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contribution of Deep Learning and Artificial Intelligence to Attaining the Sustainable Development Goals Amidst the COVID-19 Pandemic

مساهمة التعلم العميق والذكاء الاصطناعي في تحقيق أهداف التنمية المستدامة فى ضوء جائحة Covid-19 فيروس

Submitted by:

Mohammed Abd Elmoneim Al Salamony

Fayoum University
Department of Information Systems
Faculty of Computers and Artificial Intelligence

Abstract

The worldwide turmoil triggered by the COVID-19 pandemic impacted every facet of human life, significantly affecting economies worldwide. In the realm of healthcare, progress was abruptly halted and even reversed, leading to a decline in life expectancy, particularly in less developed nations. Conversely, the pandemic witnessed a substantial contribution from deep learning and artificial intelligence (AI) on a global scale. This study seeks to evaluate the pivotal role played by AI and deep learning in mitigating the threats posed by the COVID-19 pandemic, while also deriving insights applicable to sustainable development goals.

Utilizing qualitative content analysis, the findings underscored the significant contribution of AI and deep learning in addressing the challenges presented by the pandemic. These technologies, along with digital communication tools like telehealth, played crucial roles in enhancing customer interactions, providing insights into the spread of COVID-19, and expediting research and treatment efforts. Noteworthy achievements included the scaling of communication channels and the acceleration of COVID-19-related research and treatment processes.

The key takeaway from this study is that, despite the disruptions and unforeseen consequences brought about by technological advancements, the involvement of AI and deep learning highlights their potential in addressing health crises. This underscores the importance of governments fostering trust in these technologies to effectively tackle health challenges in the future, ultimately ensuring the realization of Sustainable development objectives associated with promoting health and well-being.

Keywords: deep learning; artificial intelligence; sustainable development goals

الملخص

أثرت الاضطرابات العالمية التي أحدثتها جائحة كوفيد-19 على كل جانب من جوانب حياة الإنسان، كما اثرت بشكل كبير على الاقتصادات في جميع أنحاء العالم. فمثلا في مجال الرعاية الصحية، توقف التقدم فجأة ، خاصة في الدول الأقل تطورًا. وعلى الجانب المعاكس، شهدت الجائحة مساهمة كبيرة من التعلم العميق والذكاء الاصطناعي على مستوى العالم. تسعى هذه الدراسة إلى تقييم الدور الحيوي الذي تلعبه الذكاء الاصطناعي والتعلم العميق في التخفيف من التهديدات التي يطرحها وباء كوفيد-19، مع استخلاص رؤى قابلة للتطبيق على أهداف التنمية المستدامة .من خلال تحليل المحتوى الكيفي، حيث أبرزت النتائج الإسهام الكبير للذكاء الاصطناعي والتعلم العميق في التعامل مع التحديات التي طرحها الوباء. لعبت هذه التقنيات، جنبًا إلى جنب مع أدوات الاتصال الرقمي مثل الرعاية عن بعد، دورًا حاسمًا في تعزيز تفاعل العملاء، وتوفير رؤى حول انتشار كوفيد-19، وتسريع جهود البحث والعلاج. من بين الإنجازات الملفتة كان توسيع قنوات الاتصال وتسريع عمليات البحث والعلاج المتعلقة بكوفيد-19 .النقطة المركزية التي يمكن استخلاصها من هذه الدراسة هي أن مشاركة الذكاء الاصطناعي والتعلم العميق تبرز إمكانياتها في التعامل مع الأزمات الصحية، على الرغم من الاضطرابات والعواقب غير المتوقعة التي تسببت فيها التطورات التكنولوجية. ويؤكد ذلك على أهمية أن تعزز الحكومات الثقة في هذه التقنيات لمواجهة التحديات الصحية في المستقبل، مما يضمن في نهاية المطاف تحقيق أهداف التنمية المستدامة المتعلقة بتعزيز الصحة والرفاهية.

الكلمات المفتاحية: التعلم العميق؛ الذكاء الاصطناعي؛ أهداف التنمية المستدامة

1. Introduction

The global impact of the COVID-19 pandemic reverberated through the lives of individuals and economies worldwide. Profound alterations in the psychosocial landscape resulted from measures such as isolation, economic shutdowns, and social distancing. These restrictions, among others, wrought significant changes, exerting a profound impact on countries at large[1]. The well-being of children, adolescents, and families bore a considerable impact. Leisure activities became restricted, Educational establishments, including schools and kindergartens, were shuttered, along with limitations on social interactions were curtailed owing to social distancing measures. Simultaneously, parents found themselves grappling with the dual challenges of work responsibilities and assisting their children with schoolwork, often while working remotely. In addition to the economic downturn, widespread unemployment significantly affected the mental health of individuals[1]. Razu et al. [2] Additionally highlighted was the substantial strain on healthcare professionals tasked with treating individuals afflicted by COVID-19. The substantial risk of contracting the virus loomed over all healthcare professionals, leading to a profound impact on their mental well-being. The combination of professional stress, the constant fear of infection, and a pervasive sense of helplessness further exacerbated the psychological strain experienced by these dedicated individuals[2]. Fagherazzi et al. [3] Additionally, They emphasized that the healthcare systems of nations worldwide experienced the most profound repercussions of the virus, requiring rapid adaptation to meet the escalating demand. A concerted and comprehensive approach to pandemic response became imperative. Moreover, COVID-19 stood out as a distinctive disease, given its unprecedented scale of infection, rapid transmission rate, and diverse clinical severity spectrum. As a result, the effects of the COVID-19 pandemic exceeded those of previous pandemics such as influenza, severe acute respiratory syndrome (SARS), Ebola virus, and the Middle East respiratory syndrome (MERS). According to Fagherazzi et al. [3], The advent of the COVID-19 pandemic marked the first true global pandemic in the digital era, opening avenues for the implementation of digital health solutions. Fagherazzi et al. [3] they contend that digital health solutions had attained a certain level of maturity, although their widespread deployment and acceptance within the sector were still in progress. Nonetheless, these solutions played a pivotal role in addressing the crisis. The pandemic, in essence, served as a catalyst for health practitioners to contemplate the ways in which digital health solutions can and should be harnessed to effectively combat such crises. Haleem and Javaid [4] They argue that Medical 4.0 stands out as a crucial tool in addressing the pandemic, emphasizing its utilization of advanced technologies to tackle the challenges posed by COVID-19. Consequently, there has been a growing application of artificial intelligence (AI) and deep learning in COVID-19 research. Islam et al. [5] They assert that AI has been employed in COVID-19 research across domains such as diagnosis, classification, detection, severity, and mortality risk. Moreover, they contend that the use of AI and deep learning has been steadily increasing even before the pandemic. Advanced AI algorithms have been developed to adeptly address intricate tasks with efficiency and effectiveness [6]. During the COVID-19 pandemic, AI emerged as a critical tool employed for monitoring and controlling the spread of the virus. Senthilraja, [6] Indicated that healthcare professionals started seeking technologies to monitor and control the pandemic. On the contrary, Harrus and Wyndham [7] emphasized that these technologies bring about both intended and unintended consequences. Despite this, the evident potential of AI in mitigating the adverse effects of the global pandemic became apparent. The utilization of AI saw a surge in applications when the pandemic initially emerged in China. According to Harrus and Wyndham [7], the COVID-19 pandemic served as a catalyst for affirming the value of AI practitioners, presenting a unique opportunity to demonstrate AI's capacity to benefit humanity. However, the challenges associated with technological use persisted alongside the pandemic.

Harrus and Wyndham [7] noted that the incorporation of AI in the battle against COVID-19, in a way, exacerbated pre-existing issues affecting vulnerable populations. The pandemic exacerbated social inequalities worldwide. The use of technology, such as AI, did little to alleviate disparities that existed before the pandemic. Issues like limited access to healthcare, resource inequalities, and variations in the quality of care did not see significant improvements, especially for vulnerable communities. This was

attributed to challenges such as insufficient data and obstacles related to the universal acceptance of telemedicine, among other reasons.

For instance, data from The American Public Media Research Lab revealed that individuals in certain occupations, such as cashiers, cleaning crews, delivery services, restaurant servers, and trade workers, along with their families, faced higher proportions of exposure to the virus compared to other occupational groups. Other highly exposed groups included healthcare professionals, teachers, and nursing home workers, among others.

In spite of concerns and the adverse impact of the pandemic on humanity, Senthilraja [6] Highlighted was the pivotal role of AI in monitoring the virus's spread, identifying high-risk patients, and real-time pandemic control. Additionally, it noted AI's contribution to predicting mortality risks by effectively analyzing historical patient data. Another significant aspect mentioned was AI's support in combating COVID-19 through patient screening, medical examinations, and aiding in notification and infection control recommendations. Furthermore, AI played a crucial role in enhancing the planning and treatment of COVID-19 patients.

Islam et al. [5] Moreover, it was contended that the use of AI to mitigate the impact of the COVID-19 pandemic has witnessed a notable increase, particularly in areas such as diagnosis, classification, detection, severity assessment, and mortality risk prediction. A different study conducted by Vaishya et al.[8] Suggested was the contention that healthcare, as a whole, necessitates extensive support from innovative technologies like AI, the Internet of Things (IoT), big data, and deep learning. Their literature review revealed numerous applications employed in identifying clusters of COVID-19 cases and predicting the future areas impacted by the virus through the collection and analysis of historical data. The conclusion drawn was that decision-making technologies, particularly AI, play a crucial role in managing viruses and are highly valuable in vaccine development. A different research investigation conducted by Khan et al., [9] Additionally emphasized was the effective utilization of AI in mitigating the adverse impacts of the severe COVID-19 pandemic. The study found that AI has proven successful in detecting the pandemic, conducting screenings, classifications, repurposing drugs, predicting virus trends, and providing forecasts. Against this backdrop, the current research aims to explore the contributions of AI and deep learning in addressing the COVID-19 pandemic and derive insights pertaining to lessons learned in the context of the fourth industrial revolution and the sustainable development goals, with a particular emphasis on goal three.**Sustainable Development Goals (SDGs)**

The SDGs are commonly asserted to be interconnected, indivisible, and applicable on a global scale [10]. Another characteristic of the SDGs is their universal applicability; these goals can be implemented in diverse countries with distinct realities, capabilities, and developmental levels [11]. The United Nations [10] It was also mentioned that the SDGs typically align with the national policies and priorities of various countries worldwide. Conversely, the United Nations observes the targets associated with the various SDGs [10] each country establishing its national targets based on its unique circumstances and guided by the overarching global ambition. Another crucial aspect of the targets is that each government independently determines how the global targets should be integrated into national planning processes, policies, and strategies. When the United Nations and other stakeholders introduced the goals and targets, they considered the specific challenges faced by the most vulnerable nations, including African countries, the least developed nations, landlocked developing nations, and Small Island developing states. The development of the goals also took into account the unique challenges experienced by middle-income countries and those in conflict situations.

A significant impediment to effectively monitoring and evaluating the progress and performance of member states in alignment with the SDGs is the widespread absence of baseline data for many targets. The advancements of the fourth industrial revolution offer opportunities for efficient data mining, ensuring that national and global baselines become available. This, in turn, enables the measurement of progress among member states, especially for targets lacking clear numerical objectives.

Table 1 below provides a summary of the seventeen sustainable development goals. Although the COVID-19 pandemic impacted all goals from one to seventeen, goal three was particularly affected. Goal

three aims to ensure health and well-being for all, with a significant commitment to ending epidemics of AIDS, tuberculosis, malaria, and other communicable diseases by 2030[11, 12]. The United Nations [11] The COVID-19 pandemic has been reported to reverse the previously achieved progress in health. Prior to the pandemic, significant advancements were made globally in enhancing the well-being of millions of people. Progress was evident in improving life expectancy and reducing certain diseases linked to child and maternal mortality [11, 13] The United Nations [10] It was also emphasized that the pandemic serves as a crucial moment for enhancing health emergency preparedness and investing in essential 21st-century public services. Regarding the utilization of AI and deep learning in addressing the SDGs from one to seventeen, substantial evidence indicates that, if effectively leveraged, AI can contribute significantly to achieving most of these goals. Presently, AI capabilities are being employed to advance societal objectives. For example, AI applications, coupled with satellite imagery, were utilized in Houston after Hurricane Harvey to identify secure evacuation routes for individuals trapped by rising waters. AI-powered object detection is also central to recent applications that aid many visually impaired individuals in developing countries. Notably, the Microsoft application, working in conjunction with a smartphone, utilizes AI to recognize friends, describe people, and identify specific objects such as currency bills. This serves as a testament that, when appropriately utilized, AI can play a crucial role in advancing societal goals

Table 1. Sustainable development goals.

Sustainable Development Goals	Description
Goal 1	Eradicate poverty in all its forms globally
Goal 2	Eliminate hunger, achieve food security, promote sustainable agriculture, and improve nutrition
Goal 3	Ensure universal well-being and happiness for people of all ages
Goal 4	Guarantee that every student receives an inclusive and equitable high-quality education, and that opportunities for lifelong learning are accessible to all
Goal 5	Support the attainment of gender equality for all women and girls
Goal 6	Secure the well-being and happiness of people of all ages, promoting healthy lives
Goal 7	Ensure universal access to affordable, reliable, sustainable, and modern energy
Goal 8	Promote enduring, inclusive, and sustainable economic growth, along with full and productive employment, ensuring decent work opportunities for all
Goal 9	Construct resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
Goal 10	Diminish inequality within and between countries
Goal 11	Guarantee that cities and human settlements are inclusive, secure, resilient, and enduring
Goal 12	Secure sustainability in consumption and production patterns
Goal 13	Implement prompt measures to tackle climate change and its repercussions
Goal 14	Promote sustainable development by conserving and responsibly utilizing oceans, seas, and marine resources
Goal 15	Protect, restore, and advocate for the sustainable utilization of terrestrial ecosystems, practice sustainable forest management, prevent desertification, reverse land degradation, and halt biodiversity loss
Goal 16	For sustainable development, foster peaceful and inclusive societies, ensure universal access to justice, and establish effective, accountable, and inclusive institutions at all levels
Goal 17	Enhance and revitalize the implementation mechanisms of the Global Partnership for Sustainable Development

3. Telemedicine/Telehealth and Goal Three, Ensure Healthy Lives and Promote Wellbeing for All at All Ages

Telemedicine is described as "the provision of healthcare and the exchange of healthcare information over distances"[14]. Therefore, telemedicine is not merely a technology or a medical discipline. Typically, telemedicine involves real-time or pre-recorded interactions between a client and an expert, with transmitted information encompassing text, audio, and even video. Craig and Petterson [14] Indicated that telemedicine has been utilized in emergency situations where no alternative is available, particularly in remote environments. It may also be suitable in situations where it outperforms conventional services, such as tele-radiology for rural hospitals. It is believed that telemedicine has played a beneficial role in enhancing equity of access to healthcare, improving the quality of care, and enhancing the effectiveness and efficiency of service delivery [14]. Hjelm contended that telemedicine offers several advantages, such as providing effective and efficient access to information, delivering care to individuals who have not received it before, enhancing professional education, ensuring quality control of screening programs, and reducing healthcare costs. However, despite these benefits, there are associated challenges, including potential breakdowns in the relationships between health professionals and patients, as well as issues related to the quality of healthcare information, among others [15]. Nevertheless, despite the challenges, telemedicine proves highly beneficial, particularly with increased research to mitigate these challenges. Another significant aspect of telemedicine is its role as a reliable source of data. Given that AI and deep learning heavily rely on the availability of big data, telemedicine can significantly contribute to providing such data. This data can play a pivotal role in diagnosis and prevention across various diseases, potentially averting exacerbations. Utilizing information communication technologies to overcome geographical barriers ensures accessibility to healthcare, even in remote, rural, and underserved communities in developing nations, thereby making big data accessible in these areas.

4. Brief Description of AI

AI, an expansive field within computer science, involves the creation of systems capable of intelligent and autonomous functioning. In essence, AI constitutes a constellation of diverse technologies collaboratively working to Empower machines to perceive, comprehend, act, and learn at a level of intelligence akin to that of humans. The main categories of AI are narrow AI, also known as weak AI, and general AI, also referred to as strong AI. Narrow AI, prevalent in everyday applications like weather forecasts and digital assistants, focuses on executing single or related tasks, showcasing its strength within specific domains. While narrow AI is potent, its limited scope gives rise to the terms "narrow" and "weak."

Weak or narrow AI possesses transformative potential, especially when correctly applied, influencing global work and lifestyle dynamics. It primarily emphasizes enhancing efficiencies across various settings. On the contrary, general AI, or strong AI, denotes a type of artificial intelligence in which machines emulate human intelligence, displaying strategic, abstract, and creative thinking while handling diverse complex tasks. The full realization of general AI is an ongoing process, with current AI applications serving as extensions of human capabilities rather than replacements. Therefore, effective collaboration between humans and machines is crucial.

AI manifests through various forms, such as statistical learning, focusing on speech recognition, where machines mimic human speech patterns. Another facet is natural language processing, enabling machines to read and write in a language. Computer vision allows machines to see and process information symbolically, while pattern recognition involves machines discerning patterns, particularly in deep learning contexts requiring extensive data and dimensions. Robotics is a field where machines understand and navigate their environment seamlessly.

Drawing inspiration from the human brain, AI leverages neural networks to attain cognitive capabilities. The field of deep learning involves complex neural networks learning intricate tasks.

Different types of deep learning techniques, such as convolutional neural networks for image recognition, recurrent neural networks for limited memory, and symbolic or data-based learning, contribute to AI's diverse capabilities. These techniques can be employed for classification or prediction tasks, showcasing the versatility and potential of AI applications.

5. Brief Outline COVID-19 and the Global Economy

The COVID-19 pandemic ushered in disruptions across all sectors of the global economy, affecting schools, churches, and businesses alike. Some companies, including major ones like Evergrande Group in China, struggled to recover from the pandemic's adverse effects. The energy crunch in China prompted the national government to initiate a stringent regulatory crackdown. Worldwide, the prices of fuel and food are on the rise, exacerbated by delays in the movement of goods due to port congestion and strained supply chains, leading to increased commodity prices.

The pandemic also resulted in labor shortages in certain countries. For example, the United Kingdom experienced a shortage of truck drivers, necessitating the introduction of temporary visas for 5000 lorry drivers to work in the UK. This scarcity was attributed to a combination of factors, including COVID-19 and the impacts of Brexit. Energy shortages in countries like China posed significant challenges for production, with manufacturers revising production levels downward, prompting economists to revise growth forecasts. The United Nations Department of Economic and Social Affairs [16, 17] noted that the swift rollout of vaccinations contributed to an improvement in growth prospects for some economies. Following a sharp contraction of the global economy by 3.6 percent in 2020, projections indicate a 5.4 percent expansion in the global economy in 2021. Substantial growth in the United States of America and China has bolstered the outlook for a global recovery, though the growth may not be sufficient to uplift the rest of the world's economies. Despite global growth projections, countries in South Asia, Sub-Saharan Africa, Latin America, and the Caribbean face a fragile and uncertain economic outlook in 2021. The pandemic poses a threat to many vulnerable nations, risking a lost decade due to insufficient fiscal capacity to stimulate demand and the potential for a prolonged pandemic. In numerous developing nations, economic output is anticipated to return to pre-pandemic levels in 2022 and 2023. Regarding poverty, The United Nations Department of Economic and Social Affairs [16] reported that the COVID-19 pandemic forced approximately 114.4 million people into extreme poverty, with 57.8 million of them being women and girls. Women experienced more job and income losses than men, primarily due to the increased responsibilities of caring for children during the peak of the pandemic. The significant representation of women in health service roles, caregiving, and essential services contributed to the higher number of women pushed into poverty.

Table 2 provides a summary of the global output and gross domestic product (GDP) growth, illustrating the impact of COVID-19 on GDP growth worldwide and in developed nations. The figures in the table reveal a substantial decline in world output in 2020, approximately -3.6%, compared to the 2.5% growth in 2019. The pandemic significantly affected developed nations, with a drastic 5% decline in GDP growth in 2020. Countries like the United States, Japan, and the United Kingdom experienced a profound impact, with a

9.9% fall in GDP in the United Kingdom. Other developed nations witnessed a 3.5% decrease in GDP. This underscores the substantial impact of the COVID-19 pandemic on global economies. Table 3 outlines the GDP growth of economies in transition during the COVID-19 pandemic.

Table 2. Growth of world output and Developed Nations

	2022 Projected Growth	Projected2021 Growth	2020 GDP Growth	2019 GDP Growth
World Output	4.1	5.4	3.6-	2.5
Developed Economies	3.4	5.0	5.0-	1.7
United States of America	3.2	6.2	3.5-	2.2
Japan	2.2	3.3	4.8-	0.3
The United Kingdom Great Britain and Northern Island	5.5	5.1	9.9-	1.3
Other developed Nations	2.9	3.6	3.5-	1.7

Table 3. Growth of GDP of Economies in Transition.

	2022 Projected Growth	Projected2021 Growth	2020 GDP Growth	2019 GDP Growth
Economies in Transition	3.3	3.3	-2.7	2.2
South-Eastern Europe	3.5	4.2	-3.5	3.7
Commonwealth of the Independent States and Georgia	3.3	3.3	-2.6	2.2
Russia Federation	3.0	3.0	-3.0	1.3

Table 4. Growth of gross domestic product of Developing Economies

	2022 Projected Growth	Projected2021 Growth	2020 GDP Growth	2019 GDP Growth
Developing Economies	5.0	6.1	-1.7	3.6
Africa	3.7	3.6	-3.5	2.9
Northern Africa	4.0	5.6	-5.5	3.2
East Africa	4.5	3.3	0.1	6.5
Central Africa	3.2	3.0	-1.8	1.9
West Africa	3.6	2.7	-1.0	3.3
Southern Africa	2.6	2.2	-6.1	-0.2
East and South Asia	5.7	7.1	-0.1	4.9
East Asia	5.2	7.1	1.0	5.3
China	5.8	8.2	2.3	6.1
South Asia	8.3	6.9	5.6-	3.1
India	10.1	7.5	6.8-	4.6
Western Asia	3.4	3.7	3.2-	1.2
Latin America and the Caribbean	3.3	4.3	7.3-	0.3-
South America	3.1	4.1	6.8-	0.7-
Brazil	2.4	3.0	4.1-	1.4
Mexico and Central America	3.6	4.7	8.2-	0.6
Caribbean	6.8	4.3	8.1-	0.5
Least developed countries	5.0	4.0	0.3-	4.9
World trade of Goods and Services	5.7	9.4	8.1-	1.2

Table 4 provides the GDP growth for developing countries and the least developed countries. Developing economies experienced a 1.7% decline in GDP in 2020, primarily due to the adverse effects of the COVID-19 pandemic. In Africa, GDP fell by 3.5%, contrasting with a growth of 2.9% in the previous period. Northern Africa was severely affected, witnessing a 5.5% decline in GDP from a 3.2% growth in 2019. Regions significantly impacted in developing nations included Mexico and Central America, experiencing an 8.2% decline in GDP, followed by the Caribbean with an 8.1% drop. Southern Africa also faced a substantial GDP reduction, falling by 6.1%. However, East Asia saw a positive growth of 1%, with China registering a 2.3% GDP increase compared to a 6.1% growth in 2019. Least developed nations had a modest GDP growth decline of 0.3%, relatively small compared to other developed nations. In summary, the pandemic had a profound impact on the GDP growth of nearly all countries worldwide. Another affected aspect was the world trade of goods and services, which declined by 8.1% in 2021. According to the OECD [18], the COVID-19 pandemic exposed vulnerability in the healthcare systems around the globe. The OECD indicated that the pandemic would have serious implications for health, social cohesion, trust in governments, and economic progress. According to the United Nations before the pandemic, there has been progressing in the improvement of the health of a lot of people around the globe. Progress was made in improving life expectancy and the reduction in the common killer diseases associated with child and maternal mortality. The United Nations also admit that more effort is required to ensure that many diseases are fully eradicated. It was highlighted that "the provision of more funding of healthcare systems, improved sanitation and hygiene, and increased access to physicians, significant progress can be made in helping to save the lives of millions". The pandemic, on the other hand, led to the serious loss of human life, presenting an unprecedented challenge to public health. The World Health Organization [19] As of December 31, 2020, it was reported that around 82 million people had been infected, and more than 1.8 million had lost their lives globally due to COVID-19. Preliminary estimates from the World Health Organization indicated that the excess deaths, both directly and indirectly attributable to COVID-19 in 2020, were approximately 3 million. This figure was 1.2 million higher than the official counts reported by various nations to the World Health Organization. The substantial number of deaths and infections had a severe impact on healthcare systems worldwide, leading to a reversal of the progress previously achieved in life expectancy. The subsequent section will provide a brief literature review to contextualize the current study.

6. Brief Review of Literature

The literature on the influence of Artificial Intelligence on COVID-19 is expanding and showing positive trends. For instance, Senthilraja [6], Adadi et al. [20], and Islam et al. [5], Various authors, including numerous others, have detailed the application of AI in the healthcare sector, specifically in mitigating the effects of COVID-19. The literature consistently highlights the utilization of AI in health to address the adverse consequences of the pandemic. The present research aims to explore the insights gained from the fourth industrial revolution and its impact on achieving sustainable development goals, with a specific focus on goal three, pertaining to good health and well-being. Senthilraja [6] found out that AI plays a critical role in combating the negative implications of COVID-19. It found that AI has been used in activity predictions such as physicochemical properties, and further found that AI has been helpful in the treatment and health monitoring of COVID-19 patients. AI has been applied in tracking COVID-19 at various scales such as medical, molecular, and epidemiological applications, and also insinuated that AI has been helpful in COVID-19 research by assisting in the analysis of the available data and drug development. All this information is a testimony that AI has helped address the negative implication of COVID-19.

Another study by Adadi et al. [20] Unveiled the substantial contribution of AI in addressing the challenges posed by the COVID-19 pandemic. The authors highlighted the escalating interest in employing AI for COVID-19-related matters, resulting in a surge of AI research output, marked by a notable increase in articles and review studies within a condensed timeframe. A study by Islam et al. [5]

also highlighted that the application of AI in health has been on the rise, and the rate has been increased exponentially by the COVID-19 pandemic. Yu et al. [21] Additionally suggested that AI is transforming medical practices, attributing the heightened use of AI in the healthcare sector to advancements in big data acquisition, deep learning, and the ongoing progress in computing infrastructure development. Yu et al. [13] Moreover contended that AI is now being deployed in domains traditionally reserved for human expertise, a shift propelled by advancements in data acquisition and the augmentation of computing power. Another study by Davenport and Kalakota, [22] also substantiated the assertions made by Yu et al.[21] (2018). Davenport and Kalakota [22] asserted that the surge in healthcare data is driving the application of AI in the healthcare sector. Davenport and Kalakota [22] argue that AI is utilized for treatment recommendations and diagnoses, and in certain cases, it is employed for patient engagement, adherence, and even administrative functions. Davenport and Kalakota, [22] also emphasized that while AI can now be employed in numerous scenarios, including tasks previously carried out by humans, certain implementation constraints currently hinder its complete replacement of human roles in the near future. Reddy et al. [23] also presented arguments that align with the concepts of Yu et al. [21] and Davenport and Kalakota, [22]. Reddy et al. [23] also indicated that, in the recent years, AI technology has been advancing rapidly, particularly with the growth of deep neural networks, robotics, computer vision, and natural language processing. They suggested that these AI technologies are increasingly utilized in healthcare, raising the possibility that AI may eventually assume roles traditionally performed by clinicians and administrators in the years to come. One outstanding argument by Reddy et al. [23] argued that, despite AI playing a crucial role in healthcare delivery, it is premature to assert that AI will entirely supplant the functions of human clinicians. Instead, they emphasized that AI will significantly influence clinical decision support, health interventions, patient monitoring, and administration. They foresee AI having a vital role in AI-enabled or AI-augmented health systems. Sipior [24] highlighted that AI is playing a pivotal role in combating COVID-19, offering rapid solutions that were previously unattainable across various fields and applications. The paper emphasized the surge in the exploration and utilization of AI, along with various data analysis tools, since the onset of the pandemic. It delved into management considerations essential for the successful deployment of AI applications, including planning, addressing potential biases, recognizing the importance of data, and promoting diversity in AI team membership. In conclusion, it underscored the necessity for thoughtful consideration of issues associated with the development and use of AI as humanity seeks expedient solutions. Vaishya et al. [8] also conducted a comprehensive review of AI's role in analyzing, preventing, and combating COVID-19 and other pandemics. The study identified seven distinct applications of AI, including the detection of cluster cases and predicting the virus's future impact through data collection and analysis. It emphasized AI's crucial role in vaccine development, as well as predicting and tracking both current and future patients. The review underscored AI's proficiency in emulating human-like intelligence. As the literature highlighted AI's substantial contributions to addressing COVID-19-related challenges, it prompts the question: What lessons are we gaining regarding the fourth industrial revolution and the sustainable development goals through the application of AI to mitigate the effects of COVID-19?

7. Methodology

This study utilized secondary desktop research to explore the role of AI in addressing the COVID-19 pandemic and to extract insights regarding lessons learned in the context of the fourth industrial revolution and sustainable development goals, with a specific focus on goal three. The research methodology employed qualitative content analysis. Stemler [25] defined content analysis as “a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding”. Prasad [26] Additionally described content analysis as the scientific examination of communication content. Prasad [27] Further contended that content analysis involves the exploration of meanings, contexts, and intentions embedded in messages. Stemler [25] ontends that in the era of big data, content analysis emerges as a potent methodological tool for researchers to wield with

effectiveness and efficiency. It suggests that content analysis can be applied adeptly across various data modes, encompassing textual, audio, and visual data. Given the considerable surge in COVID-19 research across diverse topics, including the role of AI in mitigating its adverse effects, content analysis stands out as a particularly effective technique. Moreover, the diverse forms of COVID-19 data, spanning text, visuals like photographs or videos, and audio, make content analysis a versatile and efficient method. Stemler further notes that the method is highly flexible, accommodating both empirical and theoretical approaches.

Table 5 provides a concise overview of all the sources considered in the content analysis. The compilation encompasses journal articles from various journals, reports, media articles, and other relevant documents.

Table 5. Sources that helped in shaping the trajectory of the study.

Journal Articles	Reports	Media Articles	Others
100	25	25	55
Journals targeted were those published from the year 2000 up wards though Work from previous years was considered. Publishers Springer Nature, Multidisciplinary Publishing, Es, Elsevier Institute of Electrical and Electronics Engineers, etc.	United Nations, The World Bank, The World Health Organization for Economic Cooperation and Development (OECD) among others Media Articles	Media articles from Various countries were used for instance United State of America, South Africa, the United Kingdom among other nations.	Various other documents were consulted to come up with the ideas that shaped the trajectory of the study.

8. Results and Discussion

Since the onset of the COVID-19 pandemic, the influence of AI as a technology within the Fourth Industrial Revolution has been evident to some degree, yet concurrently unregulated [28]. AI applications have found utility in the healthcare sector for diverse purposes, encompassing drug development and approval, population movement monitoring, disease forecasting, and other significant uses. The advent of the pandemic prompted a surge in the utilization of AI applications to mitigate the adverse effects of the virus. The subsequent section will delineate the domains in which AI was deployed to counteract the detrimental repercussions of the virus. It is noteworthy to emphasize that the proliferation of Big Data facilitated all applications of AI and deep learning.

8.1. Accelerating the Investigation and Treatment of Complications Related to COVID-19

AI played a crucial role in the efficient and effective development of COVID-19 vaccines, identifying existing vaccines that could be repurposed into new vaccines and therapeutics [28]. The development of drugs and vaccines typically involves a lengthy process, integrating various fundamental scientific disciplines like biology, chemistry, and pharmacology [28, 29].

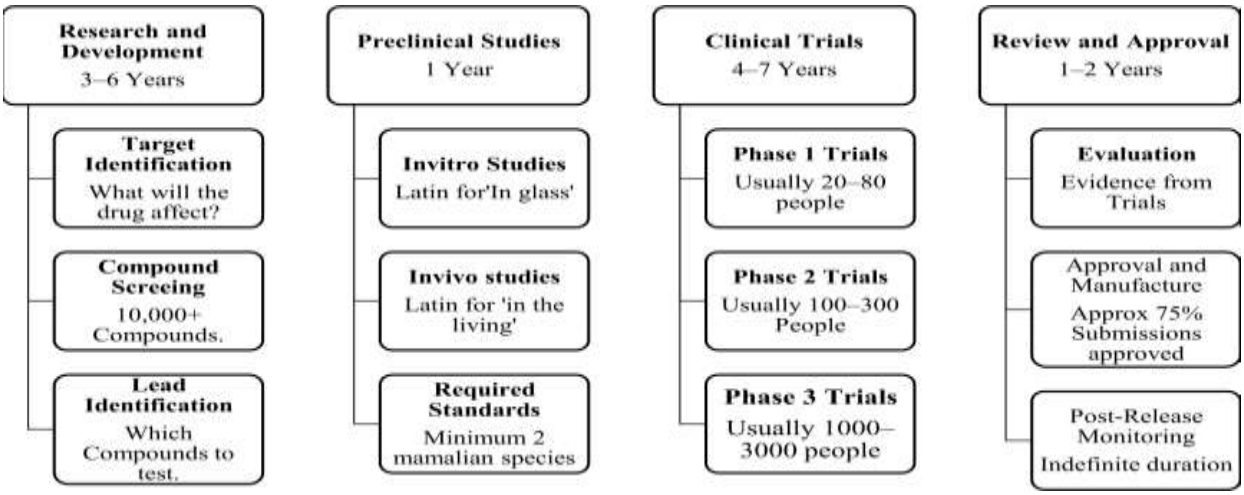

Figure 2. Traditional drug development process. [30].

Smalley [31] Stated that algorithms based on AI can be utilized in the initial phases of drug development to streamline the selection of compounds and eliminate drugs associated with potential adverse reactions. Harrus and Wyndham [28] Argued that the utilization of AI in drug development and repurposing existing drugs intensified due to the COVID-19 pandemic. Repurposing existing drugs proved advantageous in expediting drug approvals, as these drugs were already in use with measured and known side effects. The approval process would then hinge on the drug's effectiveness for the intended use, rather than its initial approval purpose. According to Richardson et al. [32], A startup named Benevolent AI, specializing in AI-driven drug development, proposed utilizing a rheumatoid arthritis drug called Baricitinib to alleviate severe COVID-19 symptoms. Acting on this information, the drug's manufacturer, Eli Lilly, collaborated with the US National Institute of Allergy and Infectious Diseases, and subsequent clinical trials demonstrated effectiveness. The connection between the arthritis drug and COVID-19 would likely have remained undiscovered without the assistance of AI[33, 34]. Algorithms based on AI demonstrated significant efficacy in developing and repurposing drugs to combat the adverse effects of the COVID-19 pandemic. Harrus and Wyndham [28] The argument emphasizes the need for continued research on drug repurposing and development beyond the COVID-19 pandemic. The insights into the capabilities of AI in these areas underscore the potential of the Fourth Industrial Revolution and its technologies, particularly AI, to significantly contribute to achieving Sustainable Development Goal three.

8.2. Leveraging AI for Predictive Analysis and Enhancing Customer Communications Amid the Pandemic

The initial detection of the COVID-19 virus was achieved through AI-powered forecasting applications, marking a pivotal moment that spurred extensive AI utilization in the battle against the pandemic. AI applications played a crucial role in offering global insights into the pandemic. For instance, BlueDot, a health monitoring company based in Canada, utilized AI to alert its employees and customers to the potential outbreak of a new pneumonia-like disease originating from China's Wuhan Province. According to Neiiler [35], The information provided by BlueDot to its customers preceded the warnings from the World Health Organization (WHO) by 10 days and even preceded the alerts from the United States Centers for Disease Control and Prevention (CDC) by seven days. Leveraging both health-related and non-health-related big data, the company effectively employed AI techniques to forecast the outbreak of the disease and its patterns of spread. BlueDot notably achieved the ability to predict, with precision, the cities where the disease would be detected next. AI also played a crucial role in predicting the spread and assessing the severity of the COVID-19 virus. For instance, Li et al. [36] Conducted a study that analyzed the data available on the epidemic situation in Hubei. Through the power of big data,

Li et al. [36] succeeded in predicting the virus's evolutionary trend using existing data and devised effective controls for the pandemic. Through the existence of data, Li et al. [36] successfully predicted the pandemic's development trends in countries like South Korea, Iran, and Italy. This demonstrates the effective application of AI in forecasting and mitigating the virus's spread and its adverse effects. Senthilraja [6] highlighted that AI systems detected the virus outbreak before it became widely known, emphasizing the ongoing importance of utilizing various AI applications to support policymakers, the medical community, and society. This indicates that AI has substantial potential in shaping relevant policies for addressing future pandemics and achieving sustainable development goals. Additionally, AI played a crucial role in diagnosing, containing, and monitoring the virus during the pandemic.

8.3. Diagnosis, Containment and Monitoring

Effectively diagnosing and swiftly screening the virus were crucial aspects in containing its spread during the pandemic. According to Nguyen [37], Numerous AI applications were suggested during the peak of the pandemic, although their implementation varied across different scenarios. Some faced challenges in large-scale adoption but were tested in smaller trials. The difficulties in training efficient AI models using data that may not accurately represent the overall population posed obstacles. Despite these challenges, the significance of AI applications increased, as rapid diagnosis of COVID-19 cases contributed to efficient hospital bed allocation and other critical initiatives. According to Zhou et al. [38], In China, the number of applications utilizing diverse deep learning techniques surpassed 100 as of March 2020. Similarly, in Italy, these applications were already in use as early as April 2020, as disclosed by [39]. Zhou et al. [38] highlighted that certain AI applications proved beneficial in distinguishing COVID-19 chest X-rays from other diseases, like influenza pneumonia. Kondylakis et al. [40] pointed out that numerous mobile applications were created in an effort to mitigate the adverse effects of the COVID-19 pandemic and curb the increasing numbers of the virus. Kondylakis et al. [40] suggested that diverse mobile applications were employed for purposes such as information sharing, self-management of symptoms, contact tracing, decision-making, risk assessment, and home monitoring. Singh, et al. [41] discovered that a variety of mobile health applications were utilized in addressing the COVID-19 disease, primarily for activities such as contact tracing and symptom monitoring. Again, Patel [42] suggested that mobile applications could serve for remote initial triage of individuals undergoing a cough test, providing additional screening and medical attention. Patel [43] emphasized that these mobile applications played a crucial role in preventing unnecessary hospital visits and the excessive utilization of limited medical resources. Senthilraja [6] suggested that AI possesses the capability to track and predict the characteristics of the virus using vast datasets from platforms like social media and media outlets, assessing the infection risk and the rate of disease spread. Another crucial aspect is AI's ability to forecast positive cases and deaths in specific regions, aiding in the preparation of strategies to combat the pandemic.

8.4. AI and Understanding How COVID-19 Spreads, Treatments and Cures

One widely employed application was geofencing, or green passports. Originally used as a marketing tool to track a cellphone's location and notify owners about nearby stores and products, geofencing saw extensive use during the pandemic for quarantine purposes by commercial entities. According to Hui [44], In China, geofencing was employed to monitor individuals during quarantine. Additionally, geofencing was utilized to delineate infected areas and provide information to health authorities, showcasing the capabilities of AI in these applications [45]. According to Wesner [46], In the United States of America, geofencing was not implemented due to concerns about limiting freedom of movement and the potential for misuse. Instead, Australia introduced a vaccine passport, recording all vaccinated individuals in a centralized database called the Australian Immunization Register. Other countries like Denmark, the European Union, Israel, and the Netherlands also adopted the vaccine passport system. Senthilraja [6] AI has played a crucial role in addressing diseases like COVID-19, particularly in response to the demand for surveillance. The virus's global spread, influenced by human activities such as migration, necessitated the development of applications capable of monitoring people's movements and tracking the virus's spread.

For instance, Blue Dot, a company utilizing AI deep learning and natural language processing, effectively tracked and reported the virus's spread. Senthilraja [6] Additionally, it was emphasized that AI plays a crucial role in treating and curing illnesses related to COVID-19, particularly through real-time data analysis. Analyzing current data provides timely information to help prevent disease spread. AI-generated insights can predict infection sites, virus influx, and guide healthcare resource allocation, including the need for beds. The argument further suggests that AI serves as a valuable tool in preventing future viruses by identifying their traits, causes, and reasons for spread.

8.5. AI Lessons on the Fourth Industrial and Sustainable Development Goals

Reflecting on the rapid achievements of AI in combating COVID-19, valuable insights can be gleaned regarding its impact on Sustainable Development Goal three. The effectiveness of AI in addressing the pandemic offers lessons on the implications of the Fourth Industrial Revolution for the realization of goal three, which aims to 'Ensure healthy lives and promote well-being for all. According to the United Nations [47], Significant strides have been made in reducing child mortality, improving maternal health, and combating HIV/AIDS, tuberculosis, malaria, and other diseases since the inception of the Millennium Development Goals. Over the past 15 years, there has been a decline in the annual number of new HIV infections from 3.1 million to 2 million, with approximately 6.2 million lives saved from malaria. Maternal mortality has fallen by 45% since 1990, and globally, preventable child deaths have decreased by over 50%. Despite this progress, the COVID-19 health crisis has exposed disparities in countries' ability to recover, hindering efforts to achieve the Sustainable Development Goals by 2030. The pandemic severely reversed strides in ensuring health and well-being for all, including commitments to end epidemics of AIDS, tuberculosis, malaria, and other communicable diseases by 2030. Nonetheless, we have witnessed the transformative power of AI in expediting research and treatment of COVID-19-related complications, forecasting, scaling customer communications, diagnosis, containment, monitoring, and understanding the virus's spread, treatment, and cure. By investing in AI, countries can surpass pre-COVID development trajectories due to its transformative impact on economies. The question arises: What are the implications of AI for achieving sustainable development goals, particularly goal 3? Figure 2 outlines the targets of goal 3, emphasizing that every individual can contribute to meeting global goals. AI, as demonstrated in its response to the pandemic, can play a pivotal role in promoting health, well-being, and achieving these targets. Figure 3 summarizes the various ways AI can contribute to achieving sustainable development goals, indicating that its application in healthcare can enhance accessibility and reduce costs, facilitating progress toward goal 3 and its targets.". This aligns with the assertions made by Vinuesa et al. [48], who found that evaluating the application of AI across various sectors is crucial, particularly considering its influence on sustainable development goals. They identified that AI has the potential to contribute to achieving 134 targets of the SDGs. They emphasized the need for national support in AI development, involving regulatory insight and oversight for AI-based technologies, to ensure the realization of sustainable development. Reddy et al. [49] also endorsed the notion that the use of AI in healthcare is becoming more apparent, with a potential for its application in routine clinical care in the near future. They also hinted at the growing promise of AI, prompting governments and technology companies worldwide to intensify their investments in AI medical applications. Holzinger et al. [50] also suggested that the primary force behind digital transformation is AI, emphasizing the undeniable vast potential of AI to generate benefits for both humanity and the environment. Holzinger et al. [50] contend that AI has the capability to contribute to discovering novel solutions for the critical challenges confronting humanity in various domains, spanning agriculture to healthcare, and beyond.

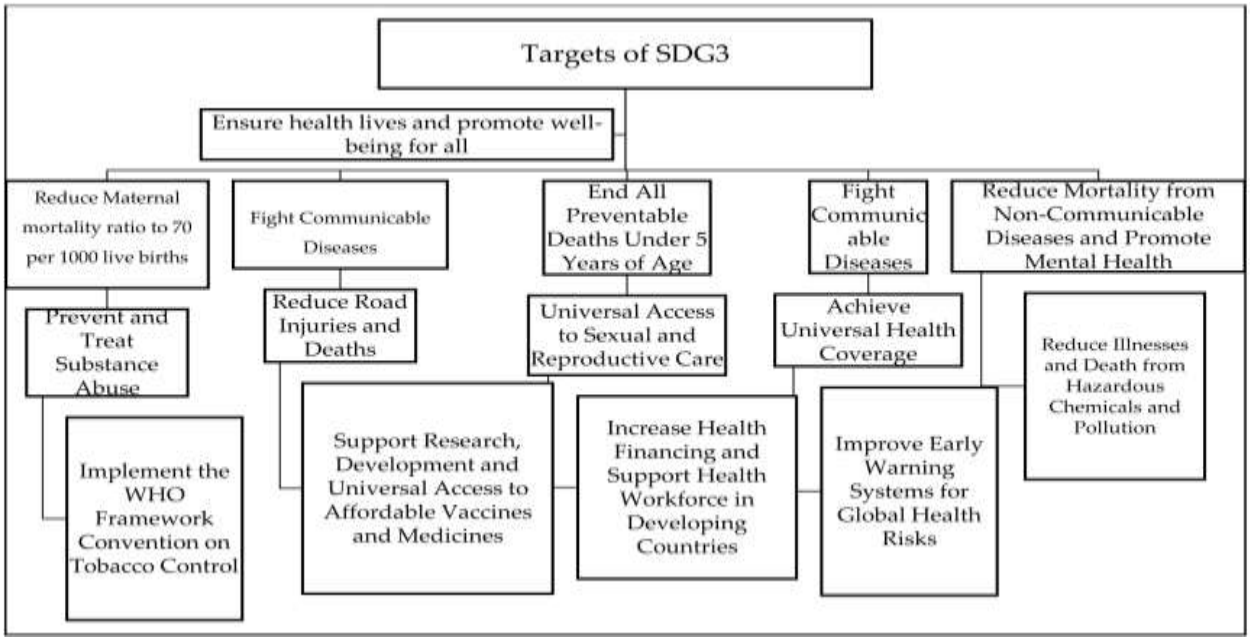

Figure 3. target of the sustainable development goal 3.

Although AI holds significant potential in contributing to the achievement of the objectives outlined in Goal 3, there are notable concerns voiced by authors like Reddy et al. [49], Morley et al. [51], Truby [52], Holzinger et al. [50], and Mhlanga[53]. For instance, Holzinger et al. [49] Emphasizing that while AI has the potential to offer innovative solutions to global challenges, it also presents unforeseen threats. It is crucial for all stakeholders—governments, policymakers, industry, and academia—to address and mitigate these potential threats. Holzinger et al. [49] Advocate for ensuring the 'safety, traceability, transparency, explainability, validity, and verifiability of AI applications in our everyday lives.' Highlighted in Figure 4 are various roles in healthcare where AI can contribute to the achievement of SDG3 and its targets. Additionally, Figure 5 outlines key ethical and regulatory considerations associated with the application of AI in healthcare. Despite ethical concerns, the study underscores AI's substantial contribution in addressing the challenges of the COVID-19 pandemic. This insight suggests that, if applied judiciously, AI and deep learning can play a pivotal role in achieving sustainable development goals, particularly in goal 3, by helping identify healthcare access disparities and ensuring universal accessibility.

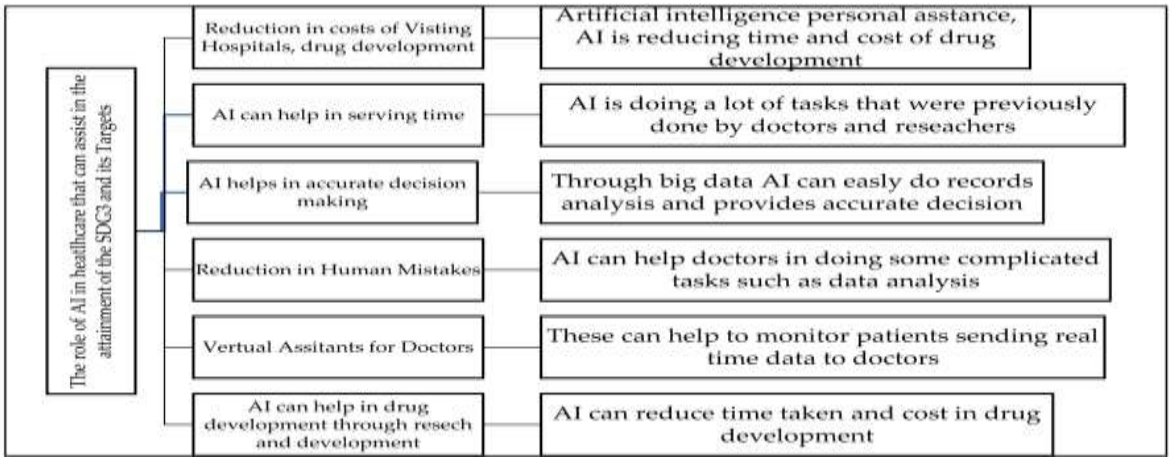

Figure 4. The Contributions of AI in Healthcare Towards Achieving SDG3 and its Targets in the Post-COVID world

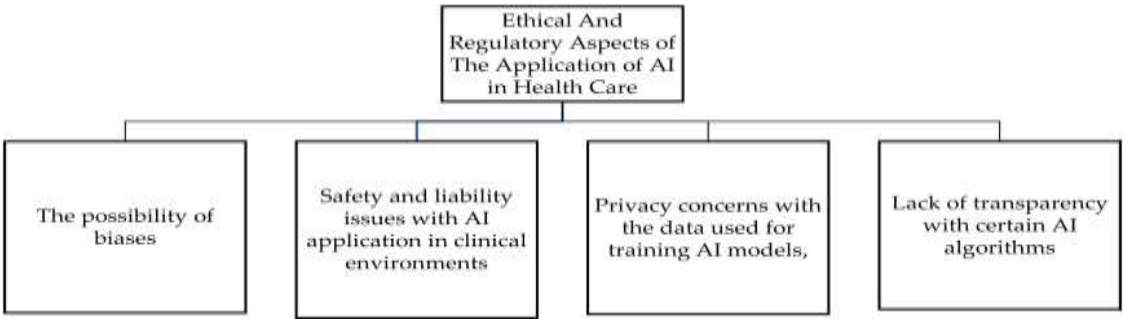

Figure 5. Ethical and Regulatory Considerations in the Implementation of AI in Healthcare

9. Conclusions and Policy Recommendation

The COVID-19 pandemic has not only disrupted and reversed progress in global health but has also led to a renewed interest in understanding the role of artificial intelligence (AI) and deep learning in addressing its challenges. While there is a growing body of research focusing on this aspect, studies that delve into the broader context of the fourth industrial revolution and its implications for sustainable development goals are limited. This study employs qualitative content analysis to explore the contributions of AI and deep learning in mitigating the threats posed by the pandemic and extract lessons applicable to the fourth industrial revolution and sustainable development goals. The findings reveal that AI and deep learning played crucial roles in various aspects, such as scaling customer communications, enhancing our understanding of COVID-19 transmission, and expediting research and treatment. These outcomes underscore the significance of building trust in AI and deep learning technologies to effectively address health challenges and achieve sustainable development goals related to good health and well-being. The insights derived from this research contribute to raising awareness about the potential positive impact of AI when appropriately utilized in the pursuit of sustainable development goals.

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