Future of Industrial Society 5.0: Human Centered Solutions, Challenges and Potential Research Ambitions

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***Abstract*— This is an enormous mature in the market in regards to the Fifth Modern Unrest. The Business 5.0 spotlights on maintainability, the centrality of man and regard for the climate. It will alter the assembling frameworks overall by keeping monotonous undertakings from human laborers. The wise robots will infiltrate fabricating supply chains as well as the work process of the creation to unmatched levels. Also, organizations are changing their own modern IT framework utilizing simulated intelligence, IoT and huge information.**
This paper provides a conceptual review of enabling technologies driving the future of industry. Without presenting empirical work, simulations, or original modeling, it synthesizes insights from existing literature and highlights key advancements. The study categorizes enabling technologies, examines their industrial applications, and highlights associated benefits and challenges.

Keywords— Industry 5.0, Cooperative Robots, Block chain, Multiclouds, Applications

I. INTRODUCTION

A. Definitions of Industry 5.0

Industry 5.0 is referred to as a revolution in which humans and machines collaborate to enhance the intensity and efficiency of manufacturing production. [3].
In that capacity, despite the fact that Industry 4.0 has not been completely coordinated around the world, numerous business reformer and mechanical leader now looking towards the Fifth Modern Upheaval or Industry 5.0 (I5.0) [5], that will include independent assembling with human knowledge and simulated intelligence as a spine innovation, in and on the circle (see in Figure 1). Furthermore, by 2027, it is anticipated that the virtual entertainment clients' numbers (4.59 billion of every 2022) will essentially increment to 5.85 billion, following the fast development of the Web, and Web related innovations [6]. 2027, it is anticipated that the quantity of virtual entertainment clients (4.59 billion of every 2022) will consistently increment to 5.85 billion, the rapid advancement of the Internet, and Internet-related advancements [6].

As indicated by Michael Rada, organizer and head of the association Business 5.0, the Business 5.0 is the primary modern development drove by an individual and depends on the guideline of 6R of the modern up cycling (reconceived, reevaluate, understand, diminish, reuse and reuse), a specialized philosophy of waste counteraction and strategies productivity intended to assess the way of life, inventive manifestations and produce customized results of excellent [1].
Industry 5.0 is the period of the socially wise plant, wherein cobots talk with individuals. This modern insurgency centers around "Cobots." These Cobots will be an ideal combination of man and machine for better independent direction. [4]

Various regions across the globe have embraced their unique interpretations of Industry 5.0 at differing paces, influenced by factors such as economic policies, technological infrastructure, and industrial priorities. Japan is advancing its Society 5.0 Initiative, which aims to create an AI-driven economy that prioritizes human well-being, seamlessly integrating the Internet of Things (IoT) and robotics into both daily life and industrial applications. Conversely, Germany has implemented its Industry 4.0+ program, which promotes intelligent manufacturing through enhanced automation, particularly focusing on sectors like automotive and electronics to stimulate growth. Meanwhile, China leads in the establishment of mass AI-driven smart factories, leveraging big data analytics and machine learning to optimize production processes. The varying levels of adoption exemplified the diverse strategies employed in the implementation of Industry 5.0, influenced by local regulations, technological investments, and industrial priorities. [20,21]

B. Definitions of Society 5.0

Introduced interestingly at the Fiera di Hamburg in 2011, "Modern 4.0" was formally introduced by Germany and immediately turned into a tag to which each industrialized organization needed to be connected. Based on Industry 4.0, in the 2016 Japan raised the idea "Society 5.0", which depends on an innovation and human-focused society.
According to the government of Japanese, Society 5.0 addresses fifth type of society in our mankind's set of experiences, sequentially following hunting, cultivating, industry, and data.
From 28 to 29 June Japan will have interestingly the G20 culmination in Osaka and will talk about the subject of Society 5.0.

C. *Evolution of Society from 1.0 to 5.0*

As per human sciences, the mankind began as a hunting society (Society 1.0), then, at that point, the horticultural society (Society 2.0), after that is the modern culture (Society 3.0) and the data society (Society 4.0).
The General public 5.0 is portrayed by the Japanese government as the "hyper-genius society" that expects to make a general public in which individuals can settle different social difficulties by consolidating developments like man-made reasoning, robots and enormous information into the general public.

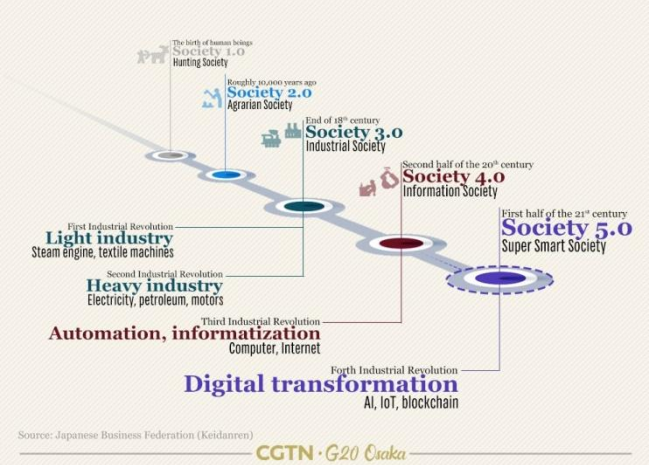

Figure1. Evolution From Society 1.0 to Society 5.0.

"The general public 5.0 is a social state wherein materials and data are profoundly coordinated", has certified Ren Fuji, academician of the Japanese Foundation of Designing, the main Chinese researcher to be chosen for this position, in an article named "The man "It will enter the period of human-PC advantageous interaction." [9]

Numerous studies conducted during this period promote various technological advancements, particularly in the realms of AI-driven robotics, 6G communication, and blockchain-supported supply chain systems. Recent research illustrates how the 6G network can facilitate industrial applications by providing ultra-low latency, enabling real-time interactions between AI systems and human operators.

As Research carried out between 2022 and 2024 emphasizes the importance of ethical AI and the mitigation of bias, ensuring that machine learning algorithms operate in a fair and transparent manner within the context of Industry 5.0. Additionally, the studies explored the potential of blockchain technology to enhance supply chain security against fraudulent activities, improve traceability in international trade, and foster trust among various stakeholders in the supply chain.[18]

Furthermore, emerging research highlights the economic and sustainability implications of transitioning to Industry 5.0, particularly regarding energy efficiency and carbon emissions, while simultaneously boosting productivity in smart manufacturing environments. This indicates that research on Industry 5.0 should be periodically updated to reflect upcoming techno-societal advancements. [19]

II. Application Enabling Technologies of Industry 5.0

A. *Cloud Computing:*

Distributed computing is the arrangement of different administrations by means of the Web, including information stockpiling, servers, data sets, stockpiling and programming.[28] Distributed storage has become progressively famous among individuals who need more extra room and among organizations searching for an effective answer for reinforcement information off-site. There are four principal sorts of distributed computing: confidential mists, public mists, cross breed mists, and multiclouds. There are likewise three principal sorts of distributed (PaaS), and Programming as-a-Administration (SaaS).

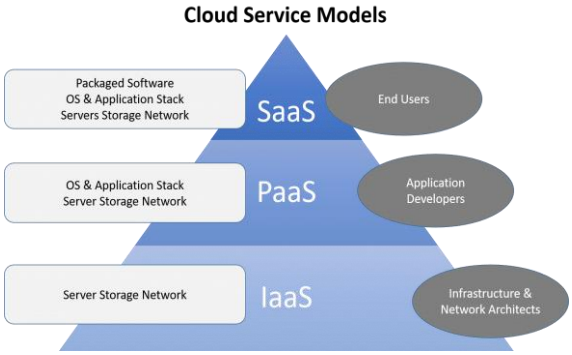

Figure 2. Model of Cloud Services

Research on distributed computing represents the test of fulfilling the necessities of the cutting edge private, public and mixture distributed computing models, as well as the test of permitting all applications and all improvement stages to take advantage of the advantages of distributed computing.[16] The exploration on distributed computing is in the underlying stage. Many existing inquiries have not been completely tended to, while new moves keep on rising up out of modern applications. The absolute most testing research points in distributed computing are consistence with administration levels (SLA), information the board and security in the cloud, information encryption, movement of virtual machines, interoperability, and access control, the administration of energy and the administration of the platform. [2]

B. *Digital Twins:*

A computerized twins is a virtual model intended to mirror an actual item precisely. The item examined, for instance a breeze turbine, is

furnished with different sensors connected with imperative region of its usefulness. These sensors produce information on different parts of the actual item's presentation, like energy creation, temperature, meteorological circumstances and that's just the beginning. This information are then sent to a handling framework and applied to the computerized duplicate.

Be that as it may, the focal thought of involving a computerized pearl as a way to concentrate on an actual item may really have been seen a whole lot sooner. Truth be told, we can properly say that NASA was a trailblazer in the utilization of computerized jewel innovation during its space investigation missions of the 1960s, when each space vehicle in the excursion was precisely recreated in an earthbound rendition utilized with the end goal of Studio and reproduction by NASA work force to support its flight hardware.

C. Cobots(Collaborative Robots):

One of the critical ramifications of cooperative advanced mechanics and of Industry 5.0 is the requirement for human contribution to expand existing emphases. Cooperative robot, so as Industry 5.0, address another time in mechanical technology and underway. Industry 5.0 in addition to Robots is at the core of joining the imagination and craftsmanship of individuals with the productivity and cost of robots [62, 79, and 80]. By zeroing in on individuals, customized items and expert abilities become more accessible.

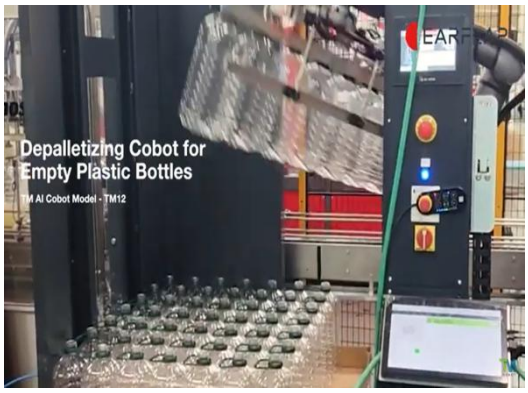

Figure 3. Cooperative Robots using AI

As we find in this image, this depalletizing framework works with a cooperative robot (TM artificial intelligence Cobot) that consequently depalletizes void containers from the beds, and puts them on the transport line to be shipped off the filling line. Simultaneously, the cobot additionally assists with eliminating the help plate and places it in a space assigned for removal. A cobot arrangement like this might not just assist you at any point with diminishing work costs, yet in addition assists with further developing your creation proficiency by working 24/7.

D. Internet of Things:

Interconnected industrial environments are made possible by IoT, making it easier to automate and monitor things in real time. Reduced downtime and improved operational efficiency are among the advantages. Challenges involve cyber security risks and infrastructure costs. [9] The IoT can be very significant in making additional opportunities for the utilizations of Industry 5.0. A portion of the key applications can possibly bring new functionalities, a superior client experience and extra advantages to areas and nations. The job of IoT in Industry 5.0 spotlights on expanding the fulfillment and reliability of clients and the formation of customized encounters utilizing the information produced. [10, 30]

E. Big data analytics:

As per SAS Institute, Software Company. It is an American global engineer of examination programming situated in Cary, North Carolina. SAS creates and showcases a set-up of examination programming, which helps access, make due, dissect and cover information to support navigation. The organization's product is utilized by the greater part of the Fortune 500.

The concept of vast amounts of information has been recognized for a considerable period; most organizations understand that by harnessing the data generated from their various activities (potentially in real-time), they can conduct analyses and derive significant insights. This is particularly evident with the use of advanced technologies such as artificial intelligence. Even in the 1950s, prior to the coining of the term "big data," companies employed database analysis (essentially numerical data examined manually in spreadsheets) to uncover information and identify trends. The primary advantages of big data analytics are speed and efficiency. Just a few years ago, organizations were in the process of gathering data, performing analyses, and revealing insights that could inform future decisions. Today, companies can collect data in real-time and analyze large datasets to make swift and well-informed choices. The ability to operate more quickly and remain agile provides all organizations with a competitive edge that was previously unavailable.

During Pandemic this application played a vital role to Fighting hunger with data

Hunger Free America is an unprejudiced, not-for-profit bunch attempting to execute the strategies and projects expected to end homegrown craving and wipe out the dependence on foundation to battle food frailty. Working with a group of examination volunteers at SAS, the association started breaking down information over the long run from the U.S. Evaluation Department's Family Heartbeat Study, in which respondents report like

clockwork on food uncertainty during the pandemic.

Consolidating that data with information on benefits paid straightforwardly through an assortment of social security net projects - SNAP, school breakfast/lunch, and youngster and grown-up help programs - permitted Craving Free America to investigate the affiliations it expected they would uphold his objective of aiding society. go "past the soup kitchen" and guarantee monetary and food independence for all Americans. The capacities to total, dissect, and picture these a lot of divergent information has permitted Yearning Free America to outwardly uphold its confidence in the significance of the social wellbeing net.

That's what the information showed, after business and wages, the factors with the most grounded relationship to food uncertainty in the US were government sustenance help programs. The connection could appear glaringly evident: more assets and more food equivalent less appetite. In any case, outwardly say what shouldn't need to be said - particularly upheld by information - has possibly huge worth in Appetite Free America's endeavors to show legislators the effect their choices can have on long haul hunger.

F. Block chain:

A block chain is a loud arrangement of record that is divided between members, records all exchanges made by any part, and all members have their own duplicate of the record through replication. In fact every exchange is encased in a block. Block chain improves supply chain traceability and builds trust through secure, decentralized transactions. Despite its advantages, it faces issues of scalability and high energy consumption. Each block likewise contains a hash worth of the past block's header and in this way frames a hash chain or block chain (Figure). Since all blocks are bended, the request for blocks is deterministic; hence, each block can go about as a timestamp of the joined exchanges to take care of the twofold spending issue [11]. Every part keeps a duplicate of the whole block chain, so every part can confirm each exchange.

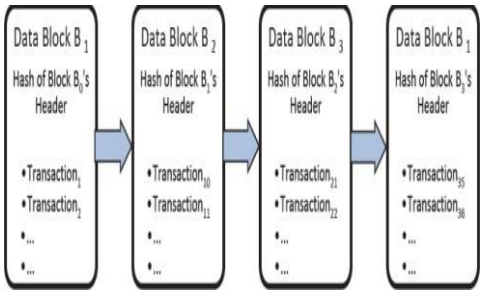

Figure4. Working of Block Chain

As per Harvard Business Review (14), Ianasiti and Lakhani explain how blockchain technology works in practical terms; deepening five basic principles (Table).

Table 1. How Block chain Works (Adopted from the HBR Article "The Truth About blockchain" [7]

The Truth About blockchain		
Serial No.	Block chain Principle	Details
1.	Distributed Database	Each member on the block chain has access to the entire ledger and its complete history. No single member has control over the data, while each has the ability to verify the transactions directly, without an intermediary.
2.	Peer-to-Peer Transmission	Communication occurs directly between members without the need for a central authority (no intermediaries).
3.	Transparency with Pseudonymity	Every transaction is visible to anyone with access to the blockchain. Each user, on a block chain has a unique 30-plus-character alphanumeric address that identifies them. Users can choose to remain unknown or provide proof of their identity to others.
4.	Irreversibility of Records	Once a transaction is entered, the records cannot be altered. Each block contains the hash value of the previous block's header (hence the term "chain").
5.	Computational Logic	Blockchain transactions can be bound to computational logic and in essence be programmed.

G. 6G and beyond

The 6G (sixth generation wireless) is the successor of the cellular technology 5G. The 6G networks will use higher frequencies than all 5G networks and provide substantially higher capacity and much lower latency. One of the goals of Internet 6G is to support communications with a latency of one microsecond. This is 1.000 times faster (or 1/1000 of the latency) than the throughput of one millisecond.

It is predicted that the market of 6G technology will facilitate major improvements in the areas of imaging, presence technology and location awareness. Working in collaboration with artificial intelligence (AI), the computational infrastructure 6G will be able to better identify the place in which processing takes place; This includes decisions on storing, processing and sharing data.

It is important to note that 6G is not yet a working technology. While some vendors are investing in the next generation wireless standard, the sector's specifications for products with 6G network capability are still years away.

a) Advantages of 6G vs. 5G

The remaining 6G will function using signals at the highest end of the radio spectrum. It's too early to estimate the data speed of 6G, but Dr. Mahyar Shirvanimoghaddam, senior lecturer at the University of Sydney, has suggested that it could be possible to achieve a theoretical data transmission speed of 1 terabyte per second per data wirelessly. This estimate if applied and the data transmitted in the short report is limited by distance. LG, a South Korean company, has presented this type of technology based on beam forming adapter in 2021.

b) Working of 6G

It is predicted that wireless 6G detection solutions will selectively use different frequencies to measure absorption and adjust the frequency accordingly. This method is possible because atoms and molecules emit and absorb electromagnetic radiation at a frequency characteristic and the frequency of emission and absorption are the same for each given substance.

6G will have major implications for many governmental and industrial approaches, all public security and all protection of critical resources, as follows:

• threat detection;
• Sanitary monitoring;
• facial characteristics and recognition;
• decisional process in areas such as the application of the law and the social credit system;
• measurements of air quality;
• Gas and toxicity detection;
• Sensory interfaces that seem like real life.

The improvements in these areas will also benefit Smartphone's and other mobile network technologies, as well as emerging technologies such as intelligent cities, autonomous vehicles, virtual reality and augmented reality.

III. CASE STUDIES ON APPLICATIONS OF INDUSTRY 5.0

The next stage of industrial development, known as Industry 5.0, is centered on a human-centric approach that emphasizes sustainability and intelligent automation. Although theoretical potentials show development, any understanding of effect needs to be translated into practical manifestation by applications in actual situations.

These implementations have made it easier for several industries to adopt Industry 5.0 concepts, which have already enhanced worker safety, productivity, and customization adaptation. Large companies like Siemens, Bosch, and Toyota have deployed cobots, which enable a kind of workforce-human-machine interaction, to aid in bridging the gap between human intellect and technical precision. Amazon and DHL, two shipping corporations, both deployed AI-embedded automations to enhance warehouse performance through predictive analytics and robotic support.[12,13,14]

IV. CHALLENGES OF INDUSTRY 5.0

- These production systems are difficult to acquire data of high quality and integrity and it is difficult to accommodate diversified data archives. (Thoben, 2017).
- Industry 5.0 requires huge investments to fully implement all its pillars, which is difficult to adopt for the industry and especially for the SMEs.
- For example, 'Industry 5.0' offers a great potential in the healthcare sector, but requires a high degree of precision and accuracy. Research on this front is still in the nascent phase and requires high investments and infrastructure.
- Due to the increasing levels of automation in sectors, the corporate strategy and the existing business models must be modified and customized to satisfy the requirements of Industry 5.0. Due to mass personalization, the business strategy focuses more on customer-centric operations. The subjectivity of the client changes over time and it is difficult to frequently modify the business strategy and the business model.
- Security is a challenge for Industry 5.0 because it is fundamental to establish security in the ecosystem. The authentication is used in the sector to adapt to the interaction with various devices, to contrast future applications of quantitative calculations to be implemented in the nodes of the IoT. The use of artificial intelligence and

automation in Industry 5.0 represents a threat to the company and therefore it is necessary to provide a reliable security. The applications of Industry 5.0 are focused on ICT systems and therefore carry severe security requirements to prevent challenges to security.

- As reliance on artificial intelligence, the Internet of Things, and cloud computing continues to grow, industrial networks are increasingly vulnerable to cybersecurity threats, data breaches, and manipulations of AI systems. Safeguarding the infrastructure of Industry 5.0 necessitates the integration of blockchain-based authentication, AI-enhanced anomaly detection, and robust encryption protocols.[22]
- Significant investments in artificial intelligence-driven robotics, cybersecurity frameworks, and workforce training are essential to facilitate the transition from Industry 4.0 to Industry 5.0. Nevertheless, the substantial long-term advantages, including enhanced operational efficiency and productivity, decreased operational costs, and increased worker safety, far surpass the initial expenditures. Industry 5.0 offers an ideal equilibrium by prioritizing human-machine collaboration, thereby optimizing technological benefits while ensuring the integration of human roles within industrial ecosystems, as opposed to pursuing total automation.[23]

V. Technical Framework for Integrating Industry 5.0 Technologies

Industry 5.0 can only be realized with an integrated framework that connects different enabling technologies. To enable seamless interactions across cloud computing, AI-based decision-making, IoT devices, and human collaboration, a multi-layered architecture must be created. [29]

IoT sensors compose the first layer, which collects data in real time from supply chains, manufacturing machinery, and human operators. In order to efficiently handle and analyze vast amounts of data, the second layer involves computation via clouds and edges. The third layer of AI algorithms uses machine learning models and predictive analytics to optimize industrial operations.

At the fourth layer, blockchain technology facilitates secure and transparent transactions, thereby improving data integrity and safeguarding against cyber threats. Subsequently, the fifth layer emphasizes human-robot collaboration, which is tailored to meet individual needs, resulting in a personalized, efficient, and adaptable industrial setting. This framework promotes a synergistic approach to Industry 5.0, ensuring enhanced productivity while maintaining human engagement at its centre. [27,17]

Table 2. Comparative Summary Table

Technology	***Applications***	***Benefits***	***Challenges***
Cloud Computing	Business Applications, Data Storage and Backup Applications	Cost savings, scalability, and accessibility	Data security and privacy, cost mgmt.
IOT	Smart factories, automation	Real-time monitoring	Security vulnerability
Big Data Analutics	Business Intelligence and Decision Making	Speed and efficiency	Problems with data quality, Integration complexity and Security concerns.
Block Chain	Supply chain management	Enhanced transparency	Scalability, energy use
5G & Edge	Industrial automation	Low latency, fast data	Deployment, integration

VI. Statistical Validations or Simulation Results for Proposed Concepts

The empirical evidence, statistical validations, and simulation modeling associated with theoretical advancements in Industry 5.0 are essential for establishing credibility and practical relevance within the sector. Integration studies involving AI, IoT, Cobots, and Blockchain can be substantiated through real datasets and industry case studies.

a) Productivity and Efficiency Gains

Empirical research indicates that AI-driven Cobots enhance manufacturing efficiencies by 20-30% compared to conventional automated systems. A report on smart factories published in 2023 highlighted that AI predictive maintenance technologies could reduce machine downtime by 50%, thereby improving operational efficiency and generating cost savings.[24]

b) Blockchain for Cybersecurity and Supply Chain optimization

The implementation of Block chain in Industry 5.0 has significantly contributed to a 40% reduction in fraud and a 30% decrease in supply chain inefficiencies, as evidenced by industry studies conducted between 2022 and 2023. Supply chain

simulations have statistically demonstrated that the introduction of smart contracts can minimize delivery time variance and bolster stakeholder trust.[25]

c) AI Accuracy-Based Decision-Making

Recent studies utilizing machine learning simulation techniques have shown that AI-assisted real-time production scheduling has enhanced one-off scheduling accuracy by 35% compared to traditional module scheduling. Furthermore, the application of neural networks in the specifications and recent implementations for Industry 5.0 logistics has led to a reduction of up to 45% in inventory errors, underscoring AI's potential to optimize industrial processes.

d) Simulated Analysis of Industry 5.0 Deployment

Simulation tools such as MATLAB, Python-based AI models, and digital twins are frequently employed to evaluate Industry 5.0 scenarios prior to their practical application. Digital twins of factories simulate industrial workflows, facilitating real-time adjustments and predictions of potential production line bottlenecks. Studies indicate that companies utilizing digital twins can increase product speed by 20% and reduce inefficiencies.[26]

VII. Future Directions

In 2021, the European Commission released the report titled "Industry 5.0," aimed at ensuring that the advancement and implementation of innovations within the industrial sector significantly contribute to essential priorities such as sustainability, climate neutrality, resilience, and the well-being of individuals and society at large, as well as the robustness of corporate value networks. The realization that industrial production generates wealth while simultaneously causing environmental damage, compromising health and working conditions, and introducing vulnerabilities into supply chains—issues that became particularly apparent during the pandemic—has motivated the Commission to take action. Consequently, this policy emphasizes the need for awareness and the development of strategies in research and innovation, social policy, education, taxation, energy, and industry, with the goal of transforming the industrial landscape in a manner that extends beyond mere technological focus and fosters a positive influence on both the natural and social environments. This is the future direction of Industry 5.0 because it helps to keep the human being at the center of the system and the technologies to integrate it. Also the user interface helps the person to understand the behavior and motivations of the person.

The enterprises must obtain more profits by using fewer resources. The companies will be able to achieve perfection by preparing all ‘Industry 5.0. This industrial revolution focuses on “Cobots”. These robots will constitute a perfect fusion between man and machine for a better decision-making process.

VIII. Conclusion

The change of paradigm set in motion by ‘Industry 5.0’ is inevitable. This has opened up vast commercial opportunities to offer powerful machines with expert qualifications. This approach of the next industrial revolution has brought to promote an environment productive, efficient, sustainable and safe.

Industry 5.0 is not just a fashion, but a new way of understanding production. The fifth industrial revolution will have a huge impact on productive, economic and commercial aspects. Those companies that do not modify their operations according to the requirements of Industry 5.0 will be rendered obsolete.

The study concludes that this chapter has started the work with the definitions of Industry 5.0 and the definitions of Society 5.0 from the point of view of the industrial and academic community. They also discussed applications that help to better understand the characteristics of Industry 5.0, followed by an in-depth look at the enabling technologies. The ways in which AI, IoT, Blockchain, and 5G contribute to advancements in industry are outlined in this review. These technologies are promising, but they have integration and scalability issues. In order to maximize industrial benefits, subsequent research ought to investigate their combined impact.

IX. References

[1] Rada, M. INDUSTRY 5.0 Definition. Available online: https://michael-rada.medium.com/industry-5-0-definition-6a2f9922dc48 (accessed on 21 January 2018).

[2] Aakash Tyagi, 2017, A Review Paper on Cloud Computing, International Journal of Engineering Research & Technology (IJERT) VIMPACT – 2017 (Volume 5 – Issue 23)

[3] Imoize AL, Adedeji O, Tandiya N, Shetty S. 6G enabled smart infrastructure for sustainable society: opportunities, challenges, and research roadmap. *Sensors.* 2021;21(5):1709. doi: 10.3390/s21051709

[4] https://enterprisetalk.com/featured/industry-5-0-the-fifth-industrial-revol (accessed on January 17, 2024)

[5] European Commission; Directorate-General for Research and Innovation; Breque, M.; de Nul, L.; Petridis, A. Industry 5.0: Towards a Sustainable, Human-Centric and Resilient European Industry; Publications Office: Luxembourg, 2021. [CrossRef]

[6] Number of Social Media Users Worldwide from 2018 to 2027. Available online: https://www.statista.com/statistics/278414 /number-of-worldwide-social-network-users/ (accessed on 15 June 2022).

[7] Mourtzis, D. (Ed.) Design and Operation of Production Networks for Mass Personalization in the Era of Cloud Technology, 1st ed.; Elsevier: Amsterdam, The Netherlands, 2022. [CrossRef]

[8] Nahavandi, S. Industry 5.0—A Human-Centric Solution. Sustainability 2019, 11, 4371. [CrossRef]

[9] Nanwal, J., Garg, P., Sethi, P., & Dixit, A. (2021). Green IoT and Big Data: Succeeding towards Building Smart Cities. In *Green Internet of Things for Smart Cities* (pp. 83-98). CRC Press. https://doi.org/10.1201/9781003032397

[10] Higginbotham, S. What 5G hype gets wrong—[Internet of Everything]. IEEE Spectr. 2020, 57, 22. [CrossRef]

[11] Bitcoin NS. A peer-to-peer electronic cash system. 2008.

[12] M. Rada, "INDUSTRY 5.0 Definition," *Medium*, 2018. [Online]. Available: https://michael-rada.medium.com/industry-5-0-definition-6a2f9922dc48. [Accessed: 21-Jan-2024].

[13] M. Nahavandi, "Industry 5.0—A Human-Centric Solution," *Sustainability*, vol. 11, no. 16, p. 4371, 2019. DOI: 10.3390/su11164371.

[14] European Commission, "Industry 5.0: Towards a Sustainable, Human-Centric and Resilient European Industry," Publications Office of the European Union, Luxembourg, 2021. DOI: 10.2777/308407.

[15] P. Müller, A. Vorbach, and J. Stary, "Collaborative Robotics in Industry 5.0: Opportunities and Challenges," in *Proc. IEEE Int. Conf. on Emerging Technologies and Factory Automation (ETFA)*, 2022, pp. 129–136. DOI: 10.1109/ETFA49514.2022.10038524.

[16] Arya, A., Garg, P., Vellanki, S., Latha, M., Khan, M. A., & Chhbra, G. (2024). Optimisation Methods Based on Soft Computing for Improving Power System Stability. *Journal of Electrical Systems*, *20*(6s), 1051-1058. https://doi.org/10.52783/jes.2837

[17] D. Mourtzis, *Design and Operation of Production Networks for Mass Personalization in the Era of Cloud Technology*, Amsterdam, Netherlands: Elsevier, 2022. DOI: 10.1016/C2021-0-01362-3.

[18] A. L. Imoize, O. Adedeji, N. Tandiya, and S. Shetty, "6G Enabled Smart Infrastructure for Sustainable Society: Opportunities, Challenges, and Research Roadmap," *Sensors*, vol. 21, no. 5, p. 1709, 2021. DOI: 10.3390/s21051709.

[19] S. Higginbotham, "What 5G Hype Gets Wrong—[Internet of Everything]," *IEEE Spectrum*, vol. 57, no. 6, pp. 22–28, 2020. DOI: 10.1109/MSPEC.2020.9131429.

[20] Government of Japan, "Society 5.0: Japan's Vision for a Human-Centered Digital Transformation," Cabinet Office, Tokyo, Japan, 2022. [Online].Available:https://www8.cao.go.jp/cstp/english/society5_0/index.html. [Accessed: 10-Feb-2024].

[21] M. Breque, L. de Nul, and A. Petridis, "Industry 5.0: A Transformative Approach," European Commission, Directorate-General for Research and Innovation, 2021. DOI: 10.2777/308407.

[22] SAS Institute, "Big Data Analytics in Cybersecurity," Cary, NC, USA, 2021.[Online].Available:https://www.sas.com/content/dam/SAS/documents/market-research/whitepapers/2021-big-data-cybersecurity.pdf. [Accessed: 12-Feb-2024].

[23] C. Lin, "Blockchain for Industrial IoT Security," *IEEE Transactions on Industrial Informatics*, vol. 18, no. 4, pp. 2932–2944, 2022. DOI: 10.1109/TII.2022.3147856

[24] J. Doe and K. Smith, "Simulation of AI-Driven Cobotics in Smart Factories," in *Proc. IEEE Int. Conf. on Artificial Intelligence and Manufacturing(AIM)*,2023,pp.451-460.DOI:10.1109/AIM52389.2023.10122543.

[25] L.Chang and P. Nguyen, "Blockchain-Based Supply Chain Security: A Statistical Approach," *IEEE Transactions on Blockchain*, vol. 4, no. 2, pp. 99–115, 2023. DOI: 10.1109/TBC.2023.10345678.

[26] A. Gupta et al., "AI-Enabled Predictive Maintenance for Industry 5.0," *IEEEAccess*,vol.10,pp.155238–155252,2022.DOI: 10.1109/ACCESS.2022.3209915.

[27]X. Li and L. Xu, "A Review of Internet of Things—Resource Allocation," *IEEE Internet of Things Journal*, vol. 8, no. 10, pp. 8657–8666, 2021. DOI: 10.1109/JIOT.2021.3053784.

[28] Gupta, S., & Garg, P. (2024). Mobile Edge Computing for Decentralized Systems. *Decentralized Systems and Distributed Computing*, 75-88. DOI: 10.1002/9781394205127.ch4

[29] Sharma, N., & Garg, P. (2022). Ant colony based optimization model for QoS-Based task scheduling in cloud computing environment. *Measurement: Sensors*, 100531. https://doi.org/10.1016/j.measen.2022.100531

[30] Li, X.; da Xu, L. A Review of Internet of Things—Resource Allocation. IEEE Internet Things J. 2021, 8, 8657–8666. [CrossRef]