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Exploring the Impacts of Industry 5.0 on Healthcare: An Inclusive Analysis and Future Perspective

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Abstract – The scientific community has increasingly focused on concerns regarding industrial humanization, sustainability, and resilience, prompted by the extensive digitization and rapid technological progress associated with the fourth industrial revolution. This article aims to outline the technologies that have emerged alongside these revolutions, tracing their evolution from Industry 1.0 to Industry 5.0 while also delineating the significant shifts that facilitated a remarkable transformation in the sector, as evidenced by the progression from Healthcare 1.0 to Healthcare 5.0. The research categorizes the various opportunities and challenges presented by the Industry 5.0 revolution within the healthcare domain, with a particular emphasis on the key technologies that benefit the healthcare informatics enterprise. The research introduces an innovative concept known as Industry 5.0, emphasizing collaboration between humans and robots instead of competition. This paradigm leverages technologies such as cloud computing, machine learning (ML), artificial intelligence (AI), blockchain technology, mixed reality, robotics, the Internet of Things (IoT), digital twins, drones, and edge computing to establish connections between robotic systems and human cognition. As previously noted, a crucial aspect of the layered framework of Industry 5.0 is its significant contribution, alongside Industry 4.0, to addressing data breaches within the healthcare informatics domain. Furthermore, the study examines the essential requirements for comprehensive, personalized healthcare services (CPHS) in the latest iteration of the healthcare Internet of Things (IoT), incorporating personalization into its analysis.

Index Terms – Industry 5.0, Healthcare 5.0, Industry 4.0, Security Framework Health Industry 5.0, Healthcare Data Breaches.

1. INTRODUCTION

The Internet of Medical Things (IoMT) has made an essential place in the current healthcare industry [1]. Multiple medical devices can be connected via the network to communicate autonomously using the Internet of Things (IoT) to gather or transmit medical data that can be used to improve security, productivity, efficiency, and human health [2]. In this category, the need for offering patient-centered, customized healthcare services has led to the emergence of healthcare informatics recommendation systems. Before the emergence of Health Industry 5.0, "Healthcare 4.0," which originated from the fourth Industrial Revolution, had made the healthcare informatics sector increasingly digital over the previous ten years. The primary goal of technology-driven healthcare applications is to provide remote and continuous healthcare informatics services, enabling the remote control of patient health issues. Personalized healthcare informatics services often support precision-based services tailored to specific health conditions and individual circumstances. The implementation of an Internet of Things (IoT)-related patient health monitoring system is one of the most promising innovative tactics for solving the global health equity gap [3].

The vision of Industry 5.0 technology is to establish a real-time, intelligent healthcare informatics domain. Precision in healthcare, AI-enabled pharmaceutical equipment, and an intelligence-based framework add to the accuracy of services in the healthcare industry and provide highly effective, personalized treatment for patients. The digital objectives of companies have only increased along with COVID-19 and the rise in the way people live, transact, and interact. Advanced technologies such as the Internet of Things (IoT), Edge Computing, Cobots, Digital Twins, artificial intelligence (AI), data science, and blockchain have changed the way the world views digitization and the potential for value creation [4]. This was the 4.0 industry. Even as these improvements take effect, a new, more advanced concept is gaining popularity around the globe. This ensures a combination of the advantages of Industry 4.0 with an additional advanced model for how people and machines will collaborate in the future Industry 5.0. One of the major issues in Industry 4.0 is that it needs to have fully Cyber-physical systems (CPS) based intelligent industries that lead to dehumanization. A fully dependent on self-driving machines is very harmful to humans, the planet, and the economy. According to Tesla's report on June 15, 2020, a total of 273 accidents were recorded with speed control on self-driving program-based cars of 80000 vehicles. If these incidents escalate, there will always be a possibility of a collision that will increase the death rate [5]. In another report by the US Food and Drug Administration published in 2016, between the years 2008 to 2013, a total of 144 people died, 1391 patients were injured in robot-assisted surgeries and 8061 devices were found faulty [6]. Therefore, from an optimal control point of view, Industry 5.0 is preferred over Industry 4.0 due to the involvement of humans in providing greater support and possibilities to mitigate mechanical disasters through human and software-enabled intelligent observations [7].

The healthcare industry is just beginning to move towards Industry 5.0. Virtual healthcare monitoring, continuous patient monitoring infrastructure with real-time capabilities, and AI-integrated pharmaceutical gadgets are only the start. The personalized healthcare and information technologies developed by Industry 5.0 will provide solutions to problems such as patient insight and continuous monitoring, as well as the possibility of early life support for patients with critical illnesses. We can see the machine and human collaboration in new ways to facilitate personalization at scale using appropriate channels through the provision of fast analytics based on patient-centric real data. This would extend to include the monitoring of abnormalities across vital signs and the provision of the correct information on early disease diagnosis—the areas in which AI has quickly established a role in the data-rich arena across numerous healthcare informatics services. For instance, radiologists might not have enough time during a life-saving procedure to review X-rays. Instead, with the use of AI, X-ray technology scans images and precisely recognizes anomalies in a matter of seconds. This enables radiotherapists to delegate laborious tasks to AI-powered algorithms and concentrate on providing prompt treatment. In time-sensitive scenarios, such a combination of human and AI power can assist in saving the lives of patients. Healthcare informatics services are set to be highly efficacious in the novel sphere that Industry 5.0 aspires to bring. As a result, based on the appointment of a competent workforce and more professional medicine, these new technologies can solve them by focusing on the right treatment, analysis, and diagnosis. The existence of reliable communication technologies is vital to the idea of real-time healthcare. The development of the Internet of Things (IoT) offers the best opportunity for widespread connectivity, while also improving throughput connectivity in remote areas [8].

Industry 5.0 facilitates the use of human-centric technology in the world as it promotes creativity among people and also connects technological advancements in accuracy and efficiency with human cognitive skills like critical thinking and problem-solving approaches. Awareness of the benefits of Industry 5.0 applications becomes critical in this league, a domain that requires work. For instance, in minimally invasive surgical procedures where time matters, it is possible to take pictures of patients using 3D vision equipment placed on a guided automated vehicle. Such technology, which is being used to save lives with Indian-made intelligent imaging technology, achieves the appropriate balance between human and machine work. To take effect and achieve significant changes in enterprises, society, and the overall outlook of the world, Industry 5.0 requires several enhancers. To achieve this, deeply embedded cultural attitudes that regard automation and machines as rivals with human resources must make way for the necessary mindset of collaboration. Therefore, technology does not replace people in the industrial process; rather, it enhances their involvement in it. IR 5.0 explores how humans and robots can complement one another's special skills [9]. With the return of the human factor into smart healthcare informatics under IR 5.0, clients will be able to receive the high-quality health services and human-created smart treatment they desire. Therefore, as a result, the employees will receive more meaningful, beneficial, and gratifying occupations. Technologies from Industry 5.0 can monitor the health management system properly and store sensitive data. The emerging field of healthcare informatics is currently successfully implementing advanced manufacturing technology to produce customized parts with digital data inputs. For more accurate clinical analysis and disease diagnosis, biosensors are helpful. It is simple to get telemedicine services, which might be useful for effective virus control like COVID-19. The 5th industrial revolution is referred to as "Industry 5.0" [10]. It is made up of advanced innovations that link wirelessly and may be utilized to strengthen automation in the healthcare informatics and manufacturing sectors. Industry 5.0 is a recent technological innovation that improves the way people and machines interact. It made significant technological advancements for the efficient, safe, and sustainable efficient manufacturing of goods and services.

The IR 5.0 innovations enhance communication between physicians and patients. Customization is the concern of Industry 4.0, whereas Industry 5.0 is employed to meet the client's demands for individually tailored products. Industry 4.0 uses digital data and software to develop smarter, faster decision-making towards digital factories, While Industry 5.0 uses modern intelligent technology concepts to establish innovative manufacturing facilities and expand the industrial system globally [11]. The advancement of this fifth industrial revolution allows for the making of interconnected networks that can accommodate many basic healthcare informatics needs. Michael Rada first brought the concept of "Industry 5.0" to the public on December 1, 2015, on platforms LINKEDIN. Industry 5.0 mandates that collaborative robots be used to help humans with risk management tasks. To meet the goals and expectations of their human operators, robots are made to recognize, comprehend, and learn from them.

1.1 Contextual Finding and Research Gap- The integration of innovative technologies and the support of all stakeholders are necessary to strengthen the healthcare system and achieve better healthcare services, including patient-centric care, pharmaceutical supply chains, digital healthcare support, data handling, and medical record privacy. Security is the prime concern of any successful industry and cannot be ignored. Health Industry 5.0 suffers from many issues and challenges, i.e. handling sensor-based IoT-related large data volumes is a significant challenge, as well as an absence of standards, skilled workforce, regulatory framework, data privacy, and data security, cost factor, scaling issues, data unification, trust factor, etc [12]. Some major findings from these studies are summarized as follows:

•Personalized care is done with the help of intelligent manufacturing-based systems and AI tools to enhance human precision in healthcare, enabling personalized treatment to patients in a highly impactful manner. Healthcare Industry 5.0 is still in its nascent stage, in which with the help of AI and healthcare experts, intensive care and medical care facilities will be provided to the patient [13].

•Industry 5.0 is moving from technology-centric to human-centric and offers various opportunities from societal, technological, ecological, environmental, and ethical perspectives [14].

•The field of human-machine and technology interaction has become increasingly important in the context of Health Industry 5.0. People's creativity and their jobs together create a vast platform for research and development in this area.

•Industry 5.0 also ensures the safety of employees because hazardous task, dangerous tasks are also carried out through Cobots.

•Industry 5.0 provides better customer satisfaction along with their personalization/Customization services.

2. RELATED WORK

2.1 Industry Migration from 1.0 to Industry 5.0

For ages, goods like clothes, food, housing, and arms have been made by hand or with the assistance of working animals. At the beginning of the 18th century, the manufacturing process began to change significantly with the introduction of IR1.0, and from that point on, the operation progressed rapidly. Here is an overview of these industrial revolutions, as shown in Figure 1.

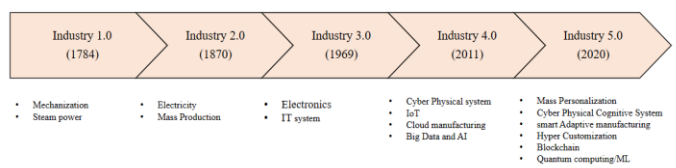

Figure 1. Industrial Revolution 1.0 to 5.0

The base of IR 1.0(1785) is a combination of water and steam-powered mechanical production equipment. The IR 2.0(1875) is based on the division of labor in the proper way to produce mass production using assembly lines and electric energy. The Base of IR 3.0(1970) on Automation by using the Tropic and IT. IR 4.0 (2010) is a method that describes the blurring of limits between the real world, digital world, and biological worlds. It is a blend of advanced innovations such as Artificial Intelligence (AI), the Internet of Things (IoT), 3D Scanning, 3D Printing, Big Data Robotics, Genetic Engineering, Edge Computing, Big Data Analytics, Digital Twins, Drones, Quantum Computing, and Blockchain Technology and many other technologies [15]. These four basic building blocks have been recognized as integral to Industry 4.0. The interconnection refers to the ability of all the available components to be properly connected and communicate with each other. These components are Devices, sensors, and Machines. Industry 4.0 calls for information transparency, which implies that machines must follow pre-informed instructions provided by humans [16].

In Industry 5.0 Technical support means that the system should be able to support the operator in any capacity context like socio-tech. It can be complex decision-making, undertaking critical situations, and problem-solving in a seemingly well-established manner. Decentralized Decisions: The cyber-physical systems that makeup Industry 4.0 should be in an independent process mode as probable and can make their own

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decisions and act without the help or assistance of an operator. IR 4.0 is an improvisation over I.R 3.0 to enable services of advanced technologies. This revolution made each and everything "Smarter". Some of the most important technologies introduced were: The Internet of Things (IoT) which provides a Connection or communications of all connected computing devices with the use of mechanical and digital devices to share data, store data, and analyze the data transfer. Cloud computing provides some services over the internet like software and database services which can be easily accessible by the user. A cyber-physical system (CPS) is the most important thing that is integrated into the sensors, physical devices, and other infrastructure coordinated with each other with the help of the internet [17].

The IR-4.0 is based upon digitization involving advanced technologies that increase productivity and efficiency. The four key domains of Industry 4.0 are- CPS-based connectivity, the Internet of Things (IoT), Cognitive Computing, and Cloud Computing [18]. The main objective of every industrial revolution is to maximize productivity by achieving mass production. IR 4.0 is based on the implementation of emerging technologies. Fundamentally in IR 4.0, the human factor may not be at the entry of these technologies but lies behind the ideology. The IR 4.0 will represent its possible outcome no earlier than 2020–2025. In IR 5.0, the human factor will center stage the coordination of humans and advanced machines in which IR 5.0 is set to achieve the goal of better productivity and efficiency and enhance man's capability. Industry 5.0 (2020) is the collaboration between human beings and machinery for designing and availing the use of highly customized products. Industry 5.0 is centered on three interrelated core values: human-centeredness, sustainability, and resilience [7]. Human centricity tends to set down human interest, taste, and need as the core pillar of the production process, transitioning from a technological perspective to human creativity and a socially oriented approach. As a result, the new role of the worker is to change the value of the worker as a 'cost' into an 'investment'. A positive work atmosphere is to be made to emphasize physical well-being, mental health, and goodness, and finally, the fundamental rights, i.e., autonomy, human value, privacy, and safety to protect the workers. Industrial workers need to enhance their skills for better career opportunities and align a balance between work and life.

Sustainability develops the recycling of natural resources, reduces waste, lowers the negative impact on the environment, and ensures long-term economic growth with enhanced resource efficiency and effectiveness [19]. It mainly focuses on the present and gives importance to the future. Resilience represents the need to increase the reliability of industrial production and provide effective safeguards against failure while ensuring the ability to provide and maintain critical and adequate infrastructure during any crisis, be it the pandemic or natural disasters caused due to climate change. Therefore, the ability to adapt to adversity with positive results is essential in Industry 5.0. In the future, the industry must be resilient enough to respond quickly to political changes and natural disasters. The goal of Industry 5.0 is to enhance technology via the use of human-machine interconnection by focusing on human-machine interaction and intelligent device communication [7].

2.2 Migration from Healthcare 1.0 to Healthcare 5.0

When a patient meets a doctor, personal information and details about the disease must be shared. The Healthcare migration from 1.0 to 5.0 is shown in Figure 2. The medical professional used to be unaware of the patient's medical history in 1970 because this was the norm then. 1990 saw the existence of Healthcare 1.0. Healthcare 1.0 was a pen-paper-based system where all the information was collected in proper note format due to the lack of digital technologies. However, over time, the condition of patients' data deteriorated, putting their confidentiality and privacy in danger. To overcome these issues, Healthcare 2.0 was introduced from 1991 to 2005 which aimed to improve the scalability and maintenance while ensuring improved privacy and data security of health information. The process was popularly termed e-Health. As a subset of healthcare informatics technology that reflected the widespread use of Web 2.0, Healthcare 2.0 emerged in the middle of the 2000s. It also minimized the number of visits to health centers or hospitals by giving the stakeholders (doctors, patients, and healthcare specialists more control over their data. It also highlighted the role of technology in patient care as an enabling force and encompassed mHealth, linked health, and digital health in one technological umbrella.

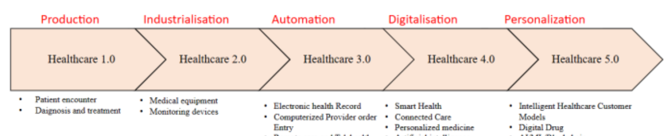

Figure 2. Healthcare Revolution 1.0 to 5.0

Healthcare 3.0 was implemented between 2006 and 2015, and it allowed healthcare providers to upload, exchange, and retrieve paginations at any time through the cloud, thanks to Electronic Health Records. However, data pilferers were able to obtain the patients' sensitive data via active security attacks on cloud servers, which were probably sold or utilized for personal benefit. The Tronic health or medical records (EHR or EMR) were devised to manage patient care across departments and groups of healthcare informatics during the past ten years, concurrently with the growth of information technologies. AI and new digital technologies have been incorporated into healthcare 3.0 since 2016 to address this issue, including the Internet of Things (IoT), Cognitive computing, digital applications, BC technology, deep learning,

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VR technology and mixed reality, robotic machines, big data analytics, and AI-enabled intelligent devices. This change is referred to as Healthcare 4.0.

Industry 4.0 gave rise to Healthcare 4.0, which made the health sector increasingly digitized. For example, x-rays, magnetic resonance imaging (MRI), computer tomography (CT), and ultrasound scans have all evolved into Electronic Medical Records [20]. The caretakers and medical professionals utilize these user-centric gadgets to monitor and treat patients' medical issues as well as provide preventative care and solutions for the patients' well-being. Patient participation is one of the main objectives of Healthcare 4.0. Thus, the patients will progressively move towards a much more responsible approach to their health as they become more knowledgeable about the numerous aspects impacting their wellness. Furthermore, Healthcare 4.0 would enable patients to access their data at any time from any given place. Additionally, this stage offers the patients the option of wearable and point-of-care devices that they can use independently and benefit from various wellness apps powered by artificial intelligence or machine learning, such as customized recommender systems [21].

Industry 5.0 furthers this revolution by redefining contemporary digital high-tech businesses by enhancing commercial tasks and enduring efficiency throughout the value chain. Hence, the healthcare industry, just like the manufacturing sector, is already witnessing a paradigm shift to Healthcare 5.0. This is a difficult time in terms of smart illness regulation and detection, virtual patient care, smart self-management, smart tracking, wellness monitoring, decision-making, emotive telemedicine, and medical research. In the wake of these challenges, healthcare 5.0 will need to incorporate intelligent sensors due to the lack of speech emotion recognition and individualized and ubiquitous health apps and emotive smart gadgets [22]. The main objective of technology-centered apps in healthcare informatics is to help healthcare function remotely and continuously regulate the patients' varied health problems. Following this intent, Healthcare 5.0 strives to serve a variety of goals, including real-time, dependable, resilient, and customized healthcare informatics services. The main objective of technology-driven applications in healthcare informatics is to enable healthcare services by autonomously regulating different patient health states through ongoing and remote monitoring of the circumstances. Reliability refers to the capacity of healthcare informatics services to carry out their necessary tasks in accordance with the established criteria for a limited time frame. Healthcare 5.0 is focused on automatic monitoring and control of the health condition and performing tasks as expected, and in the stated condition. Reliability depends on factors like battery, memory space, calculation power, and Quality of services (QoS), which can be improved by using Blockchain-based modern technology [23].

Services offered by Healthcare 5.0 must be durable enough to monitor health conditions continuously, even in the case of unfavorable surroundings circumstances, inside mechanism failures such as both hardware and software problems, data breaches, vulnerability, extreme weights, age factors, dressing sense, and impaired communications. Personalized healthcare informatics services often work most strictly by promoting the customization of a particular health phase under certain circumstances. Digital wellness is an important factor for Healthcare 5.0 which aims to provide personalized healthcare informatics facilities with the coordination of integrating cyber and physical components of services (CPHS) [24]. Their involvement improves the personalization of healthcare informatics services that are autonomous to coordinate and control/monitor health conditions. The critical importance of CPHS services can be enunciated as:

The term Reliability is to ensure that medical data is only used by authorized users and equipment. In the context of the healthcare industry, "reliability" refers to the general consistency and dependability of procedures, information, and structures. It is essential to delivering excellent health services as well as guaranteeing patient security. Integrity refers to ensuring data completeness and correctness throughout all communications to prevent incorrect diagnosis and treatment. The availability is to ensure that medical information and equipment are available to authorized users when they need them, without any failure issues. Privacy security refers to the confidentiality policies that must be adhered to under the premise that no sensitive or personal information is shared or exposed without permission.

System updating in real time assures that the doctor or system will receive the most up-to-date information to accurately diagnose and map the course of the treatment while supporting real-time response. For instance, recent blood glucose levels during fasting data can be used to determine the appropriate insulin dosage. Security provides the three essential components of security, namely "privacy," "in-integrity, and "accessibility. Each patient has specific needs that are based on the patient's fitness status, immune response, and other underlying coexisting medical issues. Deep analysis, which carefully examines all the pertinent aspects, such as the mechanical and biological processes involved in health condition monitoring, ensures that each patient's health status is determined. Different patients' immune systems may react differently to the same disease. Instead of only treating patients, the industry participants will forge lifetime relationships with people, making therapy an exception rather than a service for which the sector is mostly known. Industry 5.0 is a value-driven program that promotes technological transformation for

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a specific goal, not a technology-driven revolution. Hence, digital wellness is set to gain precedence with the advent of Health 5.0. Furthermore, personalized services reduce hospital readmission rates and provide better chronic disease management and monitoring [24]. Moreover, such facilities would also enable better post-hospitalization while providing clear and immediate value.

2.2 Upgradation of Industry 4.0 to Industry 5.0 in Healthcare Informatics

Both, the IR 5.0 component and IR 4.0 component are connected to a cloud server component for the execution of the overall process, as shown in Figure 3. Industry 5.0 is a value-driven approach that uses the technological advancement of Industry 4.0.

- Cloud Server Component

The controller's action to modify production settings is supported by the AI engine's prediction of possible equipment breakdowns or product flaws. The predictive analysis is accomplished by building training models using past production data gathered into the big data repository. Thereafter, the alerting signals get activated.

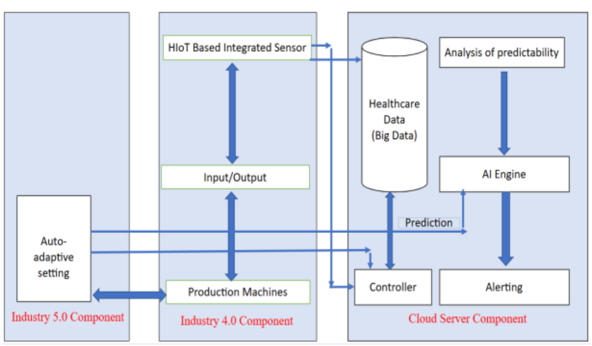

Figure 3. System upgradation from Industry 4.0 to Industry 5.0

- Industry 4.0 Component

The Healthcare Internet of Things (HIoT) devices, I/O, and manufacturing equipment can transfer digital information while operating in quasi-real-time configuration. They are all linked to a cloud controller that has an AI engine to support it. IR 4.0 automates the process and is based on a Cyber-Physical system (CPS). The key facets of Industry 4.0 include: -

•Industry 4.0 is based on the Machine-to-Machine Communication.
•There is totally virtual connectivity.
•Dehumanization is an integral aspect of this innovative technology.
•The smarter and better connectivity-based environment in the workspace is based upon the Cyber-Physical System (CPS).
•Does not provide any type of customization and personalized services.

- Industry 5.0 Component

Industry 5.0, as defined by the EU, consists of three interrelated primary pillars, namely human-centricity, sustainability, and resilience, Figure 4 shows this. As a result, Industry 5.0 includes not only the technology-driven revolution known as Industry 4.0 but also a values-driven revolution that underpins all technological progress while meeting particular societal demands. Industry 4.0 made mass customization possible, but the healthcare informatics sector needs a more personalized, user-centric approach. To meet the unique needs of the patients aided by healthcare informatics, a migration from mass customization to mass personalization is necessary, as it reduces expenses and enables both prompt and optimum results. The projected outcomes trigger the machine controller, and the machine parameters are concurrently self-adapted by the actual sensor monitoring and by the failure predictions. The opportunity in Industry 5.0 is an enhanced overview of the proper management plan, this paves the way for a predictive approach as compared to preventive maintenance applied so far. IoT devices, smart sensors, and specialized software help with monitoring and detecting early failure prediction. Only the equipment that is most susceptible to breakdowns will be stopped and corrected. The sustainability of Industry 5.0 production promises to use resources effectively and adapt to current needs [26].

Figure 4. Core Value of Industry 5.0

Versatile business plans are the outcome of machine and human collaboration. Garbage or excess output can be significantly reduced or eliminated in the process. Now, while people focus on technology and innovative solutions in response to the demand for customer happiness, a collaborative robot can perform hazardous and repetitive tasks. These abilities improve production quality, especially when the employees are inspired by their efforts and results. The intelligent, apps and specialized AI-enabled software provide real-time and forecasted outlines of the climate, rain, moisture, heat, and energy use within the network, which is known as environmental regulation. Especially in areas where the climate is so unpredictable, this is extremely helpful. We are currently on the edge of the fifth industrial revolution, which will strengthen human-machine interaction while building on

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Industry 4.0's inter-machine communication. Industry 5.0 understands that human creativity and critical thinking are incomparable to what robots can do [17]. As a result, continuous innovation works to improve processes by entrusting predictable or repetitive activities to automation while simultaneously incorporating human operators into production processes.

S.No	Analysis of security Parameter	Industry 4.0	Industry 5.0
1	Smart manufacturing, mass production, Mass Customization	✔	✔
2	Human Cyber-Physical System	✔	✔
3	Mutual cognitive Human-machine collaboration	✔	✔
4	Trust on Machines	✔	✔
5	Mass Personalization	✔	✔
6	Only Technological perspective only	✔	✔
7	Socio-Tech Value-based	✔	✔
8	Focusing on Environment, Economics, Ecology	✔	✔
9	Human-Centric, Sustainable, Resilience	✔	✔
10	support fully Automation	✔	✔
Parameter consider = ✔ Parameter not consider= X			

Table 1. A Comparative Analysis of Healthcare Security

In Table 1 we have summarized the health security parameters for both Industries. Therefore, we can say that Industry 5.0 is more prominent and cannot be ignored. The rising complexity of these interconnected systems increases their vulnerability to potential security breaches, especially within the context of healthcare so the analysis of these security parameters plays a significant role in Industry 5.0.

3. Proposed framework Health Industry 5.0

Industry 5.0 provides human-centered, sustainable, resilience-based services, integrates the societal, network, plant, and healthcare organization levels, and enables technologies that deliver value-based services. Table 2 shows the different levels of Health Industry 5.0, which cater to all levels as per the requirement. The first three levels of society, Network and Plant, are divided based on the main pillar of Industry 5.0 [27][28].

Health Industry 5.0			
	Resilience	**Sustainability**	**Human-Centricity**
Society Level	Focus on the whole society rather than the group	Sustainable uses of natural Resources on Earth	Collaborative task with a machine
		Circular Economy	Social Justice
Network Level	Supply Chain Management, Reconfigurable Services	Increase Network Efficiency, Reduce Resource and Energy Consumption	Human Cyber Physical System (HCPS), AI-Driven Network
Plant Level	Ecosystem resilience, Regeneration Plants	Reduction of CO2 Emission, Circular Ecosystem	Human-Machine Planting Collaboration, Green Revolution
Organization Level Resilient Services-Human-Centric trust services- Sustainable manufacturing society			

Management Level Integration of resilience and sustainability and Human-Centricity
Supported Technology Human-machine collaboration, Cobots, Automation with Human-Brain
Security Data Integrity, Data Integration, Data Security
Performance Value-based services, Customer Satisfaction

Table 2. A Framework for Health Industry 5.0

3.1-Health Industry 5.0 at Different Level-

To fulfill the need of society Industry 5.0 has been divided in to different level according to the need-

- Society Level

At the societal level, Industry 5.0 aims to maintain social equilibrium while improving human well-being through centralized human-based creativity, sustainable practices, and peaceful coexistence between advanced technologies. This entails rethinking international supply chains and directing product experimentation toward an inclusive, effective, and socially responsible future.

- Network Level

Industry 4.0's primary emphasis is on interconnectivity through cyber-physical systems. The Human Cyber Physical System (HCPS) is a term used to describe Industry 5.0, which is also connected to Industry 4.0-related technologies that have been integrated with the human brain. Industry 5.0 uses the help of these networked technologies to provide personalized care in the health industry that improves the quality of care and enhances the standard of life.

- Plant Level

At the plant level, the migration of traditional manufacturing converts into a smart, sustainable, and flexible environment where humans and machines collaborate in a better way with zero emissions to enhance productivity and efficiency. Industry 5.0 provides a creative thinker with a smooth transition for sustainable and human-centric plantations.

- Organization Level

The use of Creativity in Industry 5.0 plays a vital role at the organizational level in solving complex decision-making processes, ethical considerations, problem-solving approaches, and design and implementation of resources according to the user requirements. Organizational sustainability is the key focus of Industry 5.0, which minimizes waste as well as optimizes resources and services.

- Management

At the management level, emphasizing problem-solving abilities and empowering employees to achieve organizational goals encourages them to collaborate efficiently and share their thoughts. Data analytics tools are used to gather patient information about customer needs, preferences, and behaviors so that enhanced services and goods can be offered more quickly with better satisfaction levels.

- Supporting Technology

In Industry 5.0, advanced technologies such as artificial intelligence (AI) and machine learning (ML) are leveraged alongside human-machine collaboration. This industrial framework integrates human-brain-enabled technologies to enhance efficiency and productivity while reducing waste.

- Security

Industry 5.0 plays a vital role in terms of security because industries are interconnected with each other with the help of advanced technologies. However, the combination of innovative technologies such as industrial internet-of-things, artificial intelligence, and automation has revealed some vulnerabilities that require strong cyber security to be provided from time to time. Industry 5.0 involves a lot of networks Maintaining data integrity is of utmost importance in meshing and data handling.

- Performance

Performance-wise, Industry 5.0 offers services that are value-oriented and find the proper balance of productivity and efficiency at the next level. The main reason for the increased performance and efficiency of Industry 5.0 is the systematic use of real-time data analysis and automation.

3.2 Industrial Revolution's Impact on the Healthcare Industry:

The ensuing segment deliberates upon a few broad technologies that influence Industry 4.0 and Industry 5.0, as well as Healthcare informatics. More specifically, the study examines the current position of IoT, BDA, Blockchain, Deep Learning, AI, and cloud computing in Healthcare informatics within the context of both Industry paradigms. With a strong emphasis on Healthcare Data Security, we have also examined and explored the uses of AI, cloud computing, IoT, and blockchain in healthcare informatics, as shown in Table 3.

Operator	Reference	Technology/Survey	Summary Work/Objective	1	2	3	4	5	6
Industry 4.0(2010)	[[29]	IoT and BDA	Defragmenting Brain signals	H	H	L	L	L	M
	[[30]	IoT and BDA	Healthcare devices	H	H	L	L	L	M
	[31]	IoT and BDA	Neuroscience Application for Data Generation	H	H	H	L	L	M
	[32]	AI	Examine Virus affected patients with a Low spread rate	**L**	H	L	M	L	H
	[33]	AI	Auto-deleted fake information about viruses from social media	L	H	M	M	L	L
	[34]	AI	Vaccination using robots with low-risk	L	H	L	L	L	M
	[35]	Cloud Computing	The delivery system for Healthcare services			L	L	L	L

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				L	H				
	[36]	Cloud Computing	Ensure security standards and better access of any information	L	H	L	M	M	M
	[37]	Cloud Computing	Provide Cloud infrastructure as a service	M	H	L	M	M	H
	[38]	Cloud Computing	Numeral form of Electronic Medical Records	M	H	L	M	M	H
	[39]	Blockchain	Privacy-preserving framework in healthcare	M	H	L	M	L	M
	[40]	Blockchain	Signature scheme based on the distributed system for EHR	H	H	M	H	L	L
	[41]	Blockchain	Collection of health data and access to EHR	H	H	M	M	M	M
	[42], [43]	Blockchain	Personalized medicine ecosystem	M	H	M	M	M	M
	[44]	Edge Based Architecture	Collection of health data from Body Sensor Network	H	H	M	M	M	M
	[45]	Big Data, Cloud Computing	Big Data Security Intelligence for Healthcare Industry 4.0	M	H	M	H	M	M

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	[46]	Blockchain-based IoT	Multilevel Security and privacy framework	H	H	M	H	M	M
Industry 5.0(2020)	[47]	Blockchain	Protection of EHR	H	H	M	H	L	H
	[48]	Blockchain	Application of BC in Medical Network	H	H	M	H	M	M
	[49]	Blockchain	using BC Technology's advantages and disadvantages	M	H	L	H	M	M
	[50]	Blockchain	using BC security discussion and future implementation	M	H	L	H	M	H
	[51]	Blockchain	implementation of the Healthcare model using the PRISMA framework	M	H	L	M	L	H
	[52]	Blockchain	off-chain Based medical data storage and implementation	M	H	L	M	L	L
	[53]	BC and Deep Learning	Protect EHR	M	H	M	H	M	M
	[54]	Review Paper	Challenges and Opportunities Transition from industry 4.0 to society 5.0	L	L	M	M	M	H

	[55]	Review Paper	Industry 5.0- present, past, future	M	L	M	M	M	M
	[56]	Review Paper	Risk Assessment in Health Industry 5.0 Perspective	H	H	L	H	L	H
	Proposed	Review Paper	Exploring the Impacts of Industry 5.0 on Healthcare: An Inclusive Analysis and Future Perspective	H	H	H	H	M	H

Table 3. Impact of Industrial Revaluation in Healthcare Informatics

H-High Coverage M-Medium Coverage L-Low Coverage

1-Architecture, 2-Healthcare, 3-Simulation Tool/Framework, 4-Security, 5-Hardware and Physical Design, 6- Open issues and challenges

In this healthcare section Kumari Aparna, et al.[29] proposed a three-layer e-health architecture for security purposes and also discussed and analyzed various challenges. However, security techniques were discussed but there was no discussion about their privacy and confidentiality. Islam, et al. [30] surveyed IoT-based sensing devices and discussed the architecture of remote monitoring and its application but there was no proper discussion related to the security and hardware. Mahmud. et al. [31], discussed cloud-based IoT healthcare architecture, discussed the trust management model has been simulated and there is no discussion on security and hardware. Abd-Alrazaq, et al.[32] There has been no discussion related to security in this survey only using the PRISMA method for Review.Haleem, et al. [33] have discussed the open research challenge of research areas that are being impacted during COVID-19 such as vaccine development therapy, social media, economic, environmental, and biological warfare also there is no focus on simulation security hardware. Javid, Mohd, et al. [34]discussed precautions and safety challenges during COVID-19 and how cobots can help in vaccination, although they have not followed any secure architectural or practical approach. Harris et al.[35] told that the health executive has discussed some important aspects while taking cloud service. Ahuja, et al.[36] discussed health records are protected according to HIPPA guidelines and federal guidelines that raise security standards, although no architectural model or open issues and challenges are discussed in it. Zhang, et al.[37] discussed the requirements related to the security and privacy of EHR, although it has not mentioned its design and regulatory framework. Kuo Mu Su, et al. [38] cloud services and their types and challenges have been discussed, although they have given less attention to security. Kuo, et al.[39] has created a framework for security and privacy-preserving and discussed things related to architecture and security, although the focus was not on physical hardware and simulation. RUI GUO, et al[40] patient information has been secured by sharing data using blockchain technology, architecture and security theorems have been discussed in it, although simulation and future scope have not been discussed properly in it. Cyran et al.[41] covered all required aspects related to blockchain technology in this article, although the focus has been less on simulation and future scope.

The architecture and security scheme related to the virus-infected patient and the need for personalized care treatment of remote patients has been discussed, although less attention was given to simulation and future scope[42], [43]. Karunanithy et al.[44] discussed a smart health monitoring system utilizing edge devices within a wireless body area network for efficient data collection. It emphasizes leveraging local processing for real-time analytics, offering benefits like reduced latency, energy efficiency, and enhanced privacy. Manogaran et al.[45] discussed enhancing data security strategies, and ensuring the integrity and confidentiality of healthcare data in the era of Industry 4.0 advancements but there is less attention to simulation and Architecture. H. H. Pajooh et al.[46] discussed the multilevel security aspect involves implementing various layers of protection, such as encryption and access controls, to safeguard IoT devices and data. Privacy is heightened through user anonymity and control over data sharing but there is less attention on simulation and future scope.

Industry 5.0 perspective Wang, et al. [47] introduced a secure Cloud-Based Electronic Health Record (EHR) system that utilizes an Attribute-Based Cryptosystem (ABCS) and Blockchain for enhanced security. The system ensures controlled access to health data based on specified attributes and employs Blockchain for decentralized and tamper-resistant data storage in the cloud but there is less attention on simulation and physical design. Radanovik, et al. [48] discussed the potential uses of blockchain technology in the field of medicine, emphasizing benefits like improved pharmaceutical supply chain management, streamlined interoperability between healthcare systems, and safe and transparent health data management. The drawback is there is no proper design method and simulation. However, a notable drawback is the absence of a defined design method and simulation framework. Khezr et al. [49] discussed Blockchain technology in healthcare and underscored its promising applications in data security, interoperability, and transparency. The technology offers potential solutions to various industry challenges. However, a notable drawback lies in the lack of standardized protocols and regulatory frameworks, hindering widespread adoption. Tandon et al. [50] summarized the work and discussed a synthesized framework that contributes to a comprehensive understanding of Blockchain's role in the healthcare domain and offers a roadmap for future research. However, a notable drawback was identified in the review simulation and physical design. Chukwu et al. [51] identified promising applications such as data integrity and secure sharing but underscored a notable drawback: the limited scalability of current blockchain solutions and their design. This study introduces a secure blockchain-based healthcare data management system, showcasing its potential to enhance data security and interoperability within the healthcare domain. Zaabar B, et al.[52] discussed leverages blockchain's decentralized and tamper-resistant nature to safeguard sensitive health information. However, a key drawback lies in this paper in tool discussion and simulation. Quasim et al. [53] discussed the Secured Healthcare Framework presented in this study offers a promising solution for enhancing the security and privacy of healthcare data but there is less focus on simulation and research challenges. Mourtzis et al.[54] discussed the potential for a human-centric approach, integrating advanced technologies into society for the betterment of individuals and communities. However, a significant drawback lies in addressing ethical and societal concerns in designing an approach with the integration of emerging technologies. Barata J, et al.[55] discussed Industry 5.0 envisions a harmonious coexistence where humans play a central role alongside intelligent technologies. However, a significant drawback there is no simulation and design approach. Abdullah Baz, et al. [56] discussed the Security Risk Assessment Framework within Industry 5.0 provides a structured approach to evaluate and mitigate risks in the healthcare sector. However, a key drawback lies in the complexity of integrating diverse data and designing issues not properly described.

The main problem, in the entire process, is the security of healthcare data at the IoT level and Electronic Health Record Level. Industry 5.0, with a strong focus on all human-centric directions along with societal, ecology, and environmental considerations, has the potential to significantly enhance security in a healthcare system with the integration of several advanced technologies such as AI, blockchain, deep learning, and the Internet of Things. In this league, the improvised, industry 5.0 provides the extra top-line and bottom-line advantages that contemporary businesses prioritize, such as sustainability, improved client experiences, and increased profitability. Modern businesses must adopt strong network segmentation and a robust cybersecurity policy that protects all network assets due to the extent of convergence and the growing ecosystem of connected devices. In this article author has taken six comparative parameters are shown above in Table 3. If we improve the security standards in Industry 4.0 and Industry 5.0, these parameters can be contained and can be significantly reduced over some time. Blockchain technology improves healthcare data security.

3.3 Healthcare Data Breaches from 2015 to April 2025-

The Health Insurance Portability and Accountability Act (HIPAA) is a significant piece of legislation, enacted as public law 104–191, and stands as the second privacy rule established by the United States in 1996. This comprehensive law addresses various aspects of healthcare, with a primary focus on safeguarding the privacy and security of individuals' health information. These studies delve into the extent of data compromised during these breaches, shedding light on the nature and scope of the incidents. Through these endeavors, HIPAA aims to enhance its understanding of the challenges faced by healthcare organizations in maintaining the privacy and security of sensitive health information. By gaining insights into the causes and repercussions of data breaches, HIPAA seeks to continually refine and strengthen its regulations to uphold the principles of patient confidentiality and data protection within the dynamic landscape of the healthcare industry. We compiled data on healthcare data breaches from January 2015 through October 2025, when a report on violations by the Office of Civil Rights at the Department of Health and Human Services was published on the website. A report of the last 11 years presented by OCR states that the year 2021 has seen the highest number of data breach incidents, which is visible in Figure 5. In this section, we have considered all types of possible threats and attacks that generally occur in healthcare. Regulations and laws regarding data protection are not able to prevent patient data breaches and attacks. According to the Protenus Breach Barometer, the greatest number of patient records were compromised in 2015.

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The number of breaches in 2015 was 270, and the maximum amount of data compromised was 113267174.

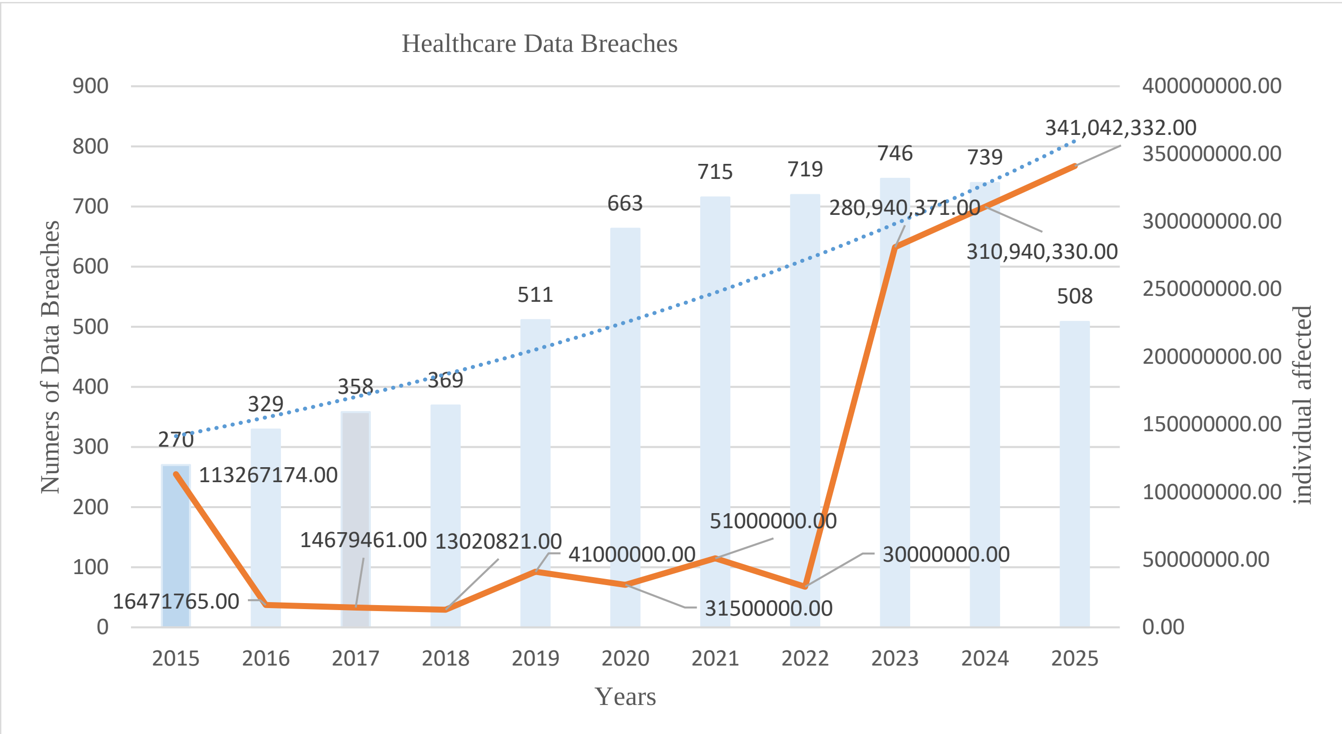

Figure-5 Healthcare Data Breaches

In till october 2025, there were 508 data breaches with 3,410,423,310 records compromised. In 2024, there were 739 breaches with 310,940,330 records compromised, and in 2023, there were 746 breaches with 28,09,40,371 records compromised.. A total of number of data breaches 329 in 2016 and 16,471,765 medical records were compromised overall. In 2017, that number came to 358, and 14,679,461 pieces of data were compromised. 2018 observed 369 breaches, resulting in 13,020,821 fewer compromised data records. The majority of data breaches were brought on by scams using external suppliers, data loss, and hacking[57].

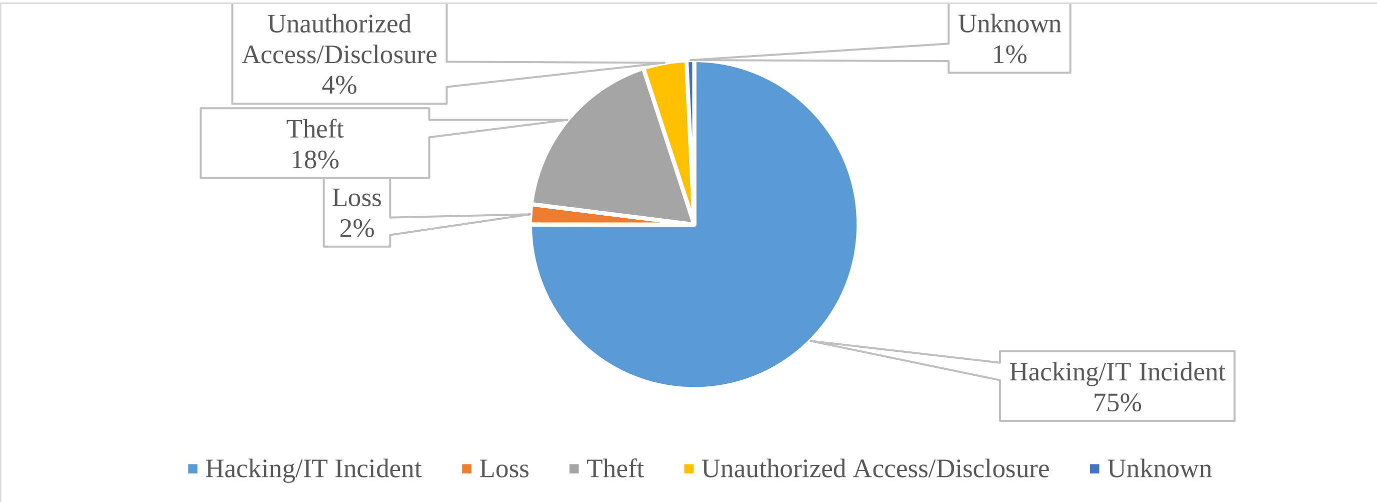

Figure 6: Healthcare Data Breach

- Hacking/IT Incident

This continues to be the leading reason for data breaches. Phishing emails are frequently used by attackers to infiltrate a system and carry out hacking. From 2020 to 2025, there was a steady increase in healthcare data breaches, and hacking incidents grew by 62%.

- Data Theft

The second most common reason for data breaches is data theft. Theft includes taking portable electronics and other illumination. The theft incident involving a personal device or data happened in 2015 about October 2025 and data theft of 18%.

- Unauthorized Access/Disclosure

A security breach is possible when somebody else logs in to a website, software, server, or services, using the same credentials or any other method. Unauthorized access may occur, for example, if someone made several unsuccessful attempts to get into a user account that wasn't their own by guessing the password or username. The total Unauthorized Access from 2015 to October 2025 is 12578287 i.e., 4%.

- Loss and Unknown

Data breach incidents may also result from the loss or incorrect disposal of outdated technology. Other hacking incidents caused the remaining 3% of data breaches.

4. The Application Area of Industry 5.0

We are already using Industry 5.0 in many industries, such as healthcare informatics, cloud manufacturing, Artificial Intelligence and Manufacturing, supply chain management, additive manufacturing (AM), production in manufacturing, smart education, automobile industries, etc. In Industry 5.0, the machines are integrated with the newest technologies like IoT, mobile edge computing, cobots, 6G and beyond, simulation/digital twins, big data analytics, augmented reality, etc., but human intelligence is also used when making decisions. This section also describes a few of the potential uses for Industry 5.0 in other areas., as shown in Figure 7.

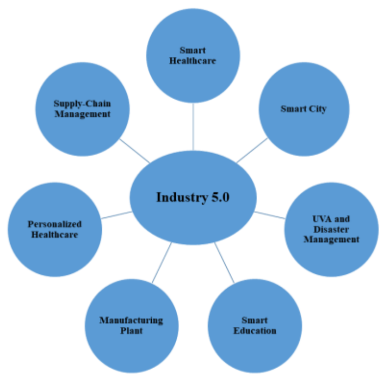

Figure 7. Application Area of Industry 5.0

4.1 Supply-Chain Management

IR 5.0 describes AI-driven pipelines in a supply-chain environment, in which the authenticity, quality, and expiry of the created product are checked. Any supply chain stakeholder may make special orders using a DApp. Before the contract is finalized, the communication network wallet freezes the currency. Once the item is received, SC is finished to permit real-time payments. SCs are used to implement orders and delivery conditions among two transacting peers. As a result, it lowers capital expenses (CAPEX) and streamlines the logistics process. Prediction models are essential in healthcare informatics-based supply chains, and the model's outputs should be comprehensible. A module that explains the model findings has been merged into the supply-chain environment with the rise of Explainable AI (XAI).4.2

4.2 Personalized Healthcare Informatics

The healthcare informatics industry is expanding rapidly in Industry 5.0. Current use cases cover telemedicine and telepresence surgery, whereby specialized cobots carry out remote surgery. With a minimum latency of less than 1 ms, a responsive network like tactile internet connects the cobot and the surgeon. Using the usage of AI and ML, healthcare informatics technology has developed along similar lines. A paradigm shift called federated learning makes it possible to train a global cloud system with local data without sending any susceptible data. The local device just shares the parameter's gradients and weights.

4.3 Manufacturing Plant

Cobots would aid people in repetitive work in production processes. Automation would be a crucial part of production facilities, merging systems, controls, and industrial activities to create a significant CPS. The pipelines, which monitor unprocessed things packing and control production, would become more sophisticated and AI-driven. The equipment inputs would first be simulated on a Digital Twin control, which would be an imitation of the actual real-time process, to assure the safety of plant operations. The manufacturing procedures could acquire intelligence because of the Digital Twin outputs being supplied as feedback to the Artificial Intelligence models. The inputs will be sent to the actual processes when enough iteration has been completed and errors have been reduced. This would ensure production safety and excellent accuracy.

4.4 Smart Education

The preservation of students' records, grade reports, and credit transfers between institutions are now real-time Blockchain-enabled use cases in the sector of education [58]. However, online meeting application software like Zoom, Google Meet, Slack, Skype, and GoToMeeting is used to assist online teaching and learning as the COVID-19 epidemic spreads. Smart education would be more inventive in Industry 5.0 since it would combine different teaching methods in a supported setting. For instance, remote laboratories with AR/VR capabilities may be set up to let students experience genuine experiments from a distance. High-Level networking bandwidth and low-level latency would be necessary, for communication purposes. Recent proposals for 6G networks include holographic telepresence, which may display real-time, 3-Dimension, and four-dimension pictures of distant people sitting in the living area of students. The virtual environment connects, communicates, and plays with real things in their real environment in the actual time frame. A responsive type service, such as FeMBB in 6G, would be used to communicate the compressed pictures once they have been produced with surrounding objects. They would then be compressed and projected into the living environment utilizing laser beams. To ensure that the environment sequence has not been changed, BC ledgers will retain the holographic state when the private data is transmitted across public channels.

4.5 UVA and Disaster Management

Services in this ambit include medical assistance, investigation and search, defense operations using a sensor-driven battleground system, and monitoring activities that will be provided on the UAV front in Industry 5.0. Block-chain would help ensure that UAV (unmanned aerial vehicle) swarm network systems are not intercepted and that malevolent UAVs cannot interfere with network communication. In the Internet of Vehicles (IoV) case, where the private information of the vehicular nodes is maintained on BC ledgers, there is a use case like that. Electric cars (EVs), for instance, can interact with other EVs to exchange energy in a peer-to-peer way, or the transactional data and charging stations are kept in BC ledgers as immutable and historical records [59]. BloCoV6 is a UAV-based BC-assisted system.

4.6 Smart City

Smart cities work to fulfill Industry 5.0's vision of a sustainable future by fostering a more eco-friendly and secure urban environment. The exploration of Industry 5.0 by futurists has already started to add a human factor or personalized care by using co-working among people and robots. A variety of smart devices in smart cities gather information using heterogeneous sensors. These sensors' data are examined, and the performance of schools, libraries, and transportation and traffic systems is improved as a result. Because smarter IoT devices are being used, the concept of a "smart city," which includes big data, AI, cloud storage, and assisted networking technologies, has gained popularity [60]. The advanced Internet-of-Everything (IoE) paradigms are the outcome of convergence. To address the current issues with energy, transportation, the environment, governance, and other factors, we need efficient methods for developing new smart cities to address these compelling issues. Some outstanding issues, such as insufficient IoT security, difficulties maintaining and updating associated machines, retaining user trust, optimizing data center prices, harm resistance, security, and confidentiality issues need to be resolved to implement smart city projects successfully and efficiently. Energy management is a crucial topic in smart cities. A threat actor might also alter the energy statistics originating from the smart grid.

4.7 Facial Expression Recognition System

Facial expression recognition technology plays a significant role in improving patient satisfaction in Health Industry 5.0, bringing about a revolutionary shift in healthcare and social welfare. Advanced facial analysis algorithms are integrated into patient health care systems, and they are used to comprehend and track feelings as well as effectively evaluate mental conditions. This technology provides the benefit of healthy environment services conducive to understanding the feelings of the patients and relieving their pain. Managing stress and anxiety provides valuable insights into assessing situations and their real reactions and interventions. Ethical considerations are paramount, keeping in mind patient confidentiality and consent, where health services can combine the emotional form with the technical form[61][62].

4.8 Smart Healthcare Informatics

The analytics based on patients' records are the main emphasis of Healthcare 4.0, yet data analytics are widely focused on healthcare cloud-based systems. The analytics will migrate to local edge models with increasing decentralization, therefore patient information confidentiality, privacy, and security must be preserved as it is vulnerable to several attacks. Smart health informatics places a lot of emphasis on sensor-assisted body area networks, in which local nodes track patient health monitors and gather data in real-time. Access to medical records should be secure and readily available for doctors, patients, and medical personnel. Designing new hospital services, advising clinicians to investigate the signs of various diseases, and improving the overall model all require secure data transfer [65].

5. The Emerging Technologies in Industry 5.0

5.1 The Industrial Block Chain

Blockchain has been increasingly popular in the financial services sector because it enables peer-to-peer electronic coin exchange between users in a distributed connection without requiring a centralized and reliable third party. Because of its intrinsic properties of immutability, chronology, and suitability in industrial domains, blockchain (BC) is a favored option as a security enabler for the Industry 5.0 environment. A blockchain's role is to ensure privacy from cybersecurity threats to make the system more secure [66]. Healthcare informatics is only one of many areas where innovative solutions are being created using blockchain, a modern innovation. A blockchain-based system is used in the healthcare informatics industry to store and distribute data of a patient across doctors, hospitals, diagnostic labs, and pharmaceutical companies. The applications based on the blockchain may accurately identify serious errors in the medical sector, even ones that could be dangerous. In the healthcare informatics industry, it can therefore improve the transparency, efficiency, and safety of the exchange of medical data [52]. With the use of this technology, healthcare informatics providers may gain knowledge and enhance the analysis of patient data. Blockchain technology is useful in preventing clinical trial theft, and it has the potential to provide better data efficiency in the healthcare informatics sector. Thus, by facilitating a distinctive information storing pattern, enabled by blockchain, the specialists can attain the highest level of security. Flexibility, connectivity, accountability, and data access authentication are all provided through Blockchain. For the healthcare industry, blockchain enables decentralized data protection and specialized risk management.

5.2 Mixed Reality

Mixed reality is being used in operating rooms, clinics, hospital wards, and medical training settings to improve results, speed up diagnosis, expand access to healthcare informatics, reduce the spread of infection, and transfer information. The ability to utilize techniques such as projecting images and data onto real-time events, such as surgical procedures, and enabling remote medical consultation and treatment, is introducing exciting possibilities in the field of healthcare informatics. This technology allows for the overlaying of holographic information onto real-life situations, facilitating enhanced visualization and understanding. It not only enhances the accessibility of medical expertise across geographical boundaries but also enables. At the patient's bedside, mixed reality will connect us with the knowledge and specialized care that is required. At the point of care, holographically, the overlaying patient data will speed up the procedures and cut down on complications.

5.3 Exoskeletons

Exoskeletons help the patients perform more workout repetitions in the same amount of time while maintaining a greater level of consistency by continually replicating the same motion thousands of times. As the patient regains strength, the therapist reduces the exoskeleton's level of support. Exoskeletons for rehabilitation can execute the same motion thousands of times, can be adjusted for each patient's ability, and can record data on each patient. The development of stronger materials, more realistic manufacturing processes, and the addition of electronics that give the devices intelligence have led to a revolution in robotic prosthetic and exoskeleton technologies.

5.4 Drones

Tiny indoor drones could eventually bring medicine from the drug store to the patient's bedside, reducing human steps. Medication administration would become faster and less prone to mistakes as a result. Doctors and pharmacists will be working faster since supplies can be brought to the patient's bedside rather than needing to spend time acquiring them. Moreover, patients who are receiving care at home rather than in a hospital environment could receive medication and supplies via drones. More hospital-based care will soon be replaced by outpatient and perhaps home-based care in the future. Drone technology may make giving this at-home care simpler and safer for many illnesses. When a healthcare informatics professional visits a patient at home, blood can be collected and transmitted right away by drone to the lab for testing. Drones may be used to deliver prescription drugs, antibiotics, and other therapies to the patient's house [67].

5.5 Additive Technology

Additive Manufacturing (AM) technology is regarded as a flexible manufacturing process with tremendous innovation potential for producing medical devices, orthoses, prostheses, medical models, inert implants, and biomanufacturing. Recent developments in biomaterials are also accelerating the clinical uses of healthcare informatics goods made via additive manufacturing. A thorough analysis of the recent advancements in AM technology calls for cutting-edge healthcare informatics solutions. A critical assessment of four-dimensional printing, three-dimensional bioprinting, and three-dimensional printing has explicitly been offered. According to the researchers, further biomaterials developments are necessary for the adoption and growth of AM technology in the field of healthcare informatics.

5.6 Nanomedicine

Nanomedicine makes use of small equipment to better understand the complicated pathophysiology of disease and to diagnose, prevent, and treat illness. The ultimate objective is to raise people's standards of living. The goal of nanomedicine can be summarized as the thorough monitoring, maintenance, and improvement of all human biological systems while operating at the molecular level and utilizing designed tools and nanostructures for therapeutic purposes. Nanomedicine, in its broadest sense, describes the use of molecular techniques and molecular understanding of the human body in the diagnosis, treatment, and prevention of illness and trauma, the easing of pain, and the maintenance and enhancement of human health.

5.7 The Internet of Things (IoT)

The IoT has been extensively used in the online exchange of health data and the networking of medical devices in the field of healthcare informatics. There are multiple sensor-based IoT applications in healthcare informatics, each with its particular advantage. The IoT, for instance, makes it possible to introduce the internet of health items. Modern technologies, including IoT, which is currently one of the wildest accepted technologies, make up the "digital data foundation" in the healthcare informatics sector. It talks about online surveillance services. Patient monitoring devices are part of the primary digital technologies used to exchange information between the h patients and medical facilities. Through IoT devices, patients may monitor their health and collect data that can then be electronically transferred to the doctors. IoT is a crucial component in the evolution of healthcare informatics, which has produced notable changes in the industry. The IoT functions recognize, detect, and validate intentions and individuals for specialized medical care. IoT technology's quick development has created the foundation for healthcare informatics through wireless connectivity. The ability for caregivers to check on the patients remotely enhances their care. A cybersecurity architecture for the Internet of Things to safeguard devices and patient details is an important prerequisite for this, A trustworthy hierarchical architecture-based healthcare IoT model for advanced security scenarios assurance cases, that is in alignment with the international healthcare informatics cybersecurity regulations and standards, would Reduce the vulnerabilities and security risks, thus improving the dependability of healthcare IoT models [68], [69], [70].

5.8 Artificial Intelligence

The use of artificial intelligence (AI) technologies, which are pervasive in contemporary business and daily life, is quickly expanding in the field of healthcare informatics. In many areas of patient care and administrative processes, healthcare informatics personnel may benefit from employing artificial intelligence since it will allow them to improvise on the existing solutions and find answers more rapidly. Even though the majority of AI and healthcare informatics technologies are very relevant to the healthcare informatics industry, hospitals and other healthcare informatics organizations may have quite different strategies for implementing them, and it will be several years before artificial intelligence in healthcare completely replaces people for a wide range of medical duties [71]. Machine learning is a popular application that mostly uses forms of artificial intelligence in the medical industry. It is a broad framework that serves as the foundation for several AI and medical technology methods.

5.9 Robotics

Robots are being used in healthcare informatics situations outside the surgical units to assist medical professionals and add to the provisions for patient care. For instance, to limit exposure to Coronavirus during the pandemic, clinics and hospitals are increasingly using robots for a far wider range of jobs. In research laboratories, Robotics and automation play a vital role in streamlining time-consuming and labor-intensive tasks. This allows researchers and professionals to focus their attention on more strategic duties aimed at achieving scientific breakthroughs. The use of robots and AI-enabled programs in healthcare settings also brings numerous benefits. For instance, medical robots can independently prepare and sanitize patients' rooms, reducing the need for human interaction in areas with infectious diseases. These robots are equipped with advanced medication identification systems that expedite the process of recognizing, matching, and administering medications to hospitalized patients. Overall, the integration of robotics and automation in research and healthcare sectors improves efficiency and minimizes risks [72].

5.10 Big Data Analytics

Pulling the signal from the noise is the primary purpose of data analytics in the healthcare informatics industry. For instance, one may have access to mountains of data, which one might use to control risk, enhance research, or do everything in between. However, if one doesn't have a systematic technique to arrange, examine, and understand the data, possessing it won't be very helpful. Therein, is the distinct advantage of Big Data analytics to generate precise results for a required context.

5.11 Cloud Computing

For patients and doctors alike, cloud computing in healthcare informatics creates well connected, easily accessible, and collaborative environment. Healthcare informatics analytics helps the services to become more competitive, increase quality, progress research projects, control risk, and manage reports. Every year, healthcare informatics practitioners generate enormous volumes of digital data. These consist of prescriptions, EMRs, insurance claims, and lab tests. Cloud computing makes it easier to manage that data effectively. Cloud computing's increased data storage capacity allows cloud-based analytical tools to make better use of the data and transform it into useful information. Collaboration is enhanced by using cloud technologies in healthcare informatics. Patients no longer need to bring their medical records with them when they visit a doctor, thanks to the EMR in the cloud. Doctors can collaborate by sharing data, reviewing previous consultations with other medical experts, and exchanging valuable information. This collaborative approach facilitates more accurate diagnoses and treatments, ultimately benefiting both healthcare providers and patients. Importantly, such collaboration not only improves the quality of patient care but also optimizes the use of time and resources within the healthcare system.

5.12 Edge Computing

To better serve the patients, the current health systems are implementing new technologies and creating advanced care models. These strategies concentrate on Clinical Decision Support (CDS), which gives fast, filtered, and patient-specific information to the doctors who can utilize the same to improve treatment. Processing, analytics, and storage of data are brought closer to the point of data origination with edge computing. Edge computing enhances the cloud by allowing IT decision-makers to select the appropriate location for workloads throughout the computing spectrum. This tactic can further aid the health systems in streamlining data collection, storage, and analysis.

5.13 Digital Twins

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A dynamic digital replica of the patient that was made by using previously accessible data is known as a "digital twin." Additionally, it is intended to continuously record data about that person's life. Fast Stream's digital twin solutions are designed to help physicians and other care providers better "know" the patient, resulting in more effective care interventions.

5.14 6G and Beyond

The sixth-generation telecommunications standard, or 6G, enables wireless communications technology and is currently being developed to support cellular data networks. The widespread use of 5G technology has compelled the experts to investigate what happens next. 6G is a future communication technology that will make wireless healthcare informatics a reality starting in 2030. Obstacles to the current smart healthcare informatics system trend include failure risk, security concerns, and privacy concerns. Healthcare informatics will entirely be AI-driven and depend on the 6G connectivity technology, changing how we view lifestyle and access of healthcare services.

6. Opportunities and Research Challenges in Industry 5.0

The industry provides us with the next generation and better technology, by using these technologies we can move towards better employment. The customer can customize the product according to their needs, tastes, and preferences and can make the product user-friendly by using automation. Industry 5.0 provides creative people with more options for where and how they might work, enhancing human participation in production. Employee safety has improved since hazardous tasks are performed with the help of cobots. A personalized product satisfies the customer, which makes the customer feel happy and attracted to the services on offer. As long as there is sufficient funding and technology, it provides entrepreneurs in creative and inventive industries a significant opportunity to produce new products and services associated with IR 5.0. The human-to-machine interaction is an important factor in today's technology and development. The IR 5.0 provides personalized care in healthcare, as was seen in treating COVID-19 cases. Moreover, the intelligent sensor-based device implants protect human life raise the quality of healthcare, and increase life expectancy in debilitative cases also. In IR 5.0, human involvement is raised in the automation and production process, and the same can be cross-verified with the follow-up on the services. Industry 4.0 was fully built on a Cyber-Physical System (CPS) and automated the processes, while IR 5.0 is a human-centric approach. Thus, IR 5.0 optimizes the performance with better planning of production with zero waste and moves on toward a sustainability approach that makes human life better. The basic purpose of IR 5.0 is to make products using creative thinking with better planning. Automation is an important phase that is based on the business model, but in IR 5.0 automation, the focus is on the customer's model and engineering an output that meets the end user's demands [73], [74], [75], [76]. There are many challenges at the Industry Level, device, or cloud level; some of them have been identified below [73], [74], [75], [76], [77]: -

6.1 Healthcare Data Security

Authentication, Integrity, Access control, Audit, Confidentiality Accountability, and Privacy are the main factors in providing security; many algorithms and standard protocols provide security in the Industry 5.0 ecosystem. Large quantities of data are being created by Healthcare devices in different types of fixed equipment with the help of sensors and sensor-embedded equipment. The current equipment infrastructure in the healthcare sector has not been built to handle such an enormous increase in data volume or the traffic that these data are being transmitted across. To ensure that the company, its products, and its service may benefit to the greatest extent possible, it is challenging to model the system and analyze the models.

6.2 Skilled Workforce of Healthcare Informatics Services Provider

In Industry 5.0, a skilled employee has to provide high-value tasks with better increments in the production process. Therefore, any technical skills, societal, and management concerns must be dealt with through standardization and enforcement of the legal stipulations. A trained workforce requires addressing several issues with management, workers, the workplace culture, management infrastructure, and established standards. Inadequate trainers and cost limitations create challenges for individuals working alongside cobots, hindering their ability to acquire the essential training needed. This underscores a prominent skill gap within this workforce sector.

6.3 Human-Robot Co-working

With the emergence of Industry 5.0, people will once more collaborate with cobots on the production floor. Although this cooperative method holds the potential for crafting personalized products, experts in the field need to tackle diverse issues associated with the interaction between humans and robots. Additionally, when people and robots share the labor, there are apprehensions about the downsizing of jobs done by humans as companies run on automated functions to trim their workforce. However, the cobots are programmed to do routine tasks, enabling humans to focus entirely on innovation and creativity.

Industry 5.0's growth has presented Human Machine Interface with new issues, which are mostly seen in two areas. The first is the professional users' human-centered requirements in healthcare scenarios, and the second is the growing number of non-medical professionals who work in other fields. Many Human Machine Interface studies struggle to meet Industry 5.0's sustainable and resilient requirements. To give customers a more accessible and easily manipulated interaction model, several researchers are using Extended Reality (Virtual Reality, Augmented Reality, Mixed Reality). Furthermore, several other related technologies have drawn the attention of various other domain researchers as well.

6.4 Reliable Resilient Services

When our system experiences dynamic fluctuations in workload, scalability can be characterized by the system's adaptability, resilience, and responsiveness. In the context of Industry 5.0, scalability pertains to how well a system performs in diverse operational scenarios, irrespective of the availability of hyper-connected systems in the network. Industry 5.0 is specifically designed to establish connections and interactions with a broad range of systems from different companies and diverse individuals. While scalability represents an enhancement in Industry 5.0 compared to Industry 4.0, it introduces a more significant challenge when orchestrating collaborative efforts between humans and robots or machines.

6.5 Regulatory Compliance and Safety-

Laws and regulations are a key prerequisite for each industrial revolution's complete acceptance. Although there are generally accessible automation norms, innovation strategies, and industrial rules, the more specific norms for this new period must be enforced. Various rules relevant to both humans and cobots need to be developed as Industry 5.0 seeks to reintroduce the use of human factors to collaborate with cobots and smart technology.

Ensuring workers' safety in cobots is also a big challenge in Industry 5.0. For industrial deployments to be effective and successful, safety and security must come first. Occupational hazards and health safeguards are preventive measures attached to the growth of productive activity to obtain goods or services in a safe and healthy environment for workers.

7. Limitation of Industry 5.0

It is crucial to embrace and trust these state-of-the-art technologies. Training the users of emerging technologies also enables both the acceptance and adaptation of the technology [78], [79], [80], [81], [82]. The elemental issues that plague the success of Health 5.0 are security, confidentiality, and privacy of the users' data, besides a lack of trained staff, a lengthy procedure, and a high budget requirement. Moreover, for adopting Industry 5.0, the compliance of legal and regulatory issues that guide cooperation with cobots and smart machines becomes imperative. Hence, both the providers and the avails of the technology need to be apprised of the same. Cognitive Technology, human-machine interaction, Quantum Technology, and Sustainable development goals, are the upcoming directions for Industry 5.0.

8. Conclusion

We have undertaken an appraisal of technological evolution from Industrial Revolution 1.0 to Industrial Revolution 5.0 and the parallel growth in Healthcare 1.0 to Healthcare 5.0. The study also explains the effect of these industrial revolutions on Healthcare informatics. In the current scenario, Healthcare Industry migration is a basic need for personalized services to increase the quality of care easily. This study maps a comparison of Industrial Revolution 4.0 and Industrial Revolution 5.0. More specifically, industry 5.0 has three unique factors that can be underpinned by Human-Centric, sustainable, and resilient services. Although Healthcare informatics is always improving, the one constant feature in this is the requirement for a safe healthcare informatics environment free from incidents of data breaches. Hence, the study also perused the Industry 5.0 framework and discussed all layers. The Industry 5.0 applications in healthcare present a viable option to thwart data poaching and pilfering in the healthcare sector. The study also deliberated upon the ongoing security issues brought on by the Industrial Revolution in the sphere of medicine. The study also cites various research challenges at the Industry Level. Thus, an attempt has been to underline the research gaps that require attention for upcoming future work in Industry 5.0 Healthcare informatics. This study traces the benefits of Industry 5.0 in proffering trustworthy, sustainable, and resilient personalized healthcare systems in the future, besides bringing all the stakeholders' healthcare data into the bracket of optimum security.

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