrate intelligent and automated digital ecosystems with human interaction. The integration of human factors in such a process allows for the customization of end-user experiences and the development of effective operations (Adel, 2022).

Industry 5.0 enabling technologies:
Technologies like Digital Twins, Edge Computing, big data analytics, Internet of Everything, 6G, cobots, and blockchain can all help businesses increase efficiency and provide customized products more quickly. Thanks to these technologies that has made "Industry 5.0" a better production paradigm that places a focus on the interactions between people and technology. Human skills are now easier to automate and are more productive than before for all people and small businesses since smart robots are designed to work alongside people.

Edge Computing:
The increasing growth of the "Internet of Things (IoT)" and the accessibility of several cloud services have led to a novel term defined as "Edge Computing", that permits processing of data at the network edge. Both the transitions to "Industry 4.0" and the transition to "Industry 5.0" benefit greatly from Edge Computing. Edge computing can satisfy demands for battery life limits, latency charges, system performance demands, data protection, and privacy (Shi, Cao, Zhang, & Xu, 2016) & Pham, 2020). Edge computing lowers the cost of communication and guarantees that programmers work well even in distant areas. Some helpful jobs that Edge Computing can perform include processing of data, cache coherency, computation offload, transferring, and delivering requests. Future Industrial 5.0 applications like autonomous vehicles, UAVs, and distant patient monitoring are supported by real-time communications from Edge Computing (Abdirad, Krishnan, & Gupta, 2021). In Industry 5.0, Edge Computing permits preemptive analytics, allowing for the early discovery of failure of machines and its mitigation through the empowerment of human decision-making.

Digital Twins:
"A Digital Twin is a digital reproduction of a physical system or object". Digital representations of real-world items, like factories, wind farms, buildings, jet engines, and even larger systems like smart cities, are possible using Digital Twins (Lu, 2020). Even though the idea of Digital Twin was first introduced in 2002, it has recently gained attention with the evolution of IoT. IoT reduced the cost of Digital Twin, making it available and economical for a variety of businesses. Through IoT devices, the information from physical objects is sent to their digital equivalent for simulation. The digital mapping of real-time objects and systems utilizing Digital Twins allows for the assessment, monitoring, and avoidance of problems before they manifest in the real world. Digital Twins has been able to reduce maintenance costs and improve system performance because to the rapid growth of ML, AI and big data analytics.

The Digital Twins aids Industry 5.0 in overcoming technological obstacles by identifying them faster, pinpointing components that may be improved or modified depending on performance, making predictions more precisely, anticipating errors in future, and eliminating substantial financial losses.

Cobots:
Recent developments in robotics and automation have made working with robots increasingly important. All devices with computing capabilities have undoubtedly become smarter, and as the result of the incredibly rapid advancements in artificial intelligence and smart technology, a new field of study called as cobots has emerged. "Collaborative robots are those designed to work with humans", and because of this, automation of human skills is now easier than ever for both individuals and small businesses. Professors Edward Colgate & Professor Michael Peshkin of Northwestern University created the first cobots in the year 1996.

The original generation of cobots were passive in their operations. They also lacked engines. The modern cobots differ from older engineering robots as they can collaborate with people outside a controlled environment. When it comes to workplace safety, Cobots typically outperform regular industrial robots because they typically have sensors integrated in them and are extremely receptive to the detection of unexpected impact (Simoes, Soares, & Barros, 2020). Industry 5.0 has a lot to gain from cobots. Robots can do their intended duty while working in tandem with people, enabling clients to offer highly personalized and customized things swiftly and precisely.

Internet of Everything (IoE):
The Internet of Everything (IoE) connects people, processes, information, and things. (Bhattacharya, 2020). It significantly contributes to the creation of new possibilities for the "Industry 5.0" applications (Higginbotham, 2020)

In Industry 5.0, IoE has enabled the ability to bring forth new features, a better user experience, and anticipated advantages for businesses. The role of the IoE in Industry 5.0 has facilitated the improved consumer satisfaction and loyalty. It helps to reduce congestion from communication lines and lowers latency, and thus offers Industry 5.0, the chance to cut operating costs. Efficiency in the supply chain and logistics is a difficult problem for Industry 5.0 but, IoE will streamline production procedures and cut down on supply chain waste. Since the IoE has advanced so much, humans now share information wirelessly, primarily with the aid of wireless sensors.

Big Data Analytics:
Big data is currently a very hot topic for debate in academia and industry (Cheng, Chen, Sun, Zhang, & Tao, 2018; Javaid M. , Haleem, Singh, & Suman , 2021). It represents a vast and varied collection of data gathered from many sources. In Big Data Analytics, technologies like artificial intelligence, machine learning, social media, data mining, data fusion, etc. are widely used (Hamalainen & Inkinen, 2019). Industry 5.0 often places a

lot of emphasis on big data analytics. Some companies in "Industry 5.0" can employ big data analytics to precisely know the customer, which can be used to optimize the product prices, focus on improving manufacturing efficiency, to help reduce overhead costs etc. Some businesses, including Facebook, Twitter, and LinkedIn, employ big data analytics to promote the products and boost sales based on customer happiness. The resolution of the Industry 5.0 ecosystem depends on the integration of data, highly tailored manufacturing procedures, and intelligent technologies in the production process. Big data analytics is utilized for making judgments in real-time to increase industry competitive edge. With resources that seamlessly connect, Big Data Analytics helps Industry 5.0's mass customization operations (Majeed, 2021).

Blockchain:
Industry 5.0 benefits substantially from Blockchain technology. Centralized control of a sizable number of heterogeneously linked devices is a big difficulty in Industry 5.0. Secure peer-to-peer interactions provided by blockchain provide a permanent record-keeping system (Virjyasitavat, Da, Bi & Sapsomboon, 2018). An absolute ledger also supports operational responsibility and transparency for major events in "Industry 5.0" applications. Industry 5.0 can employ the smart contracts to ensure security through authentication and automated service-oriented operations. Blockchain-based segmented and distributed approaches can also provide a better level of data and transaction security (Mohamed & Jaroodi, 2019).

Blockchain can be used to effectively manage subscribers in Industry 5.0 by generating digital identities for diverse individuals and organizations. It is necessary for access control and stakeholder identification in any business operations carried out over a public network (Mohamed & Jaroodi, 2019). These advancements can be utilized to manage various types of assets, including real estate, products, and services. Additionally, Blockchain-based cloud manufacturing promotes machine-level communication and data sharing (Zhang, 2019).

6G & beyond:
6G will eventually be able to provide Industry 5.0 with significant value-added services. Building radio infrastructure is difficult when there is a highly dense network of thousands or hundreds of thousands of sensors, hardware components, and robots. It won't be able to handle the fast-expanding bandwidth needs with current networks due to the rapid rise of smart infrastructure and projected applications (such 4G and 5G networks). The industry 5.0 revolution will be fueled by the deployment of 6G and beyond, which will enable the delivery of reduced latency, support for high-quality services, vast IoT infrastructure, and integrated AI capabilities (Chowdhury, Shajalal, Ahmed, & Jang, 2020).

Other Technologies:
Additionally, the advancement of Industry 5.0 and the applications that go along with it depends on other modern technologies, for e.g. Extended Reality (XR), Private Mobile Network (PMN), Network Slicing (NS) etc.

Many virtualized networks can be enabled on top of a single real network infrastructure using the NS idea. It disperses physical network resources over various virtualized networks. The requirements of diverse vertical applications can be accommodated by customizing and tuning each virtualized network.

XR is another cutting-edge technology with a wide range of applications. Interactions between people and machines can be improved through XR by combining the real and virtual worlds. The word "XR" refers to a broad range of technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR). XR technology will significantly enable various Industry 5.0 applications. XR technology is now used in applications connected to Industry 5.0 includes remote help, assembly line monitoring, remote healthcare, health education and training, indoor and localized outdoor navigation, driver and pilot training, maintenance, and drone/UAV pilot education and training. (Zikky, Fathoni, & Firdaus, 2018).

Challenges in the adoption Industry 5.0:
Due to the possible benefits of "Industry 5.0", it is a buzzword nowadays, but it also presents unique challenges for organizations.

- Modern technology adoption necessitates more effort and time from human labor.
- To work with intelligent robots, people must acquire competency-based skills. The human workers must have experience of working with robots and intelligent machines. Learning the essential technical abilities in addition to the skills and experience presents a challenge for human workers.
- Collaborative robots, artificial intelligence, real-time data, the Internet of Things, customized factories are all necessary components of industry 5.0 that calls for huge investments.

- Additional expenditures associated with training human workers for new jobs are to be incurred to boost output and efficiency.
- Since it's crucial to build trust in ecosystems, security presents a barrier for Industry 5.0. To defend against potential quantum computing applications when deploying Internet of Things nodes, the industry uses authentication on a large scale. Automation poses hazards to the company, thus it is necessary to have reliable security for it. Since “Industry 5.0” applications are severely reliant on ICT systems, stringent security standards are essential to guard against security risks.
- In smart manufacturing systems, self-organized systems require higher autonomy and social abilities. The shift from the present environment to industry 5.0 is difficult since the current systems lack independence, like integrated decision making.
- This trend further polarizes the workforce as middle-skill employment shrinks and the workforce is split into two groups: highly skilled and experienced labor and lesser paid and unqualified workers. The divide between competent and incompetent persons in society may increase as a result of this.
- Due to higher levels of automation in the sectors, the current firm strategies and business models must be modified to meet the specifications of industry 5.0. As a result of mass personalization, business strategy will emphasize customer-centric operations more. Customer subjectivity changes over time, making it difficult to often change corporate strategies and organizational frameworks.
- Drawing regulatory frameworks in industry 5.0 is difficult because of the use of automation. For instance, who will be responsible for failures and to what extent?
- Social diversity in terms of acceptance, measurement of the creation of social and environmental value, complexity of the system and transdisciplinary research disciplines, agile, outcome-focused innovation policy that is ecosystem-oriented are some more inherent challenges in Industry 5.0.

Conclusion:

This industrial revolution involves utilizing human-machine interface to expedite and simplify tasks. The personalization concept is advanced by Industry 5.0. Industry 5.0 is employed more effectively to create a virtual environment, cutting-edge computers, and IT to satisfy the highly individualized demand. Artificial Intelligence, Big data, Cloud Computing, Internet of things (IoT), COBOTS, innovation, and creativity are all optimally integrated in Industry 5.0. It is estimated to generate higher-value jobs with more room for innovation and creative thinking. It contributes to raising labor productivity and giving customers more customization options. On the other hand, skill development for the workforce is a massive task because of highly automated industrial systems. Industry 5.0 offers a larger threat to cyber security in critical industrial automation and production lines because of its growing connectivity and adoption of standard communications protocols. Industry 5.0 may give computers more autonomy, but humans will always have the last say in ethically significant decisions. Generally, industry 5.0 is projected to revolutionize the manufacturing systems and processes by facilitating increased human-robot collaboration to deliver customized products to clients. Through programmers like Make in India, Skill India, and Start-up India, India hopes to become a manufacturing hub. With the help of these programmers and initiatives, Industry 5.0 has a great deal of potential to make India the leader in intelligent and cooperative production systems.

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