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A Historical and Scientific Overview of Industry 5.0

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ABSTRACT:
Industry 4.0 has been around for the last 10 years, improving businesses but also having its limits. Now, Industry 5.0 has arrived to address those shortcomings. Smart factories are boosting productivity, but Industry 4.0 has its restrictions. This paper talks about the opportunities, challenges, and future research for Industry 5.0. Industry 5.0 is changing the way we think about technology by focusing more on collaboration between humans and machines, rather than just on technology itself. It aims to improve customer satisfaction with personalized products. In today's business world, Industry 5.0 is crucial for gaining a competitive edge and boosting economic growth for factories. The paper examines the potential uses of Industry 5.0, discussing its definition and the advanced technologies needed for this revolution. It also covers applications in areas like healthcare, supply chains, manufacturing, and cloud manufacturing. The technologies explored include big data analytics, the Internet of Things, collaborative robots, block chain, digital twins, and future 6G systems. The paper also looks at the challenges companies face in managing the interaction between robots and humans on assembly lines.

Keywords: Industry 5.0, artificial intelligence, smart manufacturing, big data, internet of things, cobots

I. INTRODUCTION:

Throughout history, people have recognized the power of technology to drive progress, starting with the First Industrial Revolution in the late 18th century. This revolution began with using basic resources like water, steam, and fossil fuels to create mechanical power. In the 1870s, during the Second Industrial Revolution (Industry 2.0), manufacturers started using electrical energy and assembly lines for mass production. The Third Industrial Revolution (Industry 3.0) in the 1970s introduced automation in production through electronics and Information Technology (IT).[1]

In the Fourth Industrial Revolution (Industry 4.0), technologies like the Internet of Things (IoT), cloud computing, and Artificial Intelligence (AI) help create Smart Cyber-Physical Systems (CPS), which connect the virtual and physical worlds in real-time. Industry 4.0 reflects the rapid technological, industrial, and social changes of recent years. With the rise of key technologies like big data analytics, AI, and digital twins, it improves production efficiency and enhances the quality of products and services.[2]

1. History of Industrial Revolution

During the industrial revolution, which occurred in Europe and America between the eighteenth and nineteenth centuries, primarily agrarian rural communities transitioned to urban and industrial settings. Manufacturing was frequently done in private homes using hand tools or simple machinery prior to the industrial revolution, which started in Britain in the late 18th century.[3] For certain uses, industrialisation entailed a shift to factories, machines, and mass manufacturing. The industrial revolution, which enhanced banking, transportation, and communication networks, was largely driven by the growth of the steam engine and the steel and textile industries. In addition to improving some people's quality of life an increasing the quantity and variety of manufactured commodities, industrialisation has also produced jobs.[3]

1. Industry 1.0

The Industrial Revolution began in the 1800s with Industry 1.0, which introduced water- and steam-powered machines to help workers. These innovations boosted production and allowed businesses to grow, improving living standards for some people. The textile industry, in particular, underwent a major transformation. Machines powered by coal and steam made manufacturing more efficient and expanded the use of machinery

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in production. These advancements made work faster, easier, and more productive.[4]

Fig 1: Industry 1.0

2. Industry 2.0

Between the 1760s and 1840s, new technological systems were introduced, including electrical technology, which became a major power source by the early 20th century. Electricity was easier to use than water and steam, making it more popular. It also allowed businesses to power individual machines more efficiently, leading to better production processes.[5]

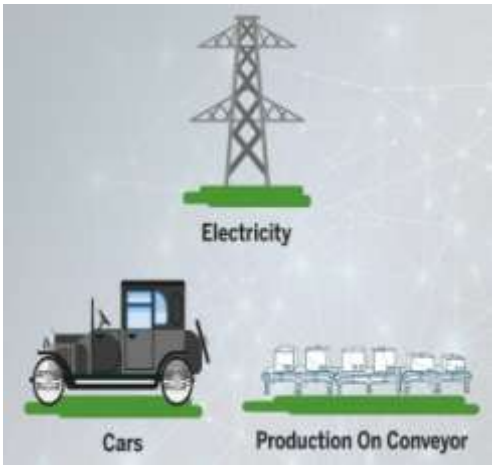

Fig 2: Industry 2.0

3. Industry 3.0

The third industrial revolution, around the 1970s, focused on increasing automation in production using electronics and IT. Industry 3.0 marked the beginning of computer use in manufacturing. With the rise of connectivity, internet access, and renewable energy, automation advanced significantly. Automated systems, like Programmable Logic Controllers (PLCs), were introduced to reduce the need for human labor. However, human input and involvement were still necessary.[6]

Fig 3: Industry 3.0

4. Industry 4.0

Industry 4.0, also known as the Fourth Industrial Revolution, focuses on the integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data, and robotics into manufacturing processes. It aims to create smart factories where machines, devices, and systems are interconnected, enabling real-time

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data sharing and decision-making. Key features include automation, predictive maintenance, efficient resource use, and improved productivity. Industry 4.0 revolutionizes production by combining physical and digital technologies, making manufacturing more intelligent, flexible, and efficient.[7]

Fig 4: 11 Pillars of Industry 4.0

A. Principles of Industry 4.0

1. Interoperability

Interoperability involves using the Internet of Things (IoT) and the Internet of People (IoP) to enable communication between objects, machines, and people.

2. Virtualization

The use of virtualisation CPSs should develop and simulate a virtual model of the real environment. CPSs need to keep an eye on the items that are currently present in the immediate surroundings.

3. Decentralization

The CPSs should be able to work autonomously in order to create a more flexible production environment that allows for personalised product development and problem-solving. When there are conflicting goals or failures, the issue might be elevated to a higher level. Still, the requirement for a quality assurance remains part of the entire process following the complete deployment of such technology.

4. Real-Time Capability

The requirements of being a smart factory include the ability to gather, store, or analyse real-time data and make decisions based on new inventions. This is true not just for market analysis but also for internal processes. This also makes it possible for the production to be improved and flexible.

5. Service-Orientation

A focus on service Production must be customer-focused. People and smart objects/tools need to be able to connect directly via the Internet of Services in order to create customer-focused goods. For this reason, the Internet of Services becomes essential

6. Adaptability

A focus on service Production must be customer-focused. People and smart objects/tools need to be able to connect directly via the Internet of Services in order to create customer-focused goods. For this reason, the Internet of Services becomes essential. [7]

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B. Challenges of Industry 4.0

1. Safety

The largest obstacle to implementing Industry 4.0 approaches is the risk to IT security. This internet connectivity allows for the possibility of security lapses and data spills. Another significant issue that needs to be taken into account is cyber theft. The issue could result in financial losses for the producers as well as harm to their reputation. For this reason, security analysis is critical.

2. Funds

This kind of transformation requires a lot of funding for new technologies. The CEO is the only person who can decide to make such a move. Similarly, the risk needs to be carefully considered in that situation. Such a shift will require a large number of discoveries, which may cause small companies to become unknown and hence lose their market position.

3. Employment

It may be necessary for the workers to acquire newly developed or different skills. The employment rate may rise as a result, but workers will suffer since a large portion of the workforce will become unknown. Some employees may find it difficult to keep up with the industry's constant work. More different educational programs must be started as a remedy for this, but the older workforce cannot be accepted. It can take some time to resolve this.

4. Privacy

In addition to consumers, producers have problems about privacy. Because of networked manufacturing, producers must stock and analyse data. Consumers may consider this a risk to their privacy. This also applies to customers. It will be difficult for businesses that are still waiting to disclose their data to be on the route to a more transparent the atmosphere. Another significant issue is showing the gap between companies and their customers.[7]

C. Problem in the adoption of Industry 4.0

- When Industry 4.0 is completely adopted, many workers who lack education will lose their jobs.
- People with higher levels of education are essential to implement Industry 4.0 because it requires highly qualified industrial engineers.
- Issues with IT security: Industry 4.0 depends heavily on IT, thus maintaining strong IT security is important.
- Fear of IT bugs: Many crucial and private procedures could become changed due to the possibility of unexpected, short IT breakdowns.
- The machine-to-machine connection still has stability issues; it cannot be stable enough or dependable enough overall to meet Industry 4.0 criteria.
- In the near future, it will happen that cyber-human technology's powerful detecting capabilities will remove the possibility of errors, increasing the probability that several businesses will accept Industry 4.0. Nowadays, a large number of participants think that cyber technologies are more dependable than human controlled systems that produce precise results.[7]

II. INDUSTRY 5.0

Definition:

The term "Industry 5.0" describes the use of robots and intelligent machinery by humans. It is about robots using modern technology like big data analytics that help people work more quickly.[8]

Principles of Industry 5.0

a. Interoperability: When computers, tools, and machines work together in a system.

b. Clarity of information: The ability of computer systems having sensors to produce a virtual representation of actual devices and machinery.

c. Technical support: Artificial intelligence and computer systems to help employees with work, strategy, and decision-making.

d. Fragmented decision: Computer systems are capable of doing a number of different tasks independently.[9]

1. Internet of Things:

The Internet of Things (IoT) is about connecting smart devices to each other so they can work together to complete tasks. One big advantage of IoT is that it makes complicated systems easier. It's like an ecosystem where these devices share information and create a smart environment to reach their objectives.[10]

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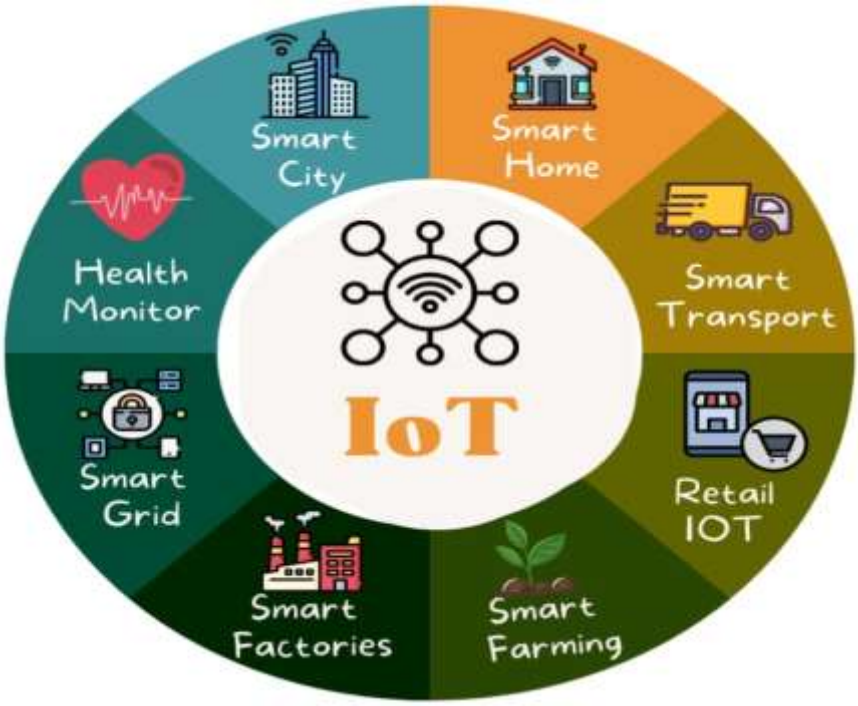

Fig 5: Internet of Things

2. Factory of Things:

The Factory of Things (FoT) applies the Internet of Things (IoT) to production systems. It focuses on connecting machines, visualizing data, and analysing manufacturing processes. The idea of a smart factory represents the future, aiming to create more efficient and automated manufacturing systems.[11]

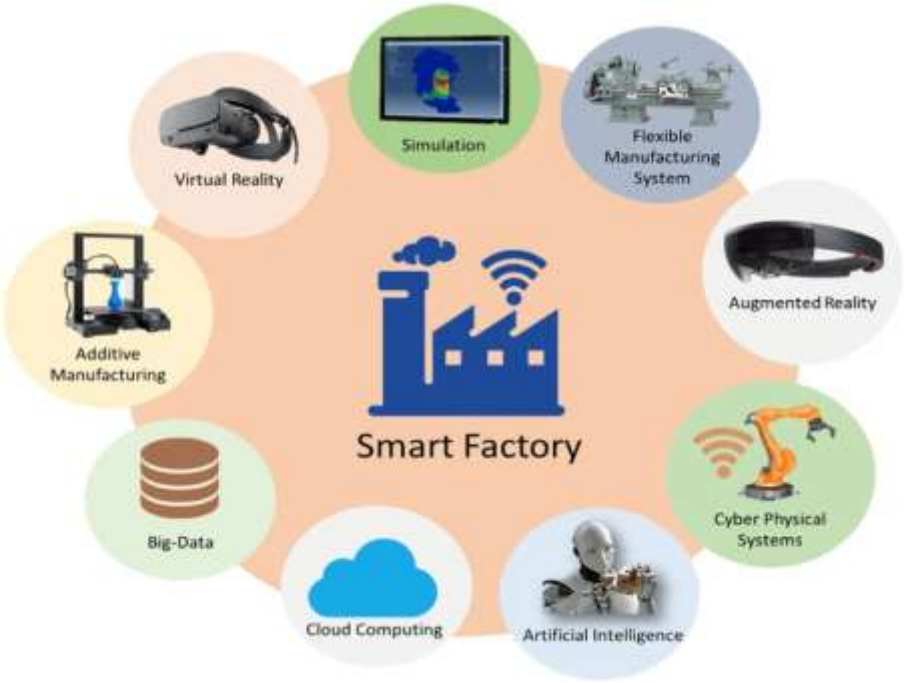

Fig 6: factory of Things

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3. Big Data:

Big Data The term "big data" describes records that are larger than what can be captured, stored, managed, and analysed by conventional database software tools. The premise behind big data is that you can learn more and make more accurate predictions the more you know about a subject. Big data has transformed industries including safety, agriculture, and health by combining with machine learning and predictive modelling, which is leading the way in artificial intelligence.[12]

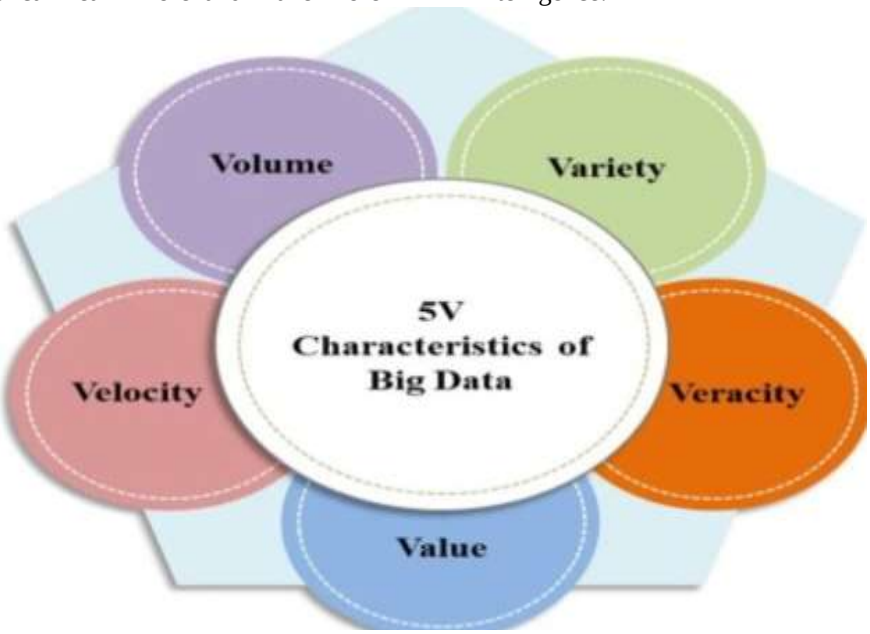

Fig 7: 5V Characteristics of Big Data

4. 6R Principle:

The 6R Principle The 6Rs can be used in practically every stage of life and business. It is not intended for a single market, such as Waste Prevention.

*** Recognize**

Recognize the source from which, most of the waste comes. Recognize the main waste sources and detail their reasons to be resolved.

*** Rethink**

Rethink the methods to solve the waste generation and disposal of waste. Rethink all the possibilities of waste disposal whether it is reasonable or not.

*** Realize**

Realize the waste source and methods to dispose of them in safely. The environmental factors should be considered at this time. And we should all the safe practices to reduce and destroy the waste safely

***Reduce**

This process aims to save resources, materials, and energy during product design and transportation. It also encourages using simpler materials. From the start, the goal is to design products that are easy to take apart, even though this might cost more at first. Another aim is to use fewer parts in products and cut down on waste by following Lean methods. Reducing pollution is also a key focus, with strategies to address it. The process works to improve product quality to reduce returns and recalls. It also focuses on efficient transportation and better use of resources in supply chains, both when delivering and when handling returns.

*** Reuse**

To reduce the utilization of new raw materials products can be reused. One of the goals of this procedure is to extend the component and product life. To develop a secondary market is so another option to reuse products or parts. Still to make these goals practical is not easy, since the complexity, risk of failure and complication in product warranty will increase.

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*** Recycle**

This process requires using recyclable materials. The goal is to find ways to add more recyclable parts to new products. However, some recycled materials can harm the environment, which goes against the idea of reuse. There might also be quality problems, and it can be hard to keep the same functionality with recycled parts. One of the biggest challenges is convincing customers to accept products made from recycled materials.[13]

Fig 8: 6R Principle

3. Aspects of Industry 5.0

However, with the advent of Industry 5.0, this threat will be eliminated. There will be a growing need for original, specific, and customised products in a society where everyone wants to fully express themselves. Human innovation, rather than robot-controlled mass manufacturing, will be the great in such a time.[14]

a. When man meets machine

We are in the initial phase of Industry 5.0, which suggests more interaction with modern technology and people, but we will have to wait and see if there is a robot revolution. For example, IOT devices placed across manufacturing lines can gather critical production data, and robots can finish automated manufacturing process. The Business Process Management (BPM) software monitors the data to identify mistakes and, in the case of an error, initiates a procedure that notifies the appropriate staff, allowing them to take action and make decisions.

With the use of artificial intelligence and smart data analysis, the BPM software may offer the person multiple choices to help them choose the optimal course of action. As you Even if technology controls these procedures in this case, people are still at the core of the decision-making process. Methods, decisions, and business outcomes are all improved in this interactive setting.

Industry 5.0 promises businesses better flexibility, more prepared to react to change, and a more responsive workplace by transforming and automating their core business operations while maintaining human input in essential decision-making. However, it cannot guarantee an effective plan. Businesses can achieve higher productivity, flexibility, and profitability in this cooperative setting by implementing digital transformation. [15]

b. Labour Landscape

The Workplace The future of employment will be significantly impacted by unexpected changes. Many of the major transformational forces that are currently influencing global sectors have a big impact on jobs, from expanding skill gaps to creating essential positions to shifting occupations and achieving the highest labour productivity. Some jobs that haven't been created yet will be produced in the future. A new degree of interaction between employees and technology will be necessary for the fundamental shift in the workplace.

Changing the work environment can positively impact the future. For instance, reducing

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the gender gap in various sectors can allow automation to decrease workloads and encourage women to contribute their skills more effectively to the formal economy. A more flexible workforce is reshaping the labour market, which can help balance gender representation in workplaces. Greater flexibility will also influence self-employment and quotas in the future.

The shift towards freelance work is supported by demographic changes, particularly the influence of a forward-thinking generation in today's and tomorrow's workforce. Their expectations are driving changes in how work is structured. As new jobs emerge, the ongoing industrial revolution will replace out dated roles, increasing the demand for education systems to equip employees with the necessary skills.[16]

c. Effect on society

The changes brought by the upcoming industrial revolution will have a big impact on society and cannot be overlooked. Technologies like artificial intelligence, self-driving cars, genetic engineering, mobile devices, and brain-related advancements are transforming how we live. These innovations, along with trends like rapid urban growth, population changes, and a highly connected world, will reshape society. This new industrial revolution will introduce technologies that merge biology, physical systems, and digital systems.

The next industrial revolution will bring big changes to industries and society that cannot be avoided. However, it offers amazing benefits, such as a better quality of life, improved safety, and enhanced human skills. This report explores what it means to be human during these changes and who will succeed in this new era.[16]

d. Agility takes the lead

In order to meet the demands of the Fifth Industrial Revolution's financial, inventive, and social powers, top multinational corporations are adopting an agile management culture. In order to identify the social, creative, and economic competencies driving the Fifth Industrial Revolution, top multinational corporations are embracing an active management culture.

Using agile principles while adhering to the "smarter, not harder" premise For better results, people, technology, strategy, and external changes can all be adjusted. The idea of agility in business is not new, in fact. Organisations have linked agile approaches to implementing and integrating complex technical problems for the past 20 years or so. Agile strategies originated in the software development sector.[17]

4. Industry 5.0 features

Certain characteristics of Industry 5.0 enhance its benefits and effectiveness when used in the real world.

1. Equilibrium in environment structure

Restoring balance in environmental systems is possible through a secure exit strategy from Industry 4.0's development ecosystem, especially if interconnected digital systems fail. These exits should be designed to be independent and unaffected by automated systems. For example, using paper records for critical medical information instead of relying solely on electronic systems can provide a "digital detox."

The main idea of this "orthogonal exit" is that disruptions in hyper-connected systems won't impact these separate, secure pathways. Since the Internet of Things (IoT) is a global and interconnected network, maintaining these independent exits serves as a safety measure for system components in case of failures.[18]

2. The rebound to human

A return to human touch is important as markets evolve and customers increasingly demand personalized products. Buyers are willing to pay more for items that reflect human care and craftsmanship, like handmade watches or designer products. These types of goods can only be created with human involvement, driven by consumer demand, which shapes manufacturing needs. Personalization gives a sense of luxury and uniqueness, so customers prefer human designers for something special. Industry 5.0 focuses more on individualization than mass industrialization.

Returning to earlier traditions, if someone wants to give a personalized gift, like a wooden item, they need to invest time and effort to make it unique and special for the recipient. While robots are excellent at producing standard items in large quantities, adding that "special touch" to each item is where they need human guidance. This highlights the importance of bringing the human touch back into production processes.[19]

4. Industry 4.0 vs 5.0

An innovation ends once it is fully adopted across the entire industry. As technology advances quickly, new revolutions may follow within the next decade or more. While the first three industrial revolutions took decades, the

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current revolution only lasts as long as it takes for the industry to fully implement the changes. Given the speed of these advancements, it's likely that a fifth revolution will come after the fourth. No matter how quickly or slowly some industries adopt Industry 4.0 systems; these standards will shape the future of production. As more sectors develop, some industries will grow rapidly thanks to technologies like IoT devices, cybernetic systems, and artificial intelligence. In the near future, humans and factory robots will work together on various production tasks and share the workload.[20]

	Industry 4.0	Industry 5.0
Objective	• Smart manufacturing • System optimization.	• Environmental stewardship, • Human-Centricity
Systemic Approaches	• Real-time data monitoring, • Integrated chain that follows through end of life-cycle phases.	• Socio-centric technological decisions, • 6R methodology and logistics efficiency design principles.
Human Factors	• Human Reliability, • Human-computer interaction	• Employee safety and management, • Learning/training for employees.
Enabling Technologies and Concepts	• Internet of Things, • Cyber Security, • Automation	• Internet Of Things, • Cyber Security, • Human-machine-interaction,
Environmental Implications	• Systems are economic, • Increased material consumption, • Increased energy usage	• Waste prevention and recycling, • Renewable Energy sources, • Smart and energy-autonomous sensors

5. Application of Industry 5.0

a. Smart hospital

Industry 5.0 aims to develop smart hospitals with real-time features. This technology allows for remote monitoring in healthcare, making doctors' work easier and more efficient.[21] During the COVID-19 pandemic, smart healthcare systems help doctors concentrate on treating infected patients while providing accurate data for improved treatment options.[22]

b. Manufacturing industry

Industry 5.0 introduces a new way of manufacturing that emphasizes collaboration between humans and machines. It combines the precision of advanced machinery with human creativity. To promote sustainability, it focuses on processes that reuse and recycle resources efficiently.[23, 24]

c. Cloud computing

Cloud computing provides services like databases, software, analytics, networks, and more. It enables efficient innovation and cost-effective solutions. By using the internet, data is stored and managed on remote servers, allowing users to access it online. It offers on-demand services, ranging from applications to storage and processing power.[25]

d. Collaborative robots

Industry 5.0 brings a human element back into development and production by combining human skills with the precision and strength of robots.[26] Humans play a key role in critical tasks, allowing better control and customization in production. This approach makes personalized products and specialized skills more accessible. While Industry 4.0 focuses on quality and data consistency, Industry 5.0 emphasizes teamwork

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between skilled people and robots to create tailored products, from smart devices to cars, for consumers. [27]

e. Block chain

Block chain is a decentralized and distributed technology that uses digital ledgers made up of blocks to store transaction data. It serves as a shared ledger for recording transactions and tracking assets within a business network. Block chain helps customers monitor orders, payments, and production. All participants in the network share the ledger; ensuring records are accurate and preventing duplication in the database.[28]

f.6G

6G is the sixth generation of wireless communication technology designed to support cellular networks. It is expected to be more diverse than previous generations and go beyond current mobile applications.[29] 6G will enable advanced uses like virtual and augmented reality (VR/AR), instant communication everywhere, and smarter Internet of Things (IoT) devices. Mobile network operators will likely adopt flexible, decentralized models for 6G, including local licensing, spectrum sharing, infrastructure sharing, and automated management. These advancements will be powered by technologies like edge computing, artificial intelligence, short-packet communication, and block chain. [30]

Fig 9: Application of Industry 5.0

6. Challenges of industry 5.0

- In Industry 5.0, it's easy to ignore the possible challenges. However, identifying and addressing these challenges is essential for its successful implementation in businesses.[31]
- People need to develop strong skills to work with advanced robots. Human workers must learn how to collaborate with smart machines and robot manufacturers. Besides soft skills, gaining technical skills is also a challenge. Tasks like programming industrial robots and adapting to new roles require advanced technical expertise.[32]
- Human workers need more time and effort to adapt to advanced technologies. Industry 5.0 requires the adoption of customized software-driven factories, collaborative robots, artificial intelligence, real-time data, and the Internet of Things.[33,34]
- Advanced technologies require significant investment. For example, UR Cobots are expensive, and training workers for new roles adds extra costs. Companies also face challenges in upgrading their production lines for Industry 5.0.[35]Adopting Industry 5.0 is costly because it involves smart machines and

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highly skilled workers to boost productivity and efficiency.

7. Limitation of industry 5.0

Trust and acceptance of technology are very important. Adapting technology to humans involves training people to use new tools. Some current challenges include security, privacy issues, a shortage of skilled workers, long processes, and high costs. [36] Adopting Industry 5.0 requires following industry laws and regulations to work effectively with smart machines and cobots. The future of Industry 5.0 includes advancements like cognitive computing, better interaction between humans and machines, and quantum computing. [37, 38]

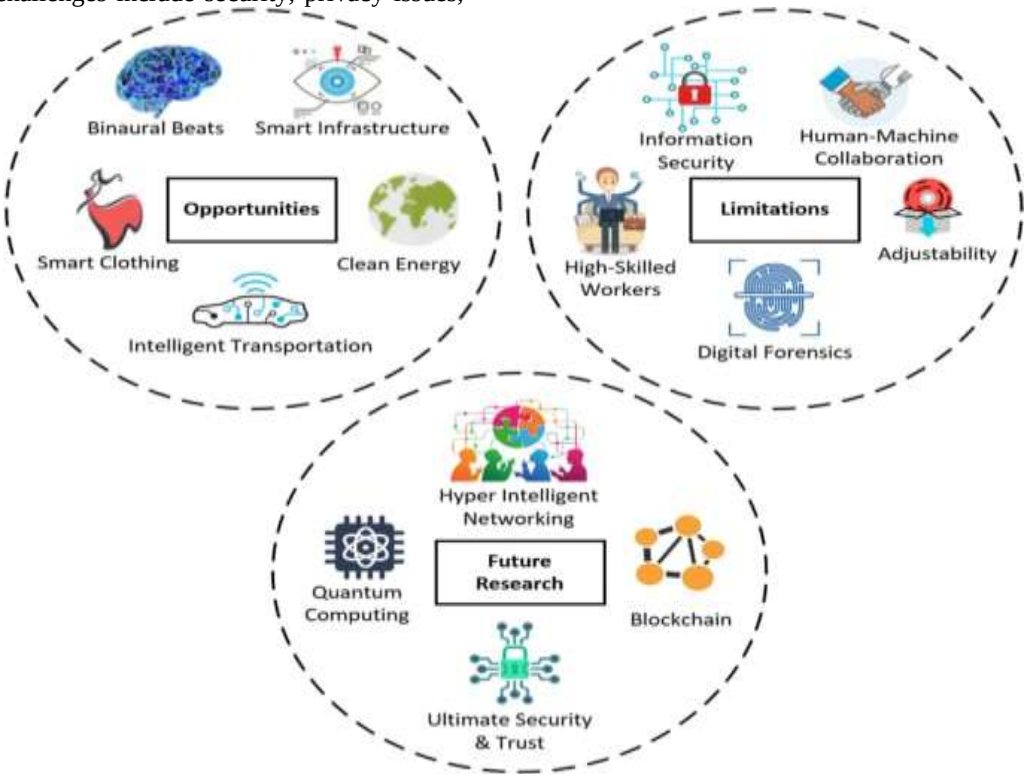

Fig 10: Opportunities, Limitation of Industry 5.0

8. Future directions

Cognitive computing is designed to mimic human thinking processes in a computer model. It uses self-learning algorithms that involve data mining, pattern recognition, natural language, and other methods, allowing computers to work in a way similar to how the human brain functions.[39]

Human and machine interaction involves communication between humans and machines through user interfaces. Natural interfaces, like gestures, allow people to control machines in a simple and intuitive way.[40, 41, 42] This is an important part of the future of Industry 5.0, as it keeps humans at the centre while integrating new technologies. The user interface also helps understand human behaviour and motivations.Quantum computing is a type of computing that uses the special properties of quantum states, like interference and entanglement, to perform calculations. Devices that carry out these calculations are called quantum computers. These computers work by calculating the probability of an object's state before it is measured [43]

III. CONCLUSION

This paper reminds us of an old saying: "Good things in life do not come easy." It discusses the four industrial revolutions that have significantly changed the world over the past four centuries. These revolutions brought many benefits but also posed several challenges.The First Industrial Revolution marked a turning point in world history, affecting almost every aspect of daily life. Here's a summary of the four revolutions: First Industrial Revolution (Mechanical): Used water and steam power to mechanize production. Second Industrial Revolution (Electrical): Introduced electricity for mass production.Third

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Industrial Revolution (Automated): Leveraged electronics and information technology to automate production. Fourth Industrial Revolution (Digitized): Focused on using information and communication technologies, blending the physical, digital, and biological worlds.The fourth revolution, building on the digital advancements of the third, is transforming industries globally with technologies like artificial intelligence, big data, and advanced robotics. This evolution led to the term "Industry 4.0." However, developing countries, unable to fully adopt Industry 4.0, adapted by implementing a hybrid system called Industry 3.5, which combines digital decision-making with existing technologies.The rapid pace of innovation has now given rise to Industry 5.0, also known as the "Personalized Revolution," where individual needs and preferences are prioritized. Looking even further, Industry 6.0, or the "Humanized Revolution," has been proposed. This vision places humans at the centre, striving for a world free from wars, violence, injustice, and poverty—a peaceful and harmonious society. In conclusion, we must strive for a wise and peaceful world where no one goes hungry, and no one lives in fear of war. The ultimate goal of this "Humanized Revolution" should be a planet full of love, free from violence and suffering.

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