A Systematic Literature Review of The Effect/Contribution of Artificial Intelligence Technology Towards Achieving the Sustainable Development Goals

Vishruti Ashutosh Dave

[redacted]

University Canada West

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Supervisor: Dr. Mohsen Saeedi

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List of Abbreviations

3D	3 Dimensional
AI	Artificial Intelligence
API	Application Programming Interface
BIM	Building Information Modeling
CC	Cloud Computing
CCTV	Closed Circuit Television
ELM	Extreme Learning Machine
I4.0	Industry 4.0
ICT	Information & Communication Technology
IoT	Internet of Things
LDC	Least Developed Countries
MODIS	Moderate Resolution Imaging Spectroradiometer
PV	Photovoltaic
SDG	Sustainable Development Goal
SVM	Support Vector Machine
UN	United Nations

Abstract

The advent of Artificial Intelligence (AI) backed technologies has revolutionized every sphere of human activities today worldwide due to the diverse techno-economic benefits attached to AI technologies. From the perspectives of sustainability AI backed technologies in integration with allied internet-based technologies seem to transform conventional machines, processes, and systems of diverse industries to derive optimal techno-economic advantages. In regard to Sustainable Development Goals (SDG) of UN charter, AI backed technologies are playing a significant role in ensuring maximized performance efficiency, resource savings and are contributing towards environmental conservation worldwide. This study investigates contribution of AI technologies in attaining SDG goals as laid by the UN charter by examining diverse secondary studies relevant to the research theme across various industries and SDG themes. The outcomes of this study suggested that AI technologies are increasingly contributing towards SDG goals across various industries globally. It is anticipated that extensive industry-wide applications of AI backed technologies is bound to revolutionize every industry and deliver optimal techno-economic and socio-environmental advantage to all stakeholders globally.

Keywords: Artificial intelligence, Sustainability, Sustainable Development Goals, Systematic Review, Industry 4.0

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1. Introduction

Considering consistent rise in industrial activities across sectors and diverse challenges facing world community today in regards to environment and sustainability the United Nations in 2015 presented seventeen Global Goals of Sustainability that cover diverse aspects of human existence such as quality education for all, elimination of poverty, preventing starvation, development of renewable energy resources, ensuring economic growth, food security, prevention of climatic change/ depletion, gender equality, improvising of health and hygiene, sustainable cities, improving quality of life on land and water and others meant to improve the quality of human lives worldwide (United Nations, 2015). Various studies have been conducted on the subject of sustainability that attract increasing attention of scholars and decision makers towards the inevitable role of sustainability in fostering human lives. A study by Geels (2014) and Sadhukhan et al, (2020) suggested that the issue of sustainability has gained exponential significance lately especially in diverse business sectors due to the lasting impact businesses exert on people and environment globally. Consistently increasing industrial activities globally in today's era of globalization pose serious threat to environment and stakeholders due to depletion in quality of atmosphere, increased industrial waste discharge into waters and land, rising levels of greenhouse emissions, and diverse other factors that compel world nations to address the issues of

sustainability through a common and integrated approach. Thus, the issue of sustainability becomes utmost crucial in the contemporary fourth industrial revolution.

Figure 1 - *The United Nations 17 Sustainable Development Goals*

(Note: Sourced from United Nations - the 17 goals, (2024); retrieved from https://sdgs.un.org/goals. Copyright 2024 by United Nations.)

1.1. Industry 4.0

Various studies are carried out by different researchers on the characteristics and nature of fourth industrial revolution. Industry 4.0 was first coined by the government of Germany with introduction of high-tech strategies in the year 2011 (Zhou et al, 2015). According to Stăncioiu (2017) and Monostori et al (2016) the foundation of the fourth industrial revolution is based on the idea of integration of ICT (Information & Communication Technology) and control mechanisms which is popularly referred as Cyber-Physical Systems. The fourth industrial revolution aims to automate business processes by way of integrating computing, communications, and technologies to manufacturing, production and service-related processes in order to ensure maximized outputs are generated thereby cutting down time, resources, and costs. The advent of fourth industrial revolution has opened new doorways of tremendous opportunities of growth and welfare globally due to incorporation of Artificial Intelligence (AI), Internet of Things (IoT), and autonomous machines that are immensely aiding humans and enterprises execute their common and complex tasks efficiently. As AI backed technologies mature organizations and societies are revolutionizing human lives by exerting a lasting inevitable and significant impact on people and the environment (Ross and Maynard, 2021).

Increased advances in diverse industrial sectors have accelerated industrial impacts on the environment and people thereby compelling countries to implement stringent measures towards sustainability essential for conserving nature and environment. The fourth industrial revolution aims to optimize resource efficiency and eliminate unnecessary wastage by integrating advanced AI backed technologies with machines. An ideal example of effective use of AI in modern businesses can be seen in the use and applications of Big Data technologies that have revolutionized manufacturing, marketing, and supply chain sectors globally. Business intelligence

technologies such as Big Data , utilize very large volume of complex and raw data, which can be utilized optimally using AI technological intervention in a way that generates meaningful and valuable outcomes for business (Aceto et al, 2019). Business intelligence technologies are extensively used by businesses today for optimally exploiting business relevant information from large volume of data to obtain accurate insights on volume of demand and supply in specified period of time. This allows organizations to determine the volume of supply and demand and make appropriate changes in product process to ensure prevention of resource wastage. Thus, fourth industrial revolution plays crucial role in addressing diverse challenges in context to sustainability and aids in achieving Sustainability Development Goals (SDG) globally (Oosthuizen, 2022). This is because industry 4.0 allows effective collaboration and change management of diverse industrial processes by integrating AI backed technologies with industrial processes. This implies that the goals under SDGs can be conveniently accomplished by way of integrating AI based technologies with conventional industrial processes regardless of nature of industry.

1.2. Artificial Intelligence and Sustainable Development Goals

The role of AI technologies in attaining sustainable goals is inevitable and essential since AI complements SDGs by way of enhancing meaning and values of things and processes across industries involving diverse human activities. According to studies by Jain et al. (2023), modern era of globalization readily adapts machine learning and machine visions in alignment with SDG goals. Additionally, increasing adaption of robotics and automation aimed to reduce human intervention and resource utilization immensely aids in achievement of SDG goals. Artificial intelligence is extensively used in diverse industries namely, water cleaning and sanitization, agriculture cultivation, food supply and distribution, virtual learning, and remote working environment. Smart grids, advanced AI controlled power systems and monitoring mechanisms are

extensively used in optimizing resource generation, utilization, and reduction of resource wastage (Jain et al, 2023).

Considering the increasing concerns towards environment and diverse social issues governments and businesses are readily incorporating AI backed technologies in various processes and tasks to ensure appropriate decision making is achieved that effectively addresses every social, environmental, and economic challenge and concern (Jain et al, 2023). It is anticipated that AI backed machines would replace human intervention maximally by 2030 consequently optimizing the efficiency and performance of various industrial activities and processes in diverse industries. It is expected that increased adaptability of AI into various industries is bound to complement.

Effective utilization of AI and ICT technologies into diverse industrial processes significantly aids in achieving the set Sustainable Development Goals (SDGS) within specified time period (Jain et al, 2023). Below given is a systematic classification of various Sustainable Development Goals and measures to address them effectively.

Table 1 - *SDGs and addressing them using AI.*

(Jain et al, 2023)

No.	**Sustainable Development Goals (SDGs)**	**Addressing SDGs Using AI**
1	No Poverty	Agricultural soil cultivation can be aptly achieved using AI for raising crops as well as livestock. AI was found very useful in gathering data via poverty maps and maximize outputs through imparting agricultural education. AI aided in reforming financial systems too. However, corrupt leadership could devastate AI backed financial processes rendering poor nations helpless.
2	Zero Hunger	AI aids in obtaining early warning signals of food shortages thus helping decision makers prevent malnutrition in time. AI aids immensely in improving crop quality, yield, and management thus helping to maximize the harvest. However, extensive AI dependency could result in false forecasting of results rendering stakeholders helpless or loss.

Table 2 - *SDGs and addressing them using AI (Continued).*

No.	Sustainable Development Goals (SDGs)	Addressing SDGs Using AI
3	Good health and wellbeing	AI can be used in determining diverse health anomalies facing population in a region such as bone deformities, tumors, heart diseases, etc. This data can be helpful in understanding factors responsible for diseases and address them aptly. However, AI can seldom trigger false alarms or mislead doctors thus requiring human intervention and monitoring too.
4	Quality Education	Virtual learning using AI tools can significantly enhance learning experience making it eco-friendly thus fulfilling sustainability goals. However, sheer dependency on AI could deplete the effectiveness of learning process that may affect quality of education.
5	Gender Equality	AI can be used to detect linguistic, racial, or ethnic similarities of suspects with even broader use and applications. On the downside, AI could also be used as a tool to

Table 3 - *SDGs and addressing them using AI (Continued).*

No.	Sustainable Development Goals (SDGs)	Addressing SDGs Using AI
		bypass standard security measures, such as in case of using synthetic facial masks.
6	Clean Water and Sanitation	AI backed predictive control techniques are used in water cleaning and sanitization. Diverse applications of AI are found to be immensely helpful in water purification across industries. However, complete, or major dependency AI technologies, may seldom lead to serious health consequences in the event of malfunction.
7	Affordable and Clean Energy	AI can be immensely useful in control and reduction of carbon emissions hence aiding in fulfilling the SDGs.
8	Decent work & Economic Growth	AI driven machines, systems and processes have tremendously boosted economic growth thereby ensuring a high-quality work environment with minimal impact on nature.
9	Industry, Innovation & Infrastructure	AI is extensively used across industries today. For example, BIM technology immensely aids civil

Table 4 - *SDGs and addressing them using AI (Continued).*

No.	Sustainable Development Goals (SDGs)	Addressing SDGs Using AI
		engineers in aptly designing 3D infrastructure with minimal use of time, resources, and money.
10	Reduced Inequality	AI can be extremely helpful in various identification and recognition technologies such as faces, fingerprints, and other biometrics, that aids in easy identification of people without grounds of discrimination. AI can, on the other hand, cause job related inequalities in developing nations due to inclusion of specified criteria suiting or targeting only a specific group.
11	Sustainable Cities and Communities	AI is immensely helpful in monitoring and control of civilized urban areas using CCTV cameras, traffic monitoring cameras, fire alarms etc.
12	Responsible Consumption & Production	AI technologies such as Big Data are increasingly used in monitoring demand and supply patterns, to ensure that over production and wastage is prevented.

Table 5 - *SDGs and addressing them using AI (Continued).*

No.	Sustainable Development Goals (SDGs)	Addressing SDGs Using AI
13	Climate Action	AI backed devices and machines are increasingly used in monitoring pollution levels, carbon emissions, predicting weather etc. which immensely aids in preventing major calamities such as floods and air pollution hazards.
14	Life Below Water	AI can be used in monitoring illegal fishing activities, smuggling activities and others which helps in conservation of environment.
15	Life on Land	AI technologies used in advanced geo-satellites and meteorological departments can precisely forecast extent of deforestation, its impacts and analyze its aftereffects thus allowing appropriate measures to be developed to conserve environment.
16	Peace, Justice & Strong Institution	AI can help in data synchronicity which will optimize the effectiveness of law enforcement department. This can be done by way of centralizing data of individuals which will eventually allow for precisely tracing and tracking of wanted people.

Table 6 - *SDGs and addressing them using AI (Continued).*

No.	**Sustainable Development Goals (SDGs)**	**Addressing SDGs Using AI**
17	Partnerships for Goals	Partnerships among governments and nations will substantially boost AI applications across societies, industries, and individuals, thus aiding in fostering a fully AI backed environment that will eventually help in fulfilling sustainability goals.

(*Note*: Sourced from Jain et al, 2023)

2. Research Questions

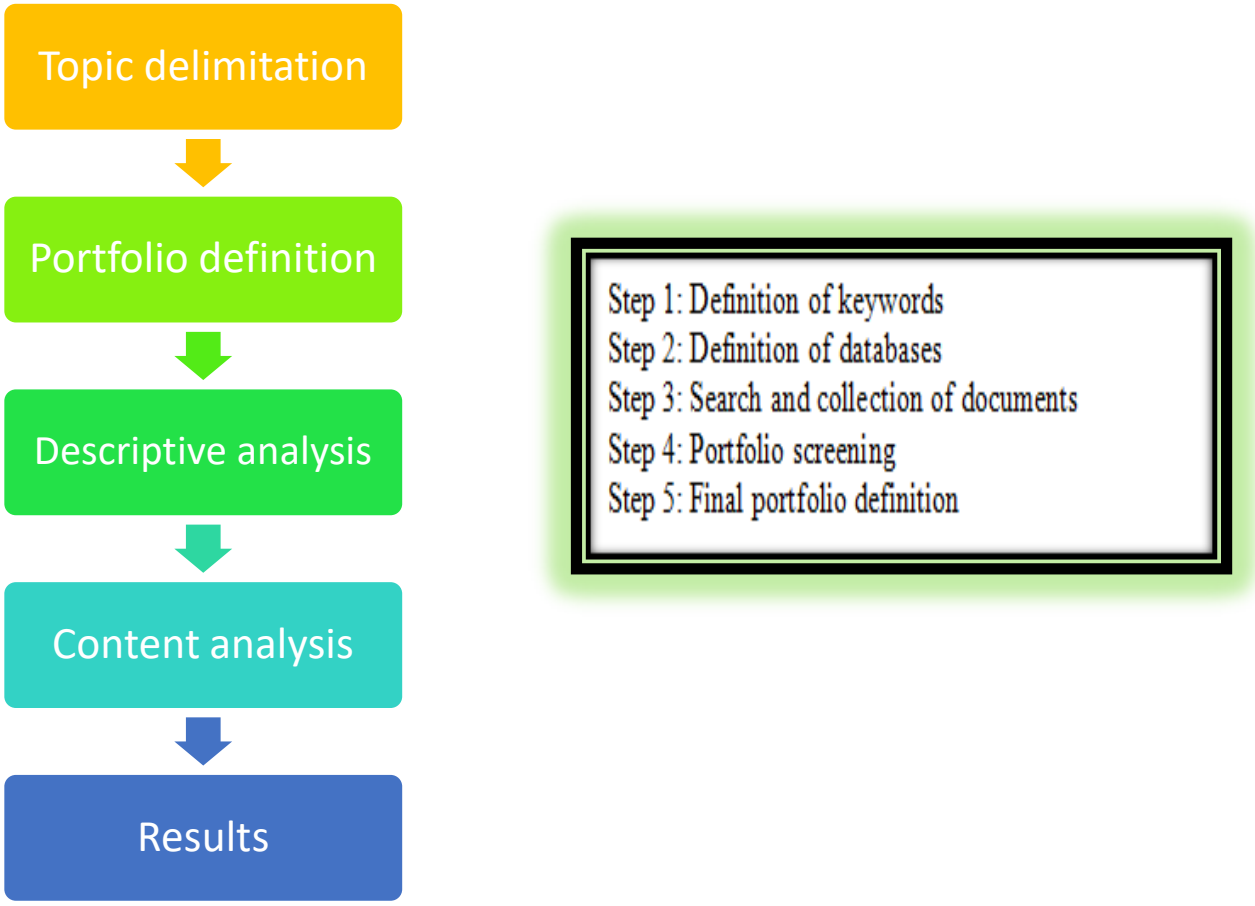
This report aims to address the following research questions based on scientific literature review:

1) Does AI address the sustainable development goals more than IoT and Cloud computing?
2) In which category of SDGs (environmental, social, and economic) AI is contributing more to achieve the goals.
3) Which SDGs and targets can potentially be contributed to by AI, more than the other SDGs in future?

3. Research Methodology

The research methodology chapter includes a systematic and in-depth review of diverse research studies on the chosen research theme. As this study surrounds AI's contribution towards achieving sustainable development goals across diverse areas of human existence, this research thus includes various research papers relating to the theme. The study will gather relevant secondary information from various authoritative and credible secondary sources, primarily including scientific journals, research publications, and allied sources to ensure validity and authenticity of the research. According to Paul and Criado (2020) an in-depth literature review is all about gathering and examining research literature relating to a specific and chosen subject of research interest which integrates past studies of the subject with existing knowledge essential for reinforcing the body of knowledge. This research mainly involves examination of scientific research publications in the form of peer reviewed journals published between the years 2010 to 2024 that focus on evolution of industry 4.0, role of AI in fostering the fourth industrial revolution and AI's contribution towards attaining sustainable development goals. This literature review is based on the framework proposed by Barros et al. (2018) and Coutinho et al. (2019), which emphasis on following a sequential procedure for conducting a systematic literature review of the subject. Given below is a systematic diagram representing the structure of the literature review process carried out.

Figure 2 - *Literature Review Process*



Source: From Barros et al. (2018) and Coutinho et al. (2019)

3.1. Topic Delimitation

This research aims to examine various research studies available in the form of secondary data, consisting of valuable information on AI's contribution in achieving sustainable development goals globally (Dhiman et al, 2024). This study includes various peer reviewed journals on the chosen subject, published between the years 2010 and 2024, which elaborate advances in AI technologies and its contribution in achieving sustainable development goals. The time boundary

set for this research is aimed to ensure optimal research data is extracted in this study in order to obtain every critical aspect of the chosen research theme.

3.2. Portfolio Definition

Step 1: Keyword Definition

This research primarily focuses on contribution of AI technologies in attaining Sustainable Development Goals (SDG) considering the era of fourth industrial revolution. The study employed a versatile perspective to ensure diverse aspects of the research theme are covered that depict how AI technologies have revolutionized various fields and industries consequently aiding in achieving sustainable development goals. Following are the important keywords extensively used throughout the course of this study.

Artificial Intelligence, Sustainability, Sustainable Development Goals, Industry 4.0 and AI, AI role in sustainability, UN SDGs, and Relationship between AI and SDGs

Using the mentioned keywords the researcher was able to conveniently retrieve appropriate peer reviewed journals from diverse data sources on the web. To ensure time specified data is retrieved the researcher applied appropriate technical tools to narrow down the search eventually succeeding in obtaining secondary literature published between the specified time frame (2010-2024) years.

Step 2 and 3: Definition of databases and collection of studies

Internet based searches immensely aided the researcher in acquiring vast volume of research relevant information available and published in diverse reputed and authoritative databases which was carefully selected for this study considering the study's scope, limitations, interests, and needs.

The researcher found various scientific publications available in globally renowned and credible secondary sources namely, Springer, Emerald, Elsevier, ScienceDirect, Nature, Wiley, MDPI, Tandfonline, and others.

Step 4: Screening the Portfolio

Post conducting the search, selecting appropriate peer review research articles for the study duplicate articles or sources if any were eliminated to ensure repetitive data and references are prevented. The researcher then performed a systematic filtering process by carrying out review of abstract, introduction, outcomes, and conclusion from all the selected research papers. The development of final portfolio was then carried out by selecting appropriate articles that related and addressed the research questions.

Step 5: Final Definition of Portfolio

Considering the set criterion of portfolio distribution and representation according to the specified parameters involving time frame, nature of publications, objectives of study, and their direct linkages to this research and its research questions/ objectives a systematic tale was constructed depicting various studies and publications relevant to this research interest and needs. This is crucial for extracting research outcomes and evaluation of its contents.

3.3. Descriptive Analysis

A systematic analysis was performed over the gathered secondary sources of information essential for generating a comprehensive elaboration of final portfolio. Based on the nature and objectives of diverse studies data sources were categorized into three different types, namely, contribution of AI in SGD achievement, relationship between AI and SDGs and role of Industry 4.0 in attaining SDGs through AI technologies.

3.4. Content Analysis

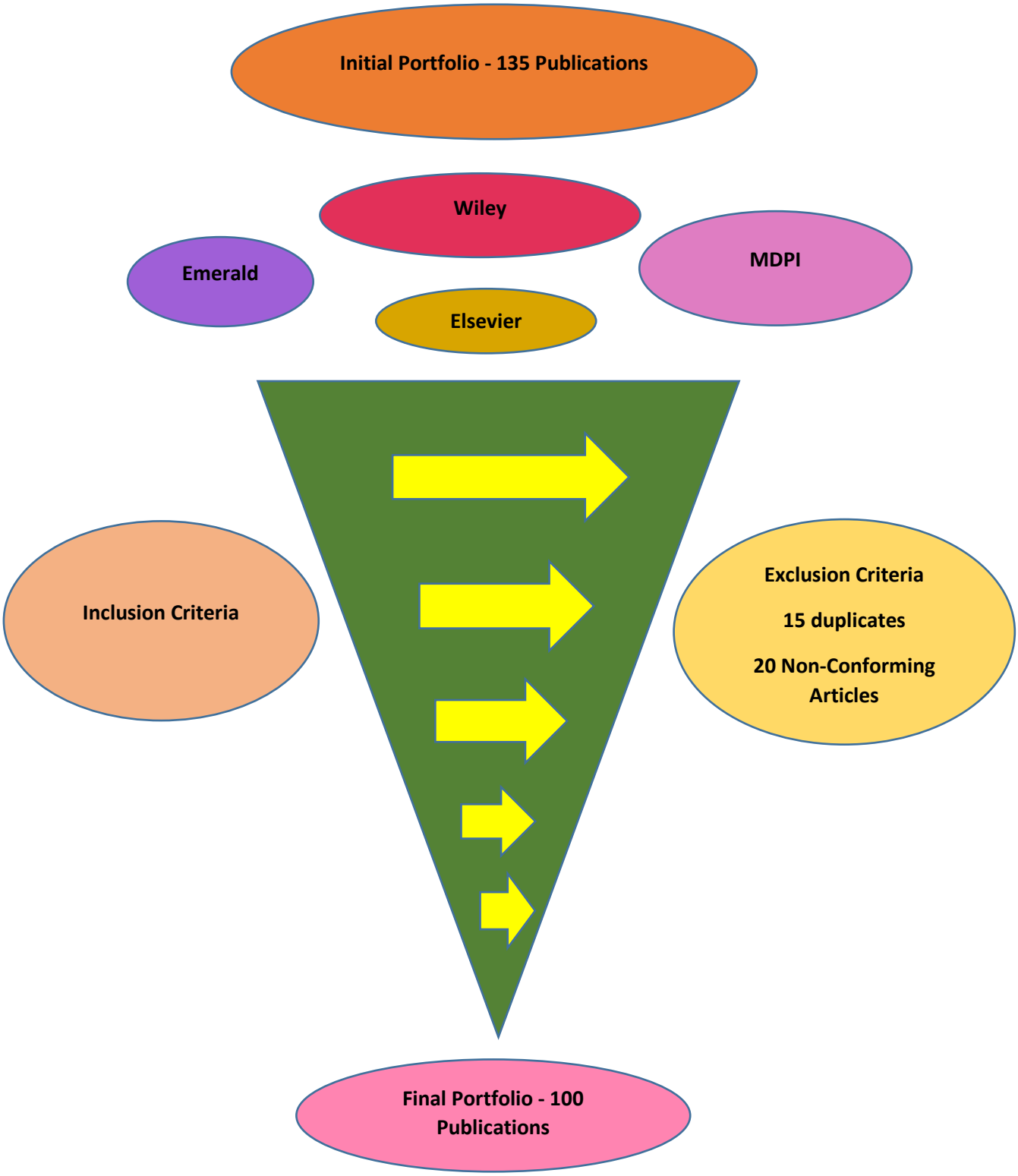
The results of this research are based on the in-depth analysis of the final portfolio included in this study. Diverse AI backed technologies, their individualistic contribution in meeting varied SDG objectives and goals and collective impacts of AI technologies on SDGs is systematically categorized and identified in this research. Post analysis of the portfolio contents determination of nature and extent of AI in addressing SDGs was carried out. Based on the studies included in this research it became feasible to justify how AIs significantly contributes to attainment of SDGs. The content analysis immensely aids in identifying how AI's contribution in SDG achievement is significant than IoT and cloud computing technologies. It also facilitated in identifying appropriate categories of SDGs where AI's role and contribution seems substantial in SDG goal achievement. Lastly, content analysis also allowed researcher in identification of targets and goals of SDGs where AI technologies played a significant role and immensely contributed to goal achievement than other allied technologies namely, IoT and cloud computing.

1) AI and Sustainability
2) Sustainable Development Goals
3) Relationships between AI and SDGs

4. Results

The initial secondary research-based literature involved a total number of 135 journals approximately which formed the basis of research portfolio obtained from a specific selection process as shown in figure 3. Out of the 135 journals selected for the study 35 publications were deselected and eliminated from this research, 15 publications due to duplication of content and 20 publications due to being non confirming articles. As advancements in AI technologies have eventually led to revolutionize the world by fulfilling diverse sustainability needs and interests, various studies have thus been carried out by different researchers about AI's role in attainment of Sustainable Development Goals (SDG) globally (Filho et al., 2023). This report is conducted to elaborate diverse aspects of AI technologies in contemporary era and their inevitability and indispensability in fulfilling SDG goals. The subsequent research analysis of the subject relates to evaluation of bibliometric outcomes and trends in scientific literature available on the virtual platform. This is carried out by way of evaluation of outcomes of AI technologies, its roles and applications in diverse fields and its contribution towards accomplishing SDG goals. The next section of the report depicts SDGs and the targets that are substantially impacted by AI backed technologies in fulfilling SDG objectives and goals.

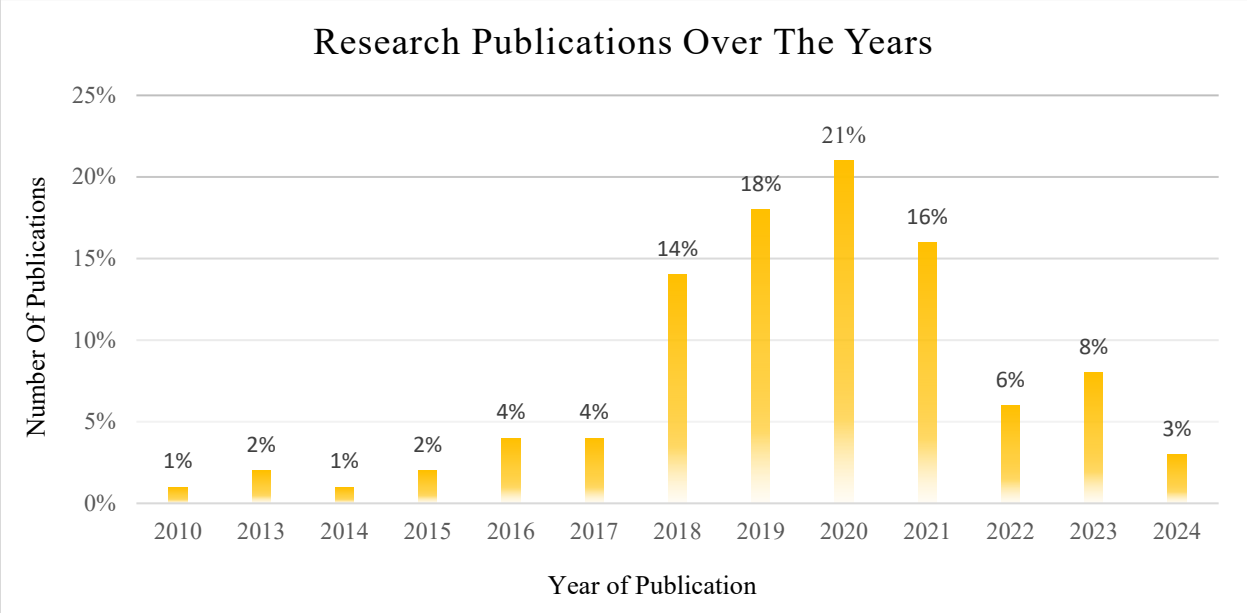
Figure 3 - *Research Funnel: Review Screening Process*



4.1. Bibliometric Results

This study incorporated diverse research publications and examined those chronologically involving specified research criteria to investigate contribution of AI technologies in achieving SDGs globally. Additionally, selected publications were systematically classified against time using a graph as shows herein. The graph shows number of publications included in this study each year which have been incorporated in this research. With time progression, it can be seen that there is exponential research carried out globally on AI impacting on sustainability between the years 2018 to 2021 which clearly reflects increasing need and awareness of AI/ sustainability worldwide in academia and research fields. However, fewer studies have been found in subsequent years indicative of research contribution impacted by COVID pandemic.

Figure 4 - *Distribution of Publications over the years.*



(*Note:* Refer Appendix 1 for data)

The findings of the research clearly showed increasing need, interest, and awareness among research community globally towards AI and its impacts on sustainability which is apparent from growing number of studies published particularly between the years 2018-2021. A drastic decline of publications in subsequent years is due to the emergence of COVID that may have impacted academia and research domains globally. An initial attempt to establish linkages between the determining components of this research, namely, Artificial Intelligence (AI) and Sustainable Development Goals (SDG) were undertaken by different researchers as depicted in various secondary studies (Filho et al.,2023). According to diverse secondary research authors of different studies conducted on AI's role in contributing towards attaining sustainable development goals argue that AI backed technologies can significantly contribute towards achieving 17 SDG goals that are set by the United Nations. It is observed that by optimally leveraging AI backed technologies diverse SDG goals can be promptly and effectively achieved. For example, diverse AI backed technologies such as machine learning can be extremely useful in weather forecasting, disaster forecasting, predicting pollution levels across a region, poverty estimation in a region, measuring economic growth of a country and diverse other area of growth and development which cannot be ascertained using conventional methods (Dhar, 2020), (Deo et al., 2019) and (Sublime & Kalinicheva, 2019). Diverse studies incorporated in this research strongly suggested immense contribution of AI backed technologies in various domains that directly and indirectly addressed challenges of SDG goals. A key point to be borne in mind is that AI has played a key role in maximizing conservation and optimal utilization of natural and manmade resources namely, water, agriculture, solar energy, electricity, control of carbon emissions, and climatic control thereby ensuring accomplishment of varied SDG goals to certain extent. It is anticipated that with extensive and worldwide applications of AI backed technologies across diverse industries, substantial

improvements in various areas, as indicated by SDGs will be realized by the year 2030. A study by Alsharkawi et al., (2021) using machine learning and field surveys on estimation of poverty levels in Jordan provided conclusive evidence of poverty figures in the country. The study found machine learning methods of AI to be immensely useful in poverty estimations in the country. Another study by Al Qundus et al., (2020) concluded that artificial intelligence backed technologies can be aptly used for disaster forecasting in a particular location. According to the study wireless sensor network decision model proved highly effective in precisely identifying flood disaster location based on comparison of past weather information of the specified location. The study used sensors located in different places in each location for gathering information such as air pressure, temperature, humidity, water levels, wind speed and precipitation and collected criterial data concerning rainfall levels and sea level air pressure with the use of Google API. Using a Support Vector Machine (SVM) model binary decisions were obtained to indicate flood or no flood scenario in each targeted region with an accuracy of over 98 percent. The data was acquired by cloud-based servers accessible in a monitoring room where decisions on whether to initiative a disaster response action was undertaken. The author suggested that AI could prove crucial in disaster management of varied natural and manmade calamities in future due to consistent advances in AI backed technologies aimed towards sustainability.

Energy forecasting and power supply management are paramount in energy sector today due to its inevitable role in efficient management of electricity. An insightful study by Ahmad and Zhang (2020) on energy consumption in diverse domestic, societal, and industrial settings was carried out using advanced machine learning, artificial neural networks, and ensemble-based approaches which yielded desired outcomes of study. The objective of this research by Ahmad and Zhang (2020), was to identify the most reliable and accurate energy planning tool essential for energy

predictions in diverse settings. The outcomes of the research eventually showed machine learning model to be most accurate, reliable, and efficient enough to handle vast amount of relevant data. The study revealed that artificial neural networks proved robust and capable of establishing unseen interlinks and features in the process. The study showed positive outcomes with increased accuracy in energy predictions using machine learning models which could revolutionize the energy sector and add value to body of knowledge.

This research found substantial volume of research publications on sustainable cities and communities (SDG11) which directly or indirectly contributed towards fulfilling other SDG goals particularly those which complement SDG 11 objectives. This included good SDG3-health and well-being, SDG6/7 clean water sanitation and affordable clean energy, SDG 9/11/12/13 which relates to industry, innovation and infrastructure, sustainable communities and cities, responsible production and consumption and climatic actions respectively. A total number of 24 scientific publications published in the years 2018, 2019 and 2020 respectively were found in this study relating to SDG 11 covering diverse aspects of how SDG 11 could be accomplished. This included renewable energy production and consumption, smart agriculture, disaster forecasting and management, measuring sustainability factors, climatic change management and forecasting, quality education and learning using AI and IoT based tools and modalities, industry innovation and economic growth and others. It is revealed through examination of diverse research studies that AI backed technologies are indeed playing and inevitable and indispensable role in accurate forecasting, planning, allocation, and management of resources essential for common welfare. This particularly applies to disaster management scenarios that requires accurate forecasting, planning and management of people and resources. This is evident form the study of Vinuesa et al. (2020) that demonstrated how AI backed technologies significantly contributed to attaining diverse SDG

in various countries worldwide. Studies conducted by Filho et al. (2022, 2023) and Vinuesa et al. (2020) strongly suggests that AI technologies can conveniently fulfill all 17 SDG goals and 169 targets recognized by the UN and which are to be attained by 2030. The study by Vinuesa et al. (2020) identified all critical fields of diverse industries that are heavily impacted by increasing AI and allied applications which primarily included education and learning, weather and meteorology, manufacturing and production, resource management, renewable energy production, planning and management, electrical vehicles for low carbon emissions, environment conservation, energy harvesting using diverse natural sources such as wind, solar, and water, economy, law and order, inequality, healthcare, addressing climatic change, poverty, food and hunger, and diverse challenges facing societies globally.

As majority of research publications surrounded environmental, economic, and social issues primarily concerning poverty, economic growth, renewable energy management, and learning it is therefore clear that sustainable development mainly concerns the socio-economic and environmental challenges facing modern societies globally (Ahmad and Zhang, 2020). Extensive applications of AI backed technologies in these areas are paramount to meet SDG objectives and goals due to the rising concerns among worldwide environmentalists and UN officials on critical issues facing humankind that revolve around poverty, starvation, global warming, climatic depletion, pandemic, and economic recessions, and increasing inequalities and concerns towards piece, justice, and law enforcement (Filho et al., 2023). This is critical as sustainability that fails to address the basic needs and interest of human existence would prove futile regardless of its inevitability in key areas and industries of civilization (Das and Mondal, 2023). The studies incorporated in this research are diligently selected for research examination and analysis and are found to be appropriate and valid for this research as it links fundamental needs and interests to

SDGs and justifies how AI backed technologies are capable of bridging the conventional gaps between human needs, sustainability goals and technologies.

Evidence of how AI has immensely aided in delivering SDGs is shown in the study by Lee (2020), that revealed optimal applications of AI in electric vehicles aimed at minimizing carbon emissions. The use of AI technologies in atomizing electric vehicles has positively impacted on the societies globally. Rising concerns towards the environment, climatic depletion, and consequences of global warming compelled technologists to develop alternative commutation technologies that are equally efficient and eco-friendly than their conventional petrol-diesel driven counterparts. According to the study by Lee (2020) further advances in AI technologies is bound to revolutionize the automobile industry thereby delivering an optimal positive impact on environment and thus fulfilling the goals of SDGs 7, 9, 11,12, and 13 respectively.

An insightful study by Fuso Nerini et al. (2019) suggested that SDG 13 relating to climatic change can alone help in achieving all SDGs by way of interlinking the 17 SDG goals. The author suggested that a deeper level interdisciplinary collaboration is required to achieve 16 different SDG goals through SDG 13 i.e. climatic change. The author further emphasizes on coordinating institutions which relates to SDG 17 i.e. partnerships for goals, with a focus on sustainable development governance and climate change essential for attaining SDG goals.

A key point to be borne in mind is the importance given to environmental issues in SDGs, as each SDG goal directly and indirectly tends to address current environmental challenges and problems facing the world community today. Carbon emissions and global warming being the primary issue of concerns very few studies have focused on these environmental issues to address climatic changes and depletion by providing appropriate solutions to address SDG goals surrounding SDG 3,6,7,11, and 13. For instance, an insightful study by Majumdar et al. (2021) provided smart and

innovative solution to address increasing traffic congestion problems in urbanized cities. The author in this study suggested use of smart phone data, traffic sensor data, network data and appropriate algorithms of machine learning and IoT devices to accurately predict the traffic jams and congestions on urban roads. This study aptly addressed the SDG 11 that relates to sustainable cities and communities and thus complements SDGs 3,8, and 9. Another study by Lee & He (2021), that directly addresses the climatic concerns i.e. SDG 13, lays emphasis on AI backed machine learning enabled wind power systems that can operate optimally using machine learning algorithms so as to generate maximal power. It was found that AI use in wind power generators accelerated automation of wind power systems which is a milestone towards attaining clean and affordable renewable energy thus complementing SDG 7,9,11,12 and 13 goals.

In yet another insightful study by Osburg and Lohrmann (2017) diverse SDG goals have been aptly addressed by adopting state of the art ICT and AI backed technologies. According to the study vast volume of data generated through diverse information technologies enabled resources could be efficiently and effectively utilized for deriving meaningful and valuable inferences which could revolutionize different areas of human activities. For example, as suggested by Osburg and Lohrmann (2017) vast electronic data when aptly utilized can prove immensely beneficial in maximizing accuracy and predictability of natural disasters. Data generated from diverse sources such as ICT technologies, Big Data, IoT resources could be immensely useful in maximizing agricultural yield, minimizing traffic jams, and reducing carbon emissions, reducing power consumption, and aiding in prevention of manmade disasters where applicable industrywide. The study by Osburg and Lohrmann (2017) has aptly addressed various SDG goals particularly concerning SDGs 4,6,7,8,9,11,12 goals.

As this study included 100 scientific publications on diverse subjects relating and complementing United Nations directed SDGs goals it thus implies that each of the publications addressed or covered few of the SDG goals depending on its goals, objectives, needs and interests of study. While a few publications merely focused on most criterial and globally concerning issues such as climate there are good number of publications found in this study that have succeeded in aptly addressing multiple SDG goals which will be represented graphically herein. Among the 100 publications included in most of the publications revolved around sustainable cities and communities due to the increasing need and applications of AI technologies in energy, healthcare, education and learning and responsible production and consumption which required significant attention. This is because urbanized cities and towns are congested with population that have increasing demands and needs for resources such as clear air, water, good health, economic growth, sustainable environment, and innovation at every stage of human lives. Increasing applications of AI is thus seen in these studies that have managed to address diverse SDGs optimally.

An insightful study by Filho et al. (2023), that aimed to integrate AI with IoT resources and evaluate its implications on sustainability revealed promising outcomes of the technological integration. According to the study that laid major emphasis on industrial production and manufacturing using automated processes, modern era is largely dependent on automated machines that are capable of handling highly complex and complicated tasks without human intervention, which proved highly efficient, time saving and economical for businesses. According to Filho et al. (2023) complex AI backed machines are far more precise, efficient, reliable, and cost effective than humans thus making them inevitable and indispensable for modernized world. The author strongly suggested that AI has multiple and diverse applications from transportation to healthcare and manufacturing to service industry thus making it highly agile and viable futuristic

technologies. In context to the SDG goals and objectives set by UN, as suggested by Filho et al. (2023) AI backed technologies in collaboration with ICT technologies are revolutionizing the world by contributing towards sustainability. Many of the SDG goals are complemented and achieved by way of consistent and extensive application of AI backed technologies particularly in the field of education and learning, environment, sustainable city development, and responsible production and consumption processes. In the comprehensive study the author suggested that there exists a strong inevitable linkage between AI technologies, ICT technologies and SDGs which complement each other eventually fostering growth and development across political, social, economic, technological, and environmental domains.

A comprehensive study by Deo et al. (2019) involved advanced universally trained Extreme Learning Machine (ELM) model which was developed using eight MODIS satellite data factors which were facilitated with geo-topographical site traits. The study revealed that the most isolated and remotest locations/ regions of Australia such as Australian deserts are extremely potential regions regarding harvesting solar renewable energy for electricity generation. Using advanced AI backed big data analytics tools and innovative computational technologies that extensively make use of remotely sensed predictors exclusively developed for solar radiation predictions over prolonged period are found to be extremely advantageous in decision makers in context to solar energy investments. Implementation of this AI backed technology model can be immensely useful and beneficial in precisely measuring the solar radiation in specific regions of the world thereby eventually allowing decision makers to make appropriate investment decisions for harnessing solar energy worldwide. According to Deo et al. (2019) contemporary technologies that are solely dependent on satellite-based information deliver approximate data and locations concerning the solar radiation which makes it quite difficult for decision makers to identify the precise location

for establishing solar power harvesting projects globally. This challenge can be aptly addressed using information generated through advanced AI backed big data analytics and advanced computational systems.

In yet another insightful study by Huang and Rust (2018) the authors suggested how AI backed technologies can play a pivotal role in transforming human-machine interactions in service industry consequently revolutionizing the world. According to the author, consistent advances in AI technologies has been found to be extremely promising in terms of developing and fostering human-machine interactions across diverse industries. The authors in their study suggested that advanced AI backed robots and machines are capable of handling analytical tasks, empathetic tasks, exhibit soft skills that require intuitive abilities of humans and deliver a desirable human-machine advantage in diverse business settings. The study Huang and Rust (2018) emphasizes on how advanced AI backed robots are delivering state of the art techno-economic advantage top stakeholders in diverse business settings. For example, kiosks machines installed at McDonald's allows customers to pick their preferred menu at the counter. Robots are increasingly used in some countries for serving customers as waiters exhibiting best of the human-machine interactions. Advanced robots such as 'Replika' has successfully replaced psychiatrists by delivering psychological comfort to clients thereby emphasizing on its inevitability and necessity in future.

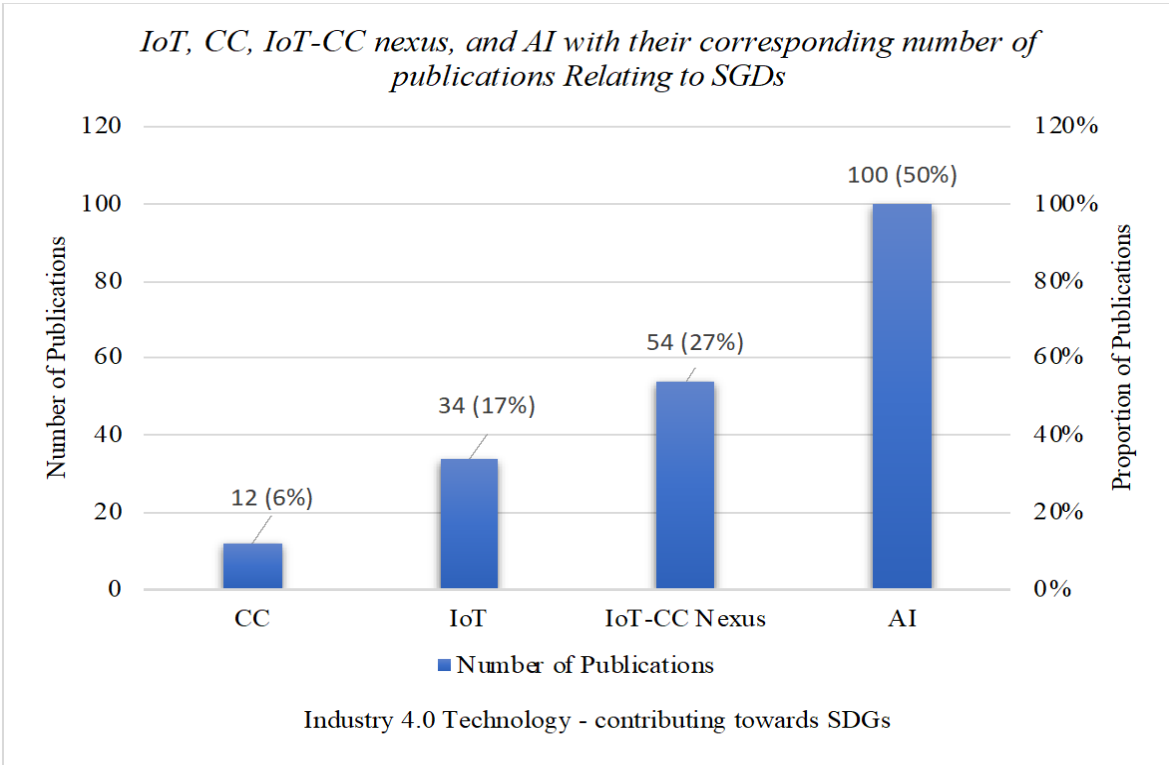
Several studies have been carried out by different researchers about AI's role in climatic monitoring and control. An in-depth study by Dhar (2020) suggested that AI is found to be extremely advantageous in reducing the effects of climatic crisis globally by way of its applications in smart grid designs, building low emissions infrastructure and lastly, modelling climatic change forecasting. However, despite of increasing anticipations from AI backed technologies various studies have found that extensive use of AI technologies in environmental sustainability

significantly increased carbon emissions which in itself posed serious hazard to the stakeholders and environment. According to the study by Dhar (2020), Deepika Sandeep, a scientist working with a Bangalore based clean energy Generation Company suggested in his study that extensive use of AI for clean energy systems may not yield desirable effects due to the fact that machine learning required substantial computational power for training which generates substantial amount of carbon footprint. This implies that AI's role and contribution in ensuring sustainability might be questionable due to the diverse challenges and hazards that arise from its very applications and usage.

Applications and uses of AI technologies, ICT technologies are seamless across industries as discussed in this study. Accomplishment of sustainability goals is subjected to diligent utilization of AI technologies considering its demerits and hazards due to the fact that AI/ICT technologies has its own limitations and disadvantages as discussed earlier herein. The fact that whether AI supersedes in benefits than conventional systems and methods is a subject of another study requiring systematic and disciplined approach to research. Considering costs, time, resource constraints, and implications on diverse sustainability areas, AI has definitely superseded conventional mechanisms and methods due to the fact that conventional methodologies and systems were developed in a period of time when climatic depletion and environmental degradation had not reached its peak of devastation. On the other hand, AI/ ICT technologies are designed and developed with a primary intent to optimize process efficiency, reduce human intervention, cut down costs and time, and generate minimal impact on the environment. This implies that as compared to conventional systems and technologies AI backed technologies certainly and effectively address SDG goals however it does have its own demerits that required attention.

This study has incorporated diverse research publications on the chosen research theme however very few studies have shed light on the demerits and limitations of AI in regard to sustainability which is a subject of concern. This is due to the fact that extensive applications of AI industrywide may perhaps supersede the conventional hazards thus posing serious problems to stakeholders globally. With advances in technologies there is anticipation that contemporary AI technologies could prove techno-economically feasible and viable across industries depending on its ability to nullify its own demerits.

Figure 5 - *IoT, CC, IoT-CC Nexus & AI's corresponding number of publications relating to SDGs.*



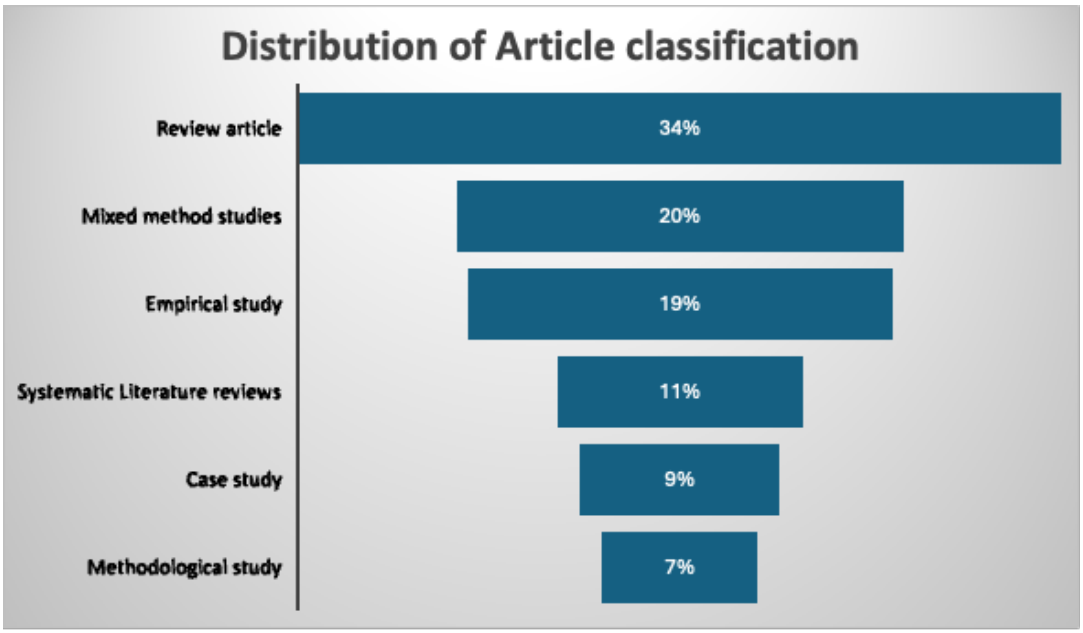
(*Note:* Refer Appendix – 2 for Data. Data for CC, IoT, IoT-CC Nexus retrieved from another study '*IOT and cloud computing for Sustainable Development Goals in industry 4.0'* by Abaee et al. (2024), and data for AI is from the literature portfolio of this paper.)

Figure 5 given above, shows systematic classification of 200 publications based on its technological category namely, Cloud Computing (CC), Internet of Things (IoT), their nexus, i.e. IoT-CC Nexus, and Artificial Intelligence (AI). The table shows a total of 200 publications used in this study for examining the nature of technologies that are significantly contributing towards attaining SDG goals. This total of 200 publications, is a result of the data of 100 publications under study in the literature portfolio of this study, being compared with the data of another 100 publications studied under another research by Abaee et al. (2024), which looked at similar publication data for CC, IoT, and IoT-CC Nexus. From the above figure 5 it can be inferred that consistent advances in IoT and CC technologies have opened new doorways of opportunities through nexus of IoT and CC technologies, which are effectively being leveraged in business intelligence technologies currently. From the table, it can be seen that 12 studies pertaining to CC technologies, 34 studies relating to IoT and 54 studies pertaining to nexus of CC & IoT technologies respectively are included for investigation from the research paper by Abaee et al. (2024). On the other hand, a total of 100 studies mainly relating to AI and sustainability have been included for drawing comparative outcomes on the issue of application of individual technologies and its nexus across industries in modern times. It can be inferred that AI technologies are extensively utilizing IoT and CC backed technologies industry-wide as suggested from the studies of (Filho et al., 2022), (Kankanhalli et al., 2019), (Majumdar et al., 2021).

It is clear that every study incorporated in this research is backed with AI technologies regardless of its nature of application in diverse fields. The publications included in this report are exclusively derived from the period of 2010 to 2024 found to be appropriate considering study's interests,

needs and objectives. Based on the systematic classifications and weightage of publications used in the study it is clearly infer-able that almost all technologies are backed by artificial intelligence applied in diverse industries. nexus of CC-IoT technologies backed by AI has a major stake in contributing towards sustainability goals. It is clear that 54 publications accounting to 27 percent of the total research studies contribute towards SDG goals strongly emphasizing on the inevitable role of integrated AI backed IoT/CC technologies in SDG achievements. In the study, as depicted in the table it is found that 50 percent of the publications involve AI backed technologies acting in nexus with IoT or CC or both thus emphasizing the indispensable role of AI in attaining SDG goals globally.

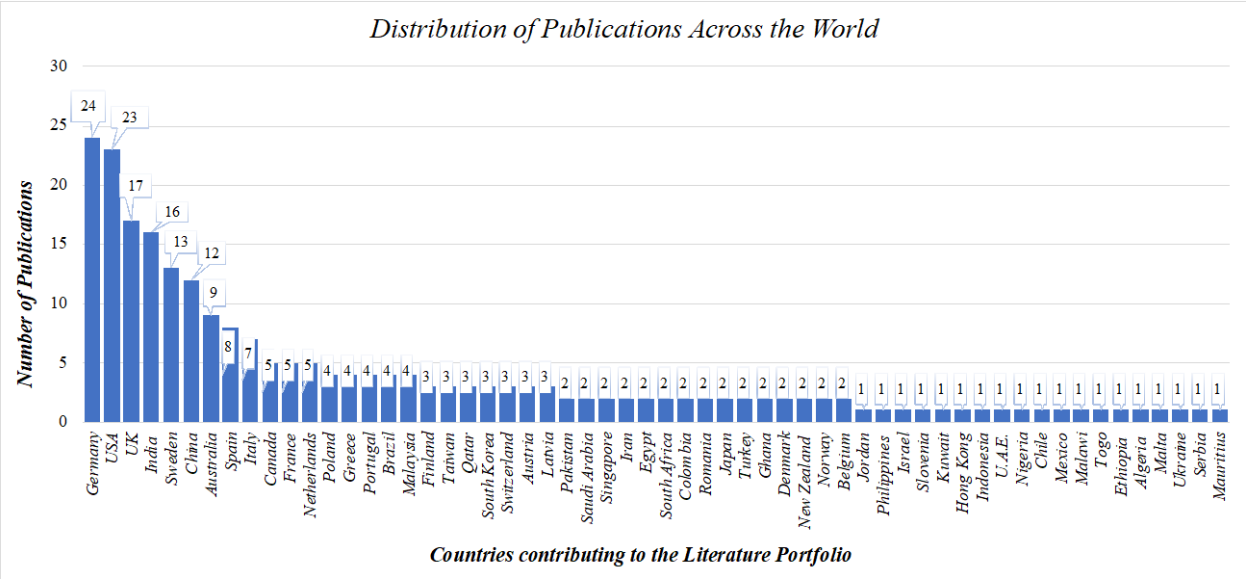
Figure 6 - *Distribution of article classifications.*



(*Note*: Refer Appendix 3 for the data.)

Above shown in Figure 6, is a systematic classification of diverse publications included in this research depicting nature of studies included in the report. The table shows 34 percent of publications are included from article review based studies, 20 percent of studies included from mixed method research, 19 percent from empirical studies, 11 percent based on literature reviews, 9 percent from case study-based methods and lastly, 7 percent of the studies included from methodological research respectively which totals to 100 percent of this research work.

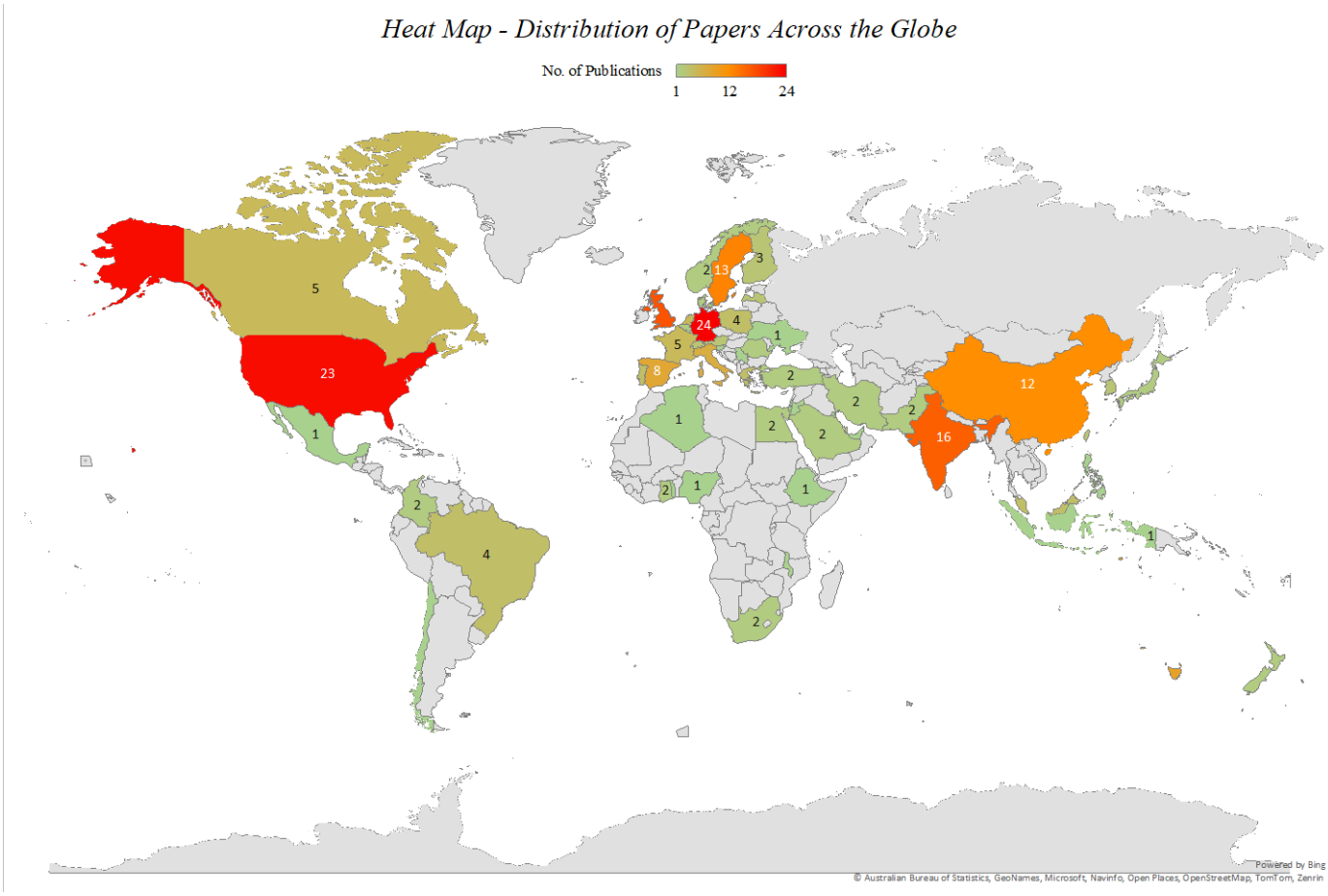
Figure 7 - *Distribution of Publications across the world.*



(*Note*: Refer Appendix 4 for data.)

The studies incorporated in this research gathered secondary data from diverse scientific studies suggesting strong impact of SDG protocols globally. It can be seen that leading countries are Germany, USA, UK, India, Sweden, China, Australia, and European nations have significant stake in publishing researched related to AI and sustainability, which have substantially contributed towards meeting SDG goals. According to the details depicting in the diagram it can be seen that Asian countries deemed developing nations have comparatively low level of participation in sustainability phenomenon, with the exception of India and China, as inferred from the figure. It implies that there is significant need for awareness and education in developing nations on the importance and inevitability of sustainability essential for common peace and welfare globally.

Figure 8 - *Heat map of distribution of papers across the world.*

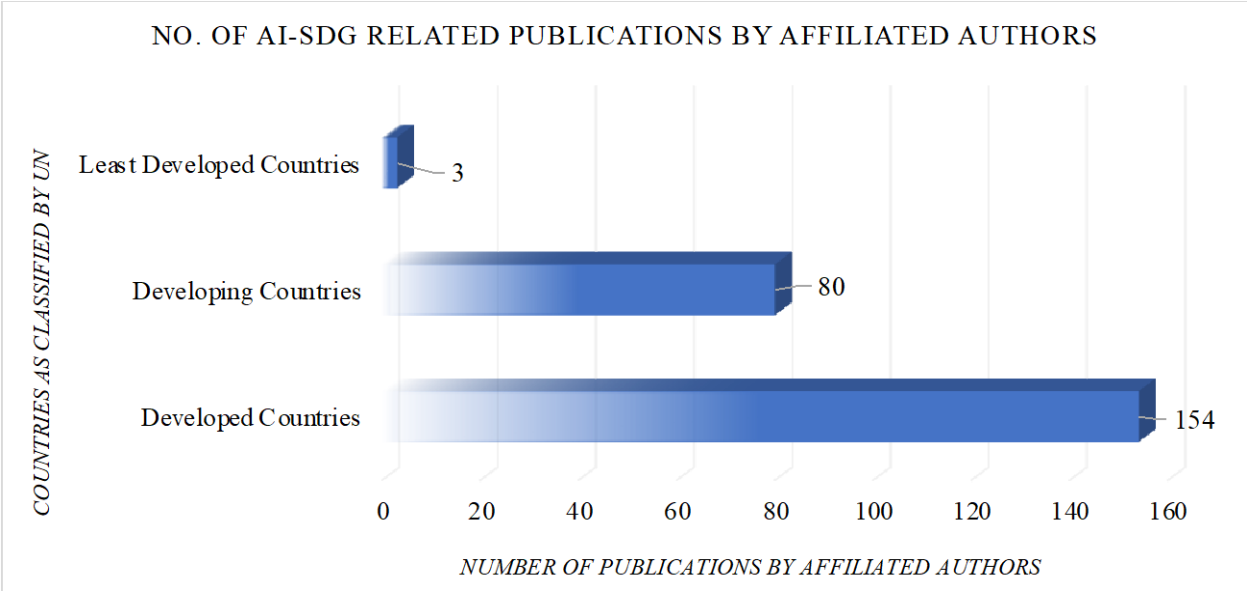


(*Note*: This heat map is made using the Maps feature in Microsoft Excel. The Ledger on top, shows the markings at which the colors/heat changes with frequencies. For ex. Green indicates fewer publications, at 12 it turns orange indicating the median range of data, and close to 24 represents the highest frequency, which is indicated in Red on map. For data, please refer to Appendix 4.)

It can be seen that majority of authors, who have contributed to the research of AI backed sustainability phenomenon hail from Germany, USA & UK, the most technologically advanced nation in terms of AI, IoT and CC in the world, with a few authors from European nations respectively. It is also revealed that India too is significantly contributing towards SDG attainment

probably due to the rapidly increasing populations and drastically depleting quality of natural resources that compelled the country to prioritize and emphasize on sustainability issue. This study found that a significant portion of studies on linking AI and sustainability are contributed by Indian authors showing increased interest among Indian scholars towards sustainability and increasing contribution of AI backed technologies in attaining sustainability.

Figure 9 - *Distribution of publication across the developed, developing & least developed countries.*



(*Note*: Refer Appendix 5, for classification of countries into Developed, Developing and Least Developed economies, as per United Nations. Refer Appendix 4, for data relating to number of authors and publications per country.)

Figure 9 shows the number of authors affiliated with countries across the world, who have contributed to the study on AI and SGDs through scientific publications. Countries have been

classified into three categories, namely, developed nations, developing nations and least developing countries, as per the UN classification of countries.

It can be understood that the contribution of developed countries towards SDGs is substantial with 154 researchers found to be studying and publishing on AI and SDGs in this report's literature portfolio. It can also be seen that, developing nations too, are significant contributors towards SDG goals with 80 researchers publishing from developing world. Lastly, the least number of researchers contributing towards SDGs through their publications, hail from the least developed countries around the world, with just 3 publications on sustainability.

As can be inferred developed countries are advanced and informed enough about the need and inevitability of sustainability and hence are significant contributors towards attainment of SDG goals. Countries like USA, UK, Germany, Sweden, India, China, France, Finland, and others are very advanced and conscious about their responsibility towards developing a sustainable environment through enforcement of appropriate policies, regulations, and laws. These nations are technologically advanced and hence are increasingly adopting an AI backed sustainable work and business culture reflected in diverse industries thus ensuring maximal AI impact on SDG goals (Filho et al., 2022), (Kar et al., 2022).

According to the sources of study's authors of developed nations exhibit advanced levels of knowledge and understandings on diverse aspects of SDGs and have significantly contributed to the body of knowledge. With advent of AI backed technologies readily adopted by diverse industries namely, healthcare, traffic management, power generation, agriculture, marketing, education and learning, disaster management, innovation and township development and other arenas tremendous potential of AI backed ICT and IoT/CC technologies is realized by developed

countries which is clearly evident form the research literature of respective developed countries (Filho et al., 2023) (Ahmad et al., 2021), (Al Qundus et al., 2020).

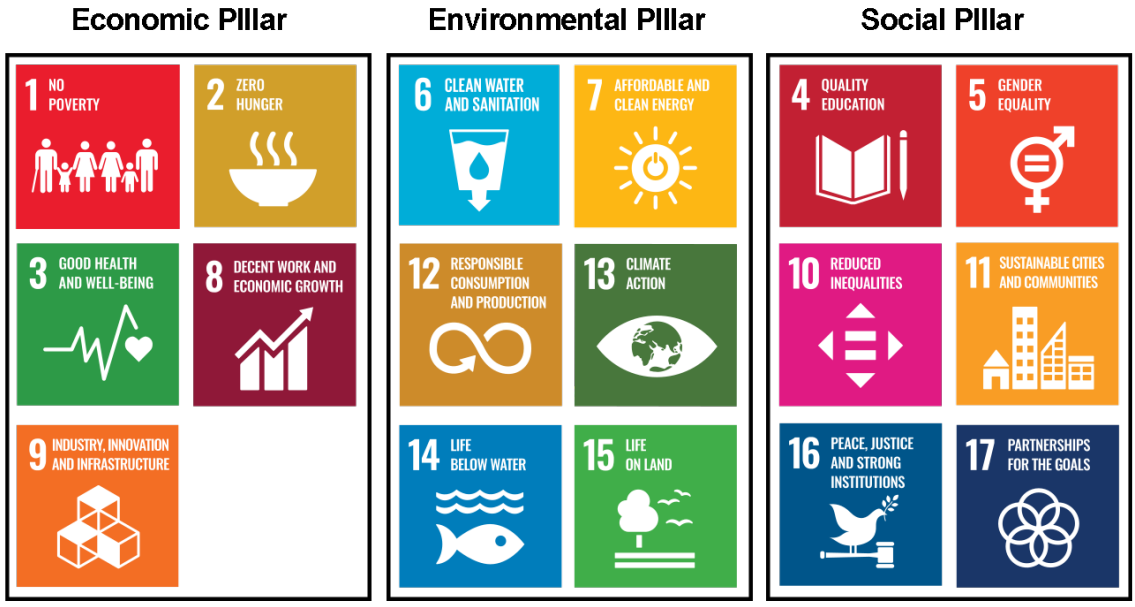
In context to the developing nations, plethora of research publications indicate increasing awareness and education of scientific and business community towards sustainability reflected through improvements across diverse industries activities (Alreshidi, 2019). It is seen that the developing countries are more focused on leveraging the techno-economic advantages of SDGs particularly in the sectors of renewable energy, education and learning, improved manufacturing, and consumption processes.

4.2. Classification of the Sustainable Development Goals

According to a comprehensive study by (Kostoska & Kocarev, 2019) the framework comprising of the set 17 SDG goals aimed to be accomplished by 2030 focuses on the very fundamental components of society that majorly complements sustainability and primarily involves the economic component, environmental component, and the social components. Therefore, in order to accomplish the set SDG goals and the associated targets of 169 varying objectives it is crucial that countries worldwide work in collaboration and integration to ensure a cumulative and collective desirable outcome is realized at an individual and a global level. It is crucial that countries, regardless of their status as developing or least developed consider SDGs as a global objective and work with determination through collaboration and integrity essential for attaining the set targets. It is obvious that in order to derive set SDG goals by 2030 countries of the world will need to foster equality among member nations, develop appropriate channels and mediums of

learning, improvise processes and practices across industries, focus on socioeconomic development by maximizing sustainable industrial activities in the region and emphasize on renewable energy production, the fundamental component of sustainability.

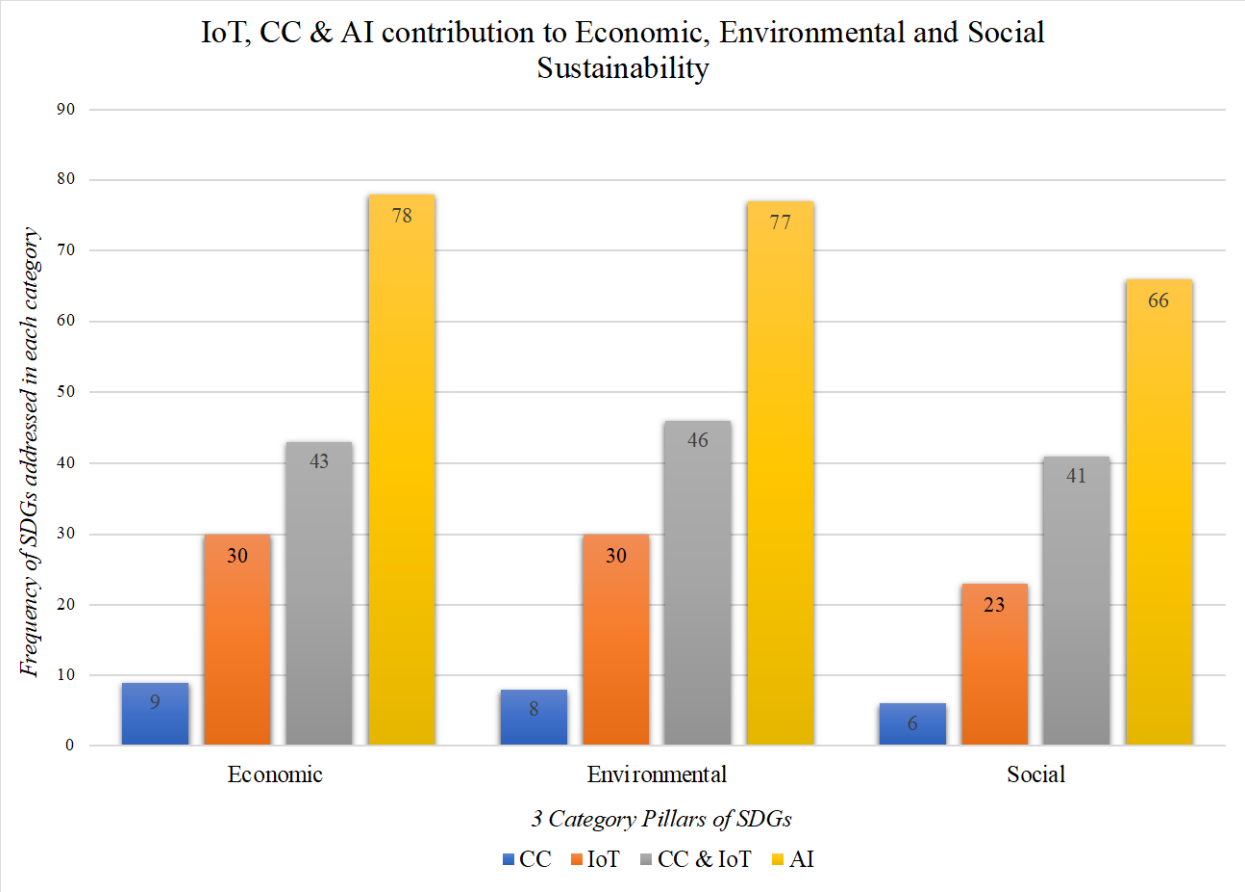
Figure 10 - *17 SDGs in three categories: Economic, Environmental, and Social.*



(*Note*: From *A novel ICT framework for sustainable development goals* by Kostoska & Kocarev (2019). Retrieved from https://doi.org/10.3390/su11071961)

4.3. AI's contribution to Economic, Environmental and Social Sustainability (SDGs).

Figure 11 - *Contribution of AI, IoT and CC technologies in sustainability of economy, environment and social.*



(*Note*: Data for the CC, IoT, CC-IoT Nexus is retrieved from another study *'Examining the role of IOT and cloud computing in achieving sustainable development goals'* by Abaee et al. (2024). While data for AI has been retrieved from the 100 research papers in literature portfolio of this study. Refer Appendix 6 for the data for this graph.)

4.3.1. Economic Sustainability

As depicted in the above given figure 11, it is evident that AI's contribution towards attainment of economic, environmental, and social goals is substantial as compared to its counterparts i.e. IoT, CC and nexus of IoT & CC technologies. The researcher examined diverse secondary sources form the current study as well as the study by Abaee et al. (2024), that investigated roles of IoT and CC technologies in attaining SDG goals. Based on careful investigation of diverse secondary studies it is aptly inferred that from the 200 studies/ sources of data employed in two different studies, i.e., data from literature portfolio of this study and data from study by Abaee et al (2024), a total of 78 studies were found relating to contribution of AI towards attainment of economic goals. On the contrary, 43 studies were found to indicate that the nexus of IoT/ CC played a key role in fulfilling SDG goals. It was also revealed that IoT contributed towards SDGs in 30 studies while CC contribute towards SDG in 9 studies respectively. Thus, the inferences obtained from comparison of the two different studies strongly suggested the inevitable and lasting impact of AI technologies in achievement of SDG goals. The economic sustainability achievable using AI majorly is derivable from education, innovation and production, affordable clean energy, through institutionalized partnerships, and consistent economic growth. Based on the outcomes of comparison and analysis of the studies it can be concluded that advances in AI and its industry wide applications is bound to generate a significant lasting impact on sustainability thereby fulfilling SDG goals.

4.3.2. Environmental Sustainability

In context to the attaining of environment goals under the SDG theme comparison of the two separate studies involving a total of 200 research publications, it is found that a total of 77 research studies were carried out strongly emphasizing AI's role in achieving environmental sustainability. This is a strong and undeniable evidence of increasing AI participation and contribution towards attainment of SDG goals. It must be borne in mind that the role of AI is far more comprehensive and deeper than IoT and CC technologies due to the fact that AI is not just limited to data generation and processing rather is far more complex and comprehensive which is evident form its diverse applications in various industries namely, manufacturing and energy production (Filho et al., 2022 & 2023). It is found in studies that significant research suggests that environment sustainability through effective waste management practices, optimal production and utilization of renewable energy sources, and sustainable business practices is bound to generate desirable impact on SDG goals.

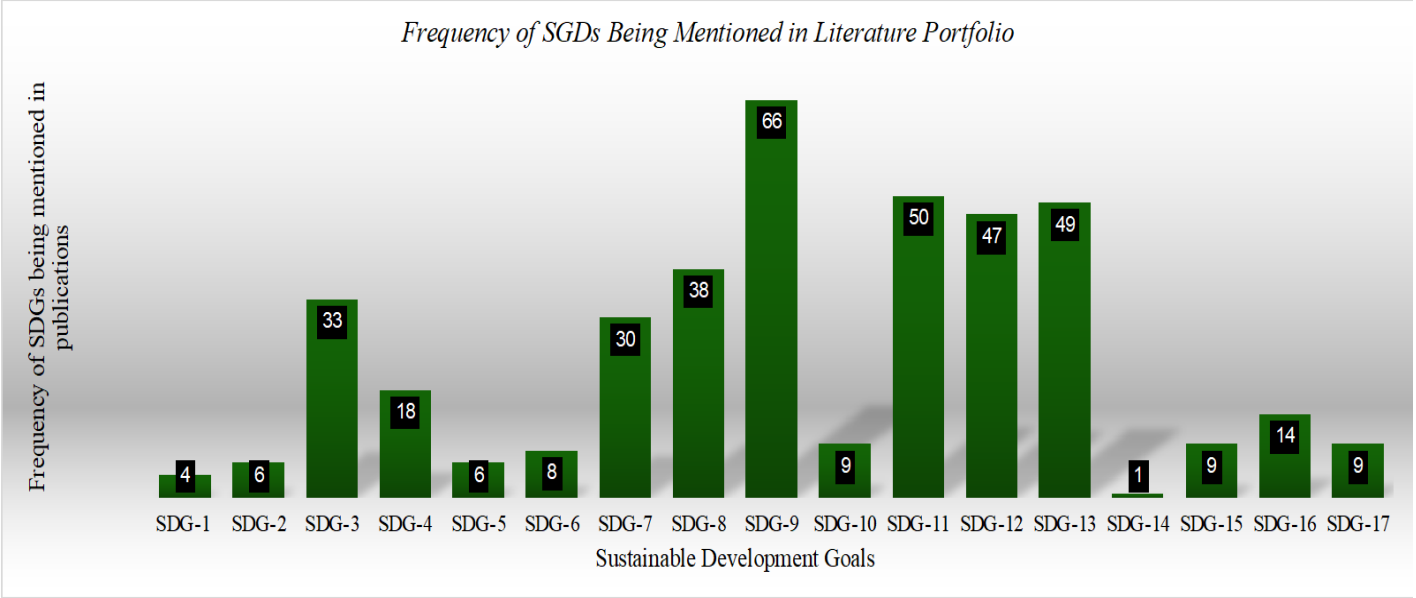
In regard to allied technologies, data showed a total of 46, 30 and 8 studies involving nexus of IoT/CC, IoT and CC respectively contributed towards SDG goals. This emphasized that a nexus of IoT and CC with a weightage of 46 superseded the contribution of individual technologies. It is therefore discernible that despite of forming a nexus between IoT and CC, AI conveniently outweighs all conventional technologies in regard to achievement of SDG goals.

4.3.3. Social Sustainability

In context to the social sustainability goals, it is evident form the obtained results of the two studies consisting of over 200 research publications, that AI still conveniently supersedes its IoT and CC counterparts with over 66 research publications whereas nexus of IoT/CC accounted to 41 while IoT accounted to 23 and CC accounted to 6 respectively. This simply implies that AI strongly and significantly contributes to attainment of SDG goals than its rivals. As social sustainability primarily relates to the quality of social environment, lifestyle of communities, and growth of overall lifestyles of people, relation of AI in regard to social sustainability has been found to be substantial particularly in relation to development of sustainable cities and communities, decent work, quality of life and well-being, equality and peace justice and string institutions of the SDG framework.

4.4. SDGs addressed in the literature portfolio.

Figure 12 - *Frequencies of SDGs being addressed in the publications under the literature portfolio of this study.*



(*Note*: Refer Appendix-7 for data of this graph, which is extracted by analyzing by data given in Table 2.)

As can be seen in the above figure 12 major emphasis is laid on specific SDGs in the secondary publications gathered in this study. In the above figure it can clearly be seen that SDG- 9, 11, 13, 12, 8, and 3 are given major consideration and emphasis which strongly denotes these SDGs are easily achievable and indispensable for world's sustenance due to the fact that these are majorly concerned to developing and developed countries that extensively utilize and implement AI backed technologies across diverse industries and spheres of everyday life. This inference is derived due to the fact that the identified SDGs primarily relate to sustainable cities and communities, innovation and infrastructure development, responsible production and consumption, economic

growth, good health and wellbeing and climatic change. These factors are majorly influencing the developing and developed world today primarily due to increased impact of globalization, industrialization, and multiculturalism that triggers need and inevitability for sustainability.

Table 7 - *SDGs addressed in articles under this study's literature portfolio.*

No.	**References**	**SDGs Addressed**
1	(Filho et al., 2023)	SDGs- 1,3,4,6,7,8,9,11,13,15,17
2	(Abdella et al., 2020)	SDGs- 2,3,12
3	(Ahmad et al., 2021)	SDGs- 3,9,17
4	(Ahmad et al., 2019)	SDGs- 7,9
5	(Ahmad et al., 2021)	SDGs-7, 12, 13,
6	(Al Qundus et al., 2020)	SDGs- 13
7	(Alizadeh et al., 2018)	SDGs- 13
8	(Alreshidi, 2019)	SDGs- 2,3,12,15
9	(Alsharkawi et al., 2021)	SDGs- 1
10	(Ahmad et al., 2020).	SDGs- 7,11,13
11	(Aly,2020)	SDGs-7
12	(Andries et al., 2018)	SDGs- 7
13	(Balogun et al., 2020)	SDGs- 7,8,9,11,13
14	(Bienvenido et al., 2020)	SDGs- 15,16
15	(Fuso Nerini et al., 2019)	SDGs- 3,11,13,15

Table 2 – *SDGs addressed in articles under this study's literature portfolio (Continued).*

No.	References	SDGs Addressed
16	(Goddard et al., 2021)	SDGs- 11
17	(Gue et al., 2020)	SDGs- 7,11,12,13
18	(Deo et al., 2019)	SDGs- 11
19	(Fuso Nerini et al., 2019)	SDGs- 13
20	(Hatti and Denai, 2020)	SDGs- 7,9,11,12
21	(Filho et al.,2022)	SDGs- 5
22	(Sharma et al., 2020)	SDGs- 3,7,8,11,13,16
23	(Das and Mondal, 2023)	SDGs- 10
24	(How et al., 2020)	SDGs- 8,9,11,12,13,15
25	(Huntingford et al, 2019)	SDGs- 13
26	(Perucica & Andjelkovic, 2022)	SDGs- 13
27	(Vinuesa et al., 2020)	SDGs- 7,8,9,11,12,13
28	(Jean et al., 2016)	SDGs- 1,8,11
29	(Khakurel et al., 2018)	SDGs- 3,4,8,9,11,12,13,
30	(Huang and Rust, 2018)	SDGs- 8,9,11,12
31	(Kotsiopoulos et al., 2021)	SDGs- 8,9,12
32	(Lee, 2020)	SDGs- 9,11,12,13
33	(Lee & He, 2021)	SDGs- 7,9,11,12,13
34	(Osburg and Lohrmann, 2017)	SDGs- 4,6,7,8,9,11,12,
35	(Liu et al, 2021)	SDGs- 8,12,13

Table 2 – *SDGs addressed in articles under this study's literature portfolio (Continued).*

No.	References	SDGs Addressed
36	(Majumdar et al., 2021)	SDGs- 9,11,13
37	(Yeh et al., 2021)	SDGs- 4,5,6,7,11,13
38	(Mrówczyńska et al., 2019)	SDGs- 13
39	(Nowosielski et al., 2020)	SDGs- 11,13
40	(Sublime and Kalinicheva, 2019)	SDGs- 13
41	(Noorbakhsh-Sabet et al., 2019)	SDGs- 3
42	(Kankanhalli et al., 2019)	SDGs- 8,9,11,12,16,17
43	(Truby, 2020)	SDGs- 3,8,9,10,11,12,16,17
44	(Androutsopoulou et al., 2019)	SDGs- 8,9,11,12,15,16,17
45	(Schappert et al, 2020)	SDGs- 3,6,7,8,9,11,12
46	(Filho et al., 2022)	SDGs- 3,4,7,8,9,11,12,
47	(Allam and Dhunny, 2019)	SDGs- 9,11,12
48	(Nishant et al., 2020)	SDGs- 7,9,11,12,13
49	(Uriarte-Gallastegi et al., 2024)	SDGs- 7,9,11,12,13
50	(Kar et al., 2022)	SDGs- 2,3,6,8,9,11,12
51	(Hengstler et al., 2016)	SDGs- 3,9,11
52	(Casares, 2018)	SDGs- 8,9,10,16
53	(Abduljabbar et al., 2019)	SDGs- 3,9,11,13
54	(Jha et al., 2019)	SDGs- 2,6,9,12,15
55	(Dhiman et al., 2024)	SDGs- 3,4,8,9,12,13

Table 2 – *SDGs addressed in articles under this study's literature portfolio (Continued).*

No.	References	SDGs Addressed
56	(Van Wynsberghe, 2021)	SDGs- 7,9,11,12,13,17
57	(Coeckelbergh, 2020)	SDGs- 7,9,12,13,16
58	(Floridi et al., 2018)	SDGs- 3,4,5,8,9,10,11,13,16,17
59	(Verdecchia et al., 2023)	SDGs- 9,12,13
60	(Galaz et al., 2021)	SDGs- 9,11,12,13,14
61	(Sorell & Draper, 2014)	SDGs- 3,9,10,11
62	(Dignum, 2018)	SDGs- 4,8,9,16
63	(Rohde et al., 2024)	SDGs- 7,8,9,11,12,13,16
64	(Dhar, 2020)	SDGs- 7,9,12,13
65	(Waltersmann et al., 2021)	SDGs- 7,9,12,13
66	(Choi & Kim, 2020)	SDGs- 7,9,12
67	(Falk & van Wynsberghe, 2023)	SDGs- 7,9,11,12,13
68	(Sætra, 2021)	SDGs- 3,4,5,8,9,10,11,13,16
69	(Shankar et al., 2020)	SDGs- 2,12,15
70	(Farahani, 2023)	SDGs- 3,8,9,10,11
71	(Fang et al., 2023)	SDGs- 11,12,13
72	(Jakšič & Marinč, 2018)	SDGs- 8,9,10
73	(Hamet & Tremblay, 2017)	SDGs- 3,9,11
74	(Reddy et al., 2018)	SDGs- 3,5,8,9
75	(Contreras & Vehi, 2018)	SDGs- 3,9

Table 2 – *SDGs addressed in articles under this study's literature portfolio (Continued).*

No.	References	SDGs Addressed
76	(Baryannis et al., 2018)	SDGs- 8,9,12
77	(Hellingrath & Lechtenberg, 2019)	SDGs- 8,9,12
78	(Chawla et al., 2018)	SDGs- 8,9,12
79	(Dahlman et al., 2019)	SDGs- 3,4,9,11,13
80	(Wuest et al., 2016)	SDGs- 9,12
81	(Ayer et al., 2010)	SDGs- 3
82	(Wang et al., 2018)	SDGs- 8,9,12
83	(Lee et al., 2018)	SDGs- 8,9,12
84	(Popenici & Kerr, 2017)	SDGs- 4,8,9
85	(Bayne, 2015)	SDGs- 4,8,9
86	(Jiang et al., 2017)	SDGs- 3,4,8,9
87	(Dilsizian & Siegel, 2013)	SDGs- 3,9
88	(Neill, 2013)	SDGs- 3,9
89	(Maté et al., 2016)	SDGs- 7,9,11,13
90	(Singh et al., 2023)	SDGs- 3,4,7,11,13,16
91	(Goh & Vinuesa, 2021)	SDGs- 2,3,4,9,11,13,16
92	(Goralski & Tan, 2020)	SDGs- 3,4,6,8,9,11,13
93	(Gupta et al., 2021)	SDGs- 1,7,8,10,13
94	(Lee et al., 2015)	SDGs- 8,9,11,12
95	(Allen et al., 2019)	SDGs- 3,4,6,9,12,13,17

Table 2 – *SDGs addressed in articles under this study's literature portfolio (Continued).*

No.	References	SDGs Addressed
96	(Nordgren, 2022)	SDGs- 7,9,11,12,13
97	(Nasir et al., 2023)	SDGs- 3,4,5,9,11,13,16
98	(Di Vaio et al., 2020)	SDGs- 12
99	(Mensah, 2019)	SDGs- 3,7,8,9,11,13,16,17
100	(Miehe et al, 2021)	SDGs- 9,11,12,13

4.5. SDG Targets addressed in the Literature Portfolio

Table 8 - *Targets Addressed in articles in the Literature Portfolio.*

No.	References	SDGs Targets Addressed
1	(Filho et al., 2023)	Target - 6.6, 7.3, 9.5
2	(Ahmad et al., 2019)	Target – 7.3, 9.5
3	(Ahmad et al., 2021)	Target – 7.3
4	(Al Qundus et al., 2020)	Target – 11.5
5	(Alreshidi, 2019)	Target -2.3, 3.8, 9.5, 13.3
6	(Balogun et al., 2020)	Target – 9.4
7	(Bienvenido et al., 2020)	Target – 9.5
8	(Fuso Nerini et al., 2019)	Target – 11.6
9	(Goddard et al., 2021)	Target – 11.7
10	(Sharma et al., 2020)	Target – 16.6

Table 3 - *Targets Addressed in articles in the Literature Portfolio (Continued).*

No.	References	SDGs Targets Addressed
11	(Gue et al., 2020)	Target – 9.5
12	(How et al., 2020)	Target – 9.5
13	(Huntingford et al., 2019)	Target – 13.3
14	(Perucica & Andjelkovic, 2022)	Target – 9.5
15	(Vinuesa et al., 2020)	Target – 1.1, 3.8, 4.4, 5.1, 6.3, 7.2, 9.5, 11.6, 13.1
16	(Jean et al., 2016)	Target – 1.2
17	(Khakurel et al., 2018)	Target – 4.4, 8.5, 9.5, 11.6, 12.5
18	(Kotsiopoulos et al., 2021)	Target – 7.2, 7.3, 9.5
19	(Lee, 2020)	Target – 9.5
20	(Lee & He, 2021)	Target – 7.2
21	(Yeh et al., 2021)	Target – 3.8, 4.4, 9.5
22	(Mrówczyńska et al, 2019)	Target – 11.6
23	(Noorbakhsh-Sabet et al., 2019)	Target – 3.8
24	(Kankanhalli et al., 2019)	Target - 9.5, 11.6, 16.6
25	(Truby, 2020)	Target – 16.5
26	(Androutsopoulou et al., 2019)	Target – 16.6
27	(Allam and Dhunny, 2019)	Target – 11.3
28	(Nishant et al., 2020)	Target - 9.5
29	(Uriarte-Gallastegi et al., 2024)	Target – 7.2
30	(Hengstler et al., 2016)	Target – 3.8, 9.1, 9.4, 11.2
31	(Casares, 2018)	Target – 16.6
32	(Kar et al., 2022)	Target – 7.3, 9.4, 11.6, 12.5, 13.2
33	(Abduljabbar et al., 2019)	Target – 3.6, 9.1, 11.2, 13.2
34	(Jha et al., 2019)	Target – 2.3, 2.4

Table 3 - *Targets Addressed in articles in the Literature Portfolio (Continued).*

No.	References	SDGs Targets Addressed
35	(Dhiman et al., 2024)	Target – 9.4
36	(Van Wynsberghe, 2021)	Target – 13.2
37	(Coeckelbergh, 2020)	Target – 13.2
38	(Floridi et al., 2018)	Target – 9.5, 16.6, 16.7, 17.6
39	(Verdecchia et al., 2023)	Target – 7.3, 9.4, 13.2
40	(Galaz et al., 2021)	Target – 13.2
41	(Dignum, 2018)	Target – 16.6
42	(Dhar, 2020)	Target – 13.2
43	(Waltersmann et al., 2021)	Target – 12.1
44	(Choi & Kim, 2020)	Target – 9.4
45	(Shankar et al., 2020)	Target – 2.4, 12.4
46	(Farahani, 2023)	Target – 3.8, 4.5, 9.4, 10.2, 11.3
47	(Fang et al., 2023)	Target – 11.6, 12.5
48	(Jakšič & Marinč, 2018)	Target – 8.10, 9.3, 10.2, 17.8
49	(Hamet & Tremblay, 2017)	Target – 3.8, 3.d, 9.5, 17.6
50	(Reddy et al., 2018)	Target - 3.8, 3.d, 9.5, 17.6
51	(Contreras & Vehi, 2018)	Target – 3.4, 3.8
52	(Chawla et al., 2018)	Target – 8.2, 9.4
53	(Wuest et al., 2016)	Target – 9.2, 9.4, 12.5
54	(Ayer et al., 2010)	Target – 3.4, 3.8
55	(Wang et al., 2018)	Target – 9.4, 12.5
56	(Lee et al., 2018)	Target – 8.2, 9.4, 12.2
57	(Popenici & Kerr, 2017)	Target – 4.4, 8.6, 9.5
58	(Bayne, 2015)	Target – 4.3, 8.2, 9.5
59	(Jiang et al., 2017)	Target – 3.4, 3.8

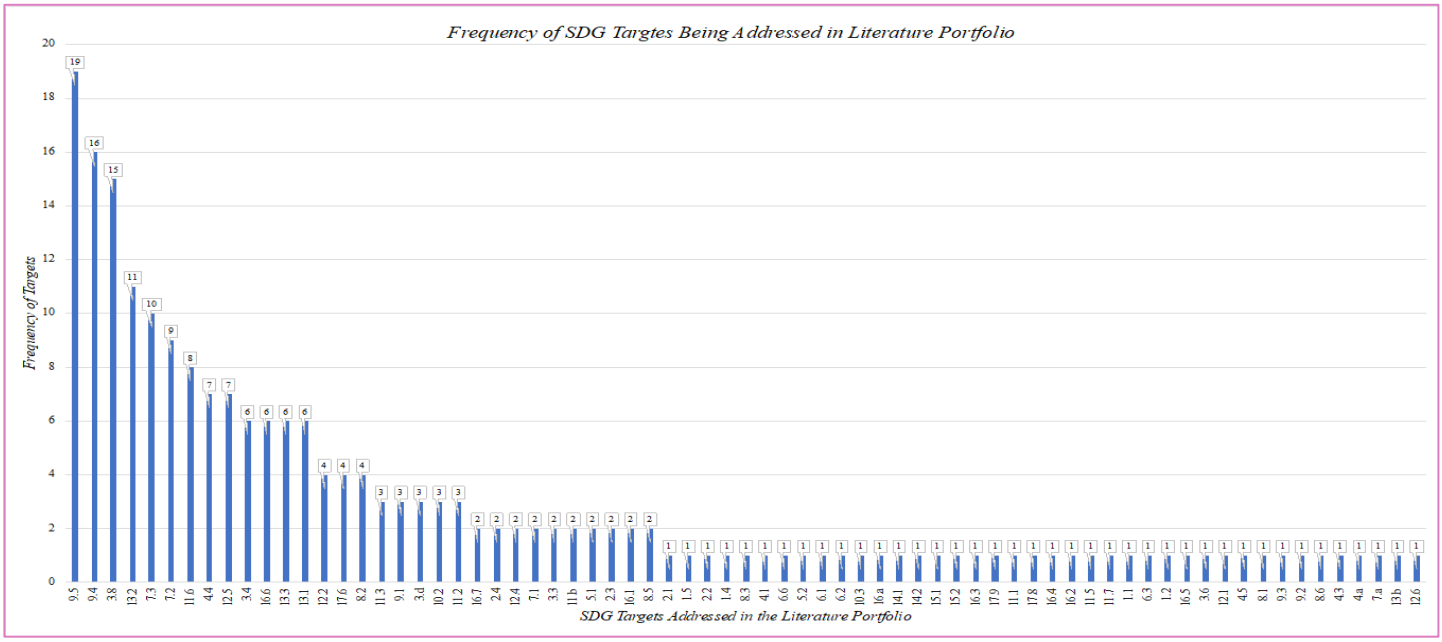
Table 3 - *Targets Addressed in articles in the Literature Portfolio (Continued).*

No.	References	SDGs Targets Addressed
60	(Dilsizian & Siegel, 2013)	Target - 3.4, 3.8
61	(Neill, 2013)	Target – 3.3, 3.4, 3.8
62	(Maté et al., 2016)	Target – 7.2, 7.3, 11.6, 11.b, 13.1, 13.3
63	(Singh et al., 2023)	Target -3.4, 3.d, 4.4, 4.a, 7.2, 7.3, 7.a, 11.3, 11.b, 13.1, 13.2, 13.3, 13.b, 16.1, 16.2, 16.4, 16.7, 16.a
64	(Gupta et al., 2021)	Target – 7.1, 7.2, 7.3, 13.1, 13.2, 13.3, 8.2, 8.3, 8.5, 9.4
65	(Nordgren, 2022)	Target – 7.2, 7.3, 9.4, 13.1, 13.2, 13.3
66	(Di Vaio et al., 2020)	Target – 12.2, 12.6
67	(Nasir et al., 2023)	Target – 1.4, 1.5, 2.1, 2.2, 3.3, 3.8, 4.1, 4.4, 5.1, 5.2, 6.1, 6.2, 7.1, 7.2, 9.1, 9.4, 10.2, 10.3, 11.1, 11.2, 12.2, 12.5, 13.1, 13.2, 14.1, 14.2, 15.1, 15.2, 16.1, 16.3, 17.6, 17.9
68	(Miehe et al, 2021)	Target – 9.4, 12.2, 12.4, 12.5

The 17 UN Sustainable development goals are further bifurcated into a total of 169 targets to make these goal more addressable and attainable. Table 3, given above, shows the number of particular targets that are addressed by papers under this study's literature portfolio. Out of the 100 papers in the literature portfolio, 68 publications have been found to be addressing the mentioned relative targets, either directly within in the paper itself in some cases, or indirectly through the research papers outcome and findings; In both cases, only the papers that have outcomes that addressed and paved a way to help attain the targets and in-turn their relative SDGs have been shortlisted and mentioned into the table 3 above. Upon further analysis data set of Targets from Table 3, we derived that the highest frequencies of targets being addressed were from SDGs under the Economical pillar, followed by SDGs under Environmental pillar, and the least targets are addressed for SDGs under the Social pillar, by AI and AI based technologies.

Figure 13, given below, shows the frequency of targets found under the literature portfolio of this study. The top 7 targets that have been addressed in the literature portfolio for the highest number of times, have been selected and discussed further. Since these targets have already been researched upon for the application and usage to AI and other industry 4.0 technologies, towards attaining sustainable development goals, these targets, and the SDGs they fall under, along with their SDG categories, are realistically, as can be seen in the discussion ahead, as most likely to higher contribution by AI, as compared to other SDGs and targets, in the near future.

Figure 13 - *Frequency of SDG Targets being addressed.*



(*Note*: Refer Appendix 8 for data, which has been derived from analyzing Table 3.)

SDG Targets with the highest frequencies:

1. ***Target 9.5*** – 'Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending'.

   (SDG 9 – Industry, Innovation & Infrastructure | SDG Category – Economic Pillar)

2. ***Target 9.4*** – 'By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities'.

   (SDG 9 – Industry, Innovation & Infrastructure | SDG Category – Economic Pillar)

3. ***Target 3.8 –*** 'Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all'.

   (SDG 3 – Good Health and Wellbeing | SDG Category – Economic Pillar)

4. ***Target 13.2 –*** 'Integrate climate change measures into national policies, strategies and planning'.

   (SDG 13 – Climate Action | SDG Category – Environmental Pillar)

5. ***Target 7.3 –*** 'By 2030, double the global rate of improvement in energy efficiency'.

   (SDG 7 – Affordable & Clean Energy | SDG Category – Environmental Pillar)

6. ***Target 7.2 –*** 'By 2030, increase substantially the share of renewable energy in the global energy mix'.

   (SDG 7 – Affordable & Clean Energy | SDG Category – Environmental Pillar)

7. ***Target 11.6 –*** 'By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management'.

   (SDG 11 – Sustainable Cities and Communities | SDG Category – Social Pillar)

   (*Note*: Targets quoted and sourced from United Nations - the 17 goals, (2024); retrieved from https://sdgs.un.org/goals)

4.5.1. Elaboration of Identified Targets Under SDGs Achievable by 2030

1) In the above table diverse targets are mentioned that are addressable under this study. These targets include target 9.5 involving consistent improvements across diverse industrial sectors with special consideration towards environment and society, improvement in scientific and technological innovations with emphasis on economic and environmental benefits. Under the umbrella of SDG 9 industry, innovation and infrastructure various targets that denote consistent advances and developments in the fields of science, engineering, research, and development are covered aimed to foster the quality of lives of developing nations.

2) By the year 2030 under target 9.4 it is anticipated that sustainable infrastructure and retrofit industries will flourish globally which are expected to become more resource efficient and eco-friendly with emphasis on green energy resources. Under the umbrella of target 9.4 various industries worldwide are obliged and expected to adapt sustainable and eco-friendly business processes, practices, and procedures so as to ensure optimal sustainable business practices industrywide globally. This is critical to fulfill SDG 9 goals and attain maximal sustainable impact on economic, environmental, and social levels.

3) Under the umbrella of SDG 3 denoting good health and wellbeing, target 3.8 puts major emphasis on quality, costs and accessibility of effective health care products and services globally.

4) Under the umbrella of SDG 13 climatic action, and in accordance with target 13.2 major emphasis will be laid on environmental protection on various levels of existence particularly industrial, societal, and governmental. This mainly involves national policies, strategies and planning by the year 2030.

5) Under the umbrella of SDG 7, targets 7.3 achievable by 2030 involving doubling of global renewable energy outputs through adaptation of diverse renewable energy sources namely, solar energy, wind energy, hydropower generators, and other innovative methods of energy generation. This fulfils SDG 7 relating to affordable clean energy. Under the SDG 7, target 7.2 suggesting scalability and sharing of renewable energy mix is emphasized.

6) Under the umbrella of SDG 11 target 11.6 suggesting sustainable cities and communities' major emphasis is laid on reduction of carbon footprints on cities and communities with focus on restoring and purification of quality of air, water, and soil. By the year 2030 nations globally are expected to focus on effective waste management practices and strategies so as to ensure minimal adverse impacts on the environment. This directly implies adoption of an optimized suitability model industrywide and globally to minimize air, water and soil pollution and maximize the efficiency of waste management practices and strategies to ensure negligible adverse impact on the environment.

7) Identification of the above 7 targets found to be the most researched ones among all targets it can be inferred that AI backed technologies would certainly play a significant role in contributing towards attaining the above 7 discussed targets by 2030. There is every probability that an integrated technological framework consisting of AI, IoT and CC would immensely aid businesses, societies, and scientific communities in attaining the critical SDG objective sand allied targets.

Based on the inferences draw-able from the identification and discussion of the above-mentioned SDG and targets it can be anticipated that increasing applications of AI technologies industry-wide is sure to deliver desirable techno-economic benefits and social-environmental advantages to consequently addressing each and every SDG goals globally.

5. Discussion

The facts and information obtained from plethora of diverse scientific research literature incorporated in this study suggested tremendous desirable impacts of AI and allied technologies towards achieving sustainable development goals as enlisted under United Nations sustainability objectives for world nations. This study has clearly identified various SDGs given by the UN sustainability report and succeeded in retrieving appropriate secondary publications relevant to the research theme. As shown in the tables contributions of various author's works emphasizing on role of AI towards sustainability attainment across the world is systematically represented. The table clearly shows various research publications depicting linkages of AI and sustainability and how they contribute towards SDG goal achievement. Various studies from diverse research databases have been included in this research necessary to establish its stance in regard to the research questions. It is therefore clearly inferred that AI plays a more significant role in SDG attainment than IoT/ CC technologies. Based on the comparative analysis of current research report and the research paper by Abaee et al. (2024), it can be known from contemporary studies that majority of AI backed technologies rely on IoT and CC based technologies which strongly suggests that IoT and CC technologies complement AI across diverse applications eventually contributing towards attainment of SDG goals. It must be understood that AI technologies are an advancement of IoT and CC technologies which complement each other and thus based on the extensive industrywide applications of AI technologies today it can be concluded, as suggested by studies, that AI certainly plays a key role in addressing SDG goals being the primary resource while IoT and CC complement AI technologies and applications consequently generating a cumulative desirable impact on the process of SDG goal achievement.

Studies from the time period of 2010 to 2024 have been included in this research that are primarily focused on role and contribution of AI in sustainability achievement. Applying an exploratory research perspective and deductive approach the study has appropriately examined around 100 research publications on the issue of AI and sustainability and their contribution towards SDG achievements. Each and every study has been investigated to ensure it contributes towards specified SDG goals as enlisted under the UN report. The study has found varying contributions of different authors as discerned through their research works concerning AI and sustainability goals. This is because of the fact that despite of a plethora of scientific research publications major research studies relate to fulfillment of specific SDG goals by AI and allied technologies. For instance, this research observed that major emphasis is given achievement of SDGs pertaining to (SDG11) sustainable cities and communities, responsible production, and consumption (SDG12), good health and well-being (SDG3) and lastly, affordable clean energy (SDG7). This research has also found that major scholarly research studies have been contributed by different researchers in the years 2018, 2019, 2020, and 2012 respectively. These studies have addressed diverse SDG objectives in their studies which demonstrated consistent efforts by world countries towards achievement of varied SDG goals. It is understandable that the enforcement of UN sustainable initiatives triggered worldwide awareness among the world nations and communities, industries, and scientific communities which is reflected by way of increasing contribution to the body of knowledge by worldwide authors. With increased scope and implementation of globalization across diverse industries and the increasing applications of AI and internet-based technologies industry 4.0 has seen an unprecedented boom by way of process automation industry-wide (Filho et al., 2022, 2023), (Vinuesa et al., 2020)., (Ahmad and Zhang, 2020). Diverse scientific publications included in this study focused majorly on-economic, environmental, and social goals

of the SDGs which strongly emphasized on the fact that these could be the primary and major areas of development and growth that needs to be achieved on a priority basis in order to realize other SDGs globally.

The study has also examined the independent and cumulative and collective impact of diverse technologies namely, IoT, CC and nexus of IoT and CC technologies on SDGs and a comparison of AI versus its IoT based counterparts to gain deeper understanding of how different technologies have contributed towards attainment of SDG goals acting independently and collectively. The study referred to previously conducted research, by Abaee et al. (2024), on role and contribution of IoT, CC and nexus of IoT and CC technologies on sustainability attainment and how this study contributes to SDG attainment working parallel to AI based technologies. This implies that a total of 200 research publications were investigated 100 from previously conducted research involving 100 studies on IoT and CC technologies and 100 studies from this research which primarily involved AI role and sustainability achievement in regard to UN's SDG objectives worldwide. Careful examination and analysis of the two studies revealed that AI in nexus with IoT and CC played a significant role and contribution in attaining SDG goals. The study showed substantial scientific literature emphasizing on increasing role of AI backed technologies in diverse areas and industries namely, manufacturing, service industry, health care, energy generation, agriculture, and scientific fields (Filho et al, 2022, 2023), and (Vinuesa et al, 2020).

From the corpus of 100 research studies relating to AI, Sustainability and SDGs, it is found that a total of 78, 77 and 66 scientific publications are found that addressed economic, environmental, and social objectives respectively. From the studies it is found that majority of studies laid significant emphasis on economic, environmental, and social SDG goals due to the fact that perhaps these categorizations directly and indirectly fulfilled allied SDG goals of the UN charter

thus ensuring attainment of various SDG goals overtime. For instance, attainment of affordable and clear energy namely, solar energy or wind energy directly impacted on sustainable cities and communities thereby fulfilling the allied SG goals of (SDG11 and SDG 15). Another ideal example of how key SDG goals contribute and complement towards attainment of allied SDG goals is attaining and fostering quality of education which directly impacted on the SDG objectives of good health and well-being, decent work and economic growth, and reduced inequality, peace justice and string institution and partnership of goals. Thus, it is inferable that SDG 4 directly and indirectly contributed towards attainment of allied SDG goals namely, (SDG 3,8,10, 16 and 1). Despite the fact that attainment of a single SDG goal complements and aids in achievement of allied SDG goals, involvement of AI backed technologies have played a substantial and inevitable role in accelerating the performances of diverse SDG processes thereby generating desirable outcomes of AI and allied technologies. Based on the extensive secondary studies extracted in this research it is now inferred that achievement of SDG goals would have never been possible without the optimal utilization and applications of AI backed technologies and the internet of things. It is evident from the study that increasing AI and IoT backed applications across diverse industries are significantly contributing towards sustainability globally thereby effectively addressing SDG goals of UN charter. Based on the tabular data and analysis of various secondary information sources it is inferred that AI outweighs IoT/CC technologies in terms of its contribution in fulfilling SDG goals. Based on the discussion and analysis of various secondary sources of information it is evident that economic benefits are majorly realized from AI's industry-wide applications due to the fact that implementation of diverse AI backed technologies complement economic development while contributing towards social-environmental benefits. Thus, AI's industry-wide

applications primarily trigger economic benefits and complement social and environmental goals of SDGs.

6. Conclusion and Recommendations

To conclude, upon careful examination and analysis of diverse secondary sources of this study and comparison to research components of previously conducted study by Abaee et al (2024), on IoT and CC and its individualistic and integrated contribution towards SDG attainment, it is found that AI and nexus of IoT and CC have revolutionized the world by delivering consistent and anticipated sustainability outcomes in diverse areas. Comparison of exiting study outcomes and inferences dawn from previous study on SDGs revealed promising anticipated outcome of AI and IoT backed technologies towards achieving SDG goals.

The contribution of AI and IoT backed technologies in economic, environmental, and social spheres is substantial due to its extensive applications across industries over which achievement of SDG goals rely. Despite the fact that, as revealed through diverse secondary studies, major emphasis is laid towards energy generation, sustainable cities, and economic growth through innovation and industrial production however there are significant gaps and flaws fond in existing research that shows minima or negligible research conducted on some of the most critical issues requiring serious attention such as poverty, starvation, gender equality, reduced inequality, and partnership for goals. Lack of contribution in these areas could severely hamper the performance of SDG initiatives as these areas directly concern the general well-being and quality of life in a given region. It is clearly inferred from this research that least developing countries have delivered negligible research contribution signifying lack of awareness, resources, and governmental interest towards the attainment of SDG goals. This implies that the achievement of SDG goals in a given

region majorly depends on governmental policies, interest and resource allocation and lack of which may severely hinder SDG initiatives. This eventually calls for active involvement of SDG 17 i.e. Partnership for goals, requiring member nations to collaborate and contribute their best to needy and poor nations for achieving SDG targets by 2030.

Listed below are some recommendations based on the learning from the literature, that can help in attaining sustainable development goals and targets:

1) **Renewable Energy Generation-** Since energy generation is crucial to the welfare and survival of stakeholders, it is vital to emphasis the renewable energy generation using solar power, wind energy and hydro power stations globally. AI backed and integrated solar power generators are found to be extremely viable and techno-economically feasible as their data driven model ensures superiority in modelling simplification and modification, extreme forecasting precision, enhanced computational accuracy. Furthermore, AI backed power systems are exceptionally performance oriented, efficient, and agile because of its data driven nature (Zhou, 2022). It is recommended that as compared to centralized PV farms based renewable energy systems, distributed energy systems such as infrastructure integrated PV systems are used, as they are found to be extremely efficient due to avoidance of long-distance power transmission thus ensuring minimal wastage of energy (Zhou, 2022). This will help in achieving SDG 7, which complements the needs and interests of SDG 3, 8, 9, 11, 12, 13, 14, and 15.

2) **Improved Education and learning-** quality and efficiency of learning and education must be improved, especially in developing and undeveloped nations, as proper education is essential and crucial for developing the right skills and delivering maximized human resource advantage. AI technology backed learning systems are increasingly gaining more significance and applicability globally due to diverse techno-economic and learning advantages, that conventional

systems of learning lacked. It was found that improved learning experience, was mutually derived by stakeholders, through the use of AI backed Learning Management Systems (LMS) (Zhang and Aslan, 2021).

3) Fostering Innovation- it is important that industry-wide innovation and upgrades are consistently implemented to ensure maximal resource efficiency and productivity essential for realizing improved economic growth, improving quality of life, and ensuring welfare of stakeholders. As innovation is an industrywide applicable term various seamless technological benefits of AI can be leveraged ranging from business intelligence based personalized marketing strategy to nanomedicine that uses nano-bots for cancerous tumor detection and depletion (Kong et al., 2023).

4) Effective Waste Management- it is strongly recommended that all countries develop and implement effective waste management practices and strategies as elimination of waste matter in the form of chemicals, electronic waste, gases, plastics, containers, metals, glass, and other hazardous substances is essential for protecting the environment. AI technologies can be effectively used in waste management processes that has the potential to revolutionize municipal waste management system by enhancing effectiveness, efficiency, and accuracy of waste management systems through effective waste collection, classification, and processing. Today, AI backed intelligent garbage bins, precise forecasting models, classification robots and wireless detection allows effective monitoring of waste bins, precisely forecast waste collection, and maximize waste management performance systems (Fang et al., 2023). Appropriate waste management practices will ensure minimal adverse impact on critical natural resources such as waters, air and soil which will consequently help to fulfill sustainable objectives of SDG 6,,11,12,13,14 & 15.

5) Partnerships and Goals- it is utmost essential that member nations collaborate and fully cooperate with the needy developing nations in terms of resource sharing, knowledge sharing, information sharing, human resource sharing, and technological resource sharing so as to ensure maximal desirable impact of SDGs are realized by 2030.

Based on the inferences obtained from this research it is clear that in order to realize the set SDG objectives and goals it is utmost important that nations rely on resource and data sharing, collaboration, and an integrated approach to overcome sustainability challenges and barriers posing the world today. Above mentioned SDG goals and targets are primarily contributed by AI technologies in future considering increasing its need and inevitability to the world society.

Recommendations for Future Research

Following are some insightful future recommendations form a research perspective, based on research gaps identified during the course of this research:

1) It is recommended that quantitative studies should be carried out on different AI technological applications worldwide, essential for understanding the realistic impacts of different AI technologies on varied aspects, like studying the impact on environmental, economic, social, and technological aspects.

2) AI technologies that succeeded in attaining specific SDG goals, directly and indirectly, should be studied and researched upon optimally; this is essential for further diversifying the scope and applications of core AI technologies in the relevant fields.

3) It is recommended that comprehensive research in qualitative/ quantitative form should be undertaken, targeting specific industries to accurately ascertain AI's impact on sectoral performance and productivity, considering the increasing AI applications industrywide. This

allows researchers to gain accurate insights into the given sector's performance optimisation, resulting from AI applications, which will help determine further ways and progress using AI.

4) It would be great research by future researchers that can aptly identify the SDGs that have succeeded in leveraging optimal AI advantage and link those fields to connected SDG goals, in a manner that ensures maximal AI techno-economic as well as socio-environmental advantage.

5) A Comprehensive model needs to be developed to identify causation and quantitative measures between CC, IOT, IOT-CC nexus and AI to identify the contribution of each technology to SDGs and how their integration boosts these contributions.

6) To study and research the negative implications of AI technology on socioeconomic disparities and develop strategies to overcome these challenges by addressing and promoting the benefits of AI technology.

7) Research needs to be conducted on developing tools and methodologies to analyze the carbon footprints of AI technologies in various areas so that, these tools can be used in reducing carbon emissions and contribute to Global Sustainable efforts.

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Appendix – 1

Table A1-*Year and Respective Number of Publications of Papers in the Literature Portfolio.*

Distribution of Publication over the years	
Year of Publication	Number of Publication
2010	1%
2013	2%
2014	1%
2015	2%
2016	4%
2017	4%
2018	14%
2019	18%
2020	21%
2021	16%
2022	6%
2023	8%
2024	3%

This data is used to analyzing the number of AI-SDG related studies being published, within the time frame of this study, i.e., 2010-2024. The data given in the table has been used to create Figure 4. It can evidently be seen that the number of publications peaked in 2018, 2019, 2020, and 2021.

Appendix – 2

Table A2 - *IoT, CC, IoT-CC nexus, and AI with their corresponding number of publications.*

Technology	Number of Publications	Publication Proportion
CC	12	6%
IoT	34	17%
IoT-CC Nexus	54	27%
AI	100	50%

Table A2 shows the number of publications in this study's literature portfolio, as well as from another similar study, '*IOT and cloud computing for Sustainable Development Goals in industry 4.0',* by Abaee et al. (2024). The data for IoT, CC and IoT-CC Nexus technologies have been retrieved from the study by Abaee et al. (2024). And the data for AI related publications is from the articles in the literature portfolio of this study. This data has been used to create Figure5.

Appendix – 3

Table A3 - *Bifurcation of publications based on their type.*

Article / Publication Type	***Frequency/ Percentage***
Review article	34 %
Mixed method studies	20 %
Empirical study	19 %
Systematic literature reviews	11 %
Case study	9 %
Methodological study	7 %
Total	100 %

The table A3 shows the various types and categories of publications, along with their proportions, that have been included into the literature portfolio for this paper. The data has been graphically represented in Figure 6.

Appendix - 4

Table A4 - *AI & SDG related Publications and their authors' affiliated countries.*

Country	No. of Publications
Germany	24
USA	23
UK	17
India	16
Sweden	13
China	12
Australia	9
Spain	8
Italy	7
Canada	5
France	5
Netherlands	5
Poland	4
Greece	4
Portugal	4
Brazil	4
Malaysia	4
Finland	3
Taiwan	3
Qatar	3
South Korea	3
Switzerland	3
Austria	3
Latvia	3

Table A4 - *AI & SDG related Publications and their authors' affiliated countries (Continued).*

Pakistan	2
Saudi Arabia	2
Singapore	2
Iran	2
Egypt	2
South Africa	2
Colombia	2
Romania	2
Japan	2
Turkey	2
Ghana	2
Denmark	2
New Zealand	2
Norway	2
Belgium	2
Jordan	1
Philippines	1
Israel	1
Slovenia	1
Kuwait	1
Hong Kong	1
Indonesia	1
U.A.E.	1
Nigeria	1
Chile	1

Table A4 - *AI & SDG related Publications and their authors' affiliated countries (Continued).*

Mexico	1
Malawi	1
Togo	1
Ethiopia	1
Algeria	1
Malta	1
Ukraine	1
Serbia	1
Mauritius	1

Table A4 shows the bifurcation of research papers being published by authors and researchers and their distribution across the globe. This data has been extracted and studied to understand the activeness and initiatives at the forefront of AI and Industry 4.0 by various nations and economies worldwide. Based on the analysis of this data, it was found that UK, Germany, USA, India, and China have the greatest number of publications respectively, followed by other European and Scandinavian countries.

The data has been further presented in 2 graphical formats. Firstly, as a Bar Graph in Figure 7. And later as a Heat Map in Figure 8. This data has been further utilized in Figure 9. Which shows the number of authors publishing research from developed, developing and least developed countries/economies. Based on the analysis and understand of results for Figure7,8, and 9. It can be concluded that Developed countries have the highest number of publications, followed by Developing countries and least developed countries, respectively. And hence, higher probability of advancing AI and other Industry 4.0 technology's integration for attaining SDGs.

Appendix – 5

Figures A1, A2, & A3, classify the world countries into Developed, Developing and Least developed countries/economies, as per the UN classification. This classification has been used for classifying countries into these categories for Figure 9.

Figure A1 - *List of the Developed Countries, as per UN classification.*

Developed economies

Europe			Other countries	Major developed economies (G7)
European Union	New EU member States	Other Europe		
EU-15	Bulgaria	Iceland	Australia	Canada
Austria	Croatia	Norway	Canada	Japan
Belgium	Cyprus	Switzerland	Japan	France
Denmark	Czech Republic		New Zealand	Germany
Finland	Estonia		United States	Italy
France	Hungary			United Kingdom
Germany	Latvia			United States
Greece	Lithuania			
Ireland	Malta			
Italy	Poland			
Luxembourg	Romania			
Netherlands	Slovakia			
Portugal	Slovenia			
Spain				
Sweden				
United Kingdom				

Source: Country classification. UN - World Economic Situation and Prospects 2014 | Country Classification. (2014). https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf. Copyright 2014 by United Nations

Figure A2 - *List of the Developing Countries, as per UN classification.*

Developing economies by region[a]

Africa		Asia	Latin America and the Caribbean
North Africa	**Southern Africa**	**East Asia**	**Caribbean**
Algeria	Angola	Brunei Darussalam	Barbados
Egypt	Botswana	China	Cuba
Libya[b]	Lesotho	Hong Kong SAR[c]	Dominican Republic
Mauritania	Malawi	Indonesia	Guyana
Morocco	Mauritius	Malaysia	Haiti
Sudan	Mozambique	Myanmar	Jamaica
Tunisia	Namibia	Papua New Guinea	Trinidad and Tobago
Central Africa	South Africa	Philippines	**Mexico and Central America**
Cameroon	Zambia	Republic of Korea	Costa Rica
Central African Republic	Zimbabwe	Singapore	El Salvador
Chad	**West Africa**	Taiwan Province of China	Guatemala
Congo	Benin	Thailand	Honduras
Equatorial Guinea	Burkina Faso	Viet Nam	Mexico
Gabon	Cabo Verde	**South Asia**	Nicaragua
Sao Tome and Prinicipe	Côte d'Ivoire	Bangladesh	Panama
East Africa	Gambia	India	**South America**
Burundi	Ghana	Iran (Islamic Republic of)	Argentina
Comoros	Guinea	Nepal	Bolivia (Plurinational State of)
Democratic Republic of the Congo	Guinea-Bissau	Pakistan	Brazil
Djibouti	Liberia	Sri Lanka	Chile
Eritrea	Mali	**Western Asia**	Colombia
Ethiopia	Niger	Bahrain	Ecuador
Kenya	Nigeria	Iraq	Paraguay
Madagascar	Senegal	Israel	Peru
Rwanda	Sierra Leone	Jordan	Uruguay
Somalia	Togo	Kuwait	Venezuela (Bolivarian Republic of)
Uganda		Lebanon	
United Republic of Tanzania		Oman	
		Qatar	
		Saudi Arabia	
		Syrian Arab Repuplic	
		Turkey	
		United Arab Emirates	
		Yemen	

Source: *Country classification*. UN - World Economic Situation and Prospects 2014 | Country Classification. (2014). https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf. Copyright 2014 by United Nations.

Figure A3 - *List of the Least Developed Countries, as per UN classification.*

List of Least Developed Countries (as of 18 December 2023)*

Country	Year of inclusion	Country	Year of inclusion
Afghanistan	1971	Malawi	1971
Angola[1]	1994	Mali	1971
Bangladesh[4]	1975	Mauritania	1986
Benin	1971	Mozambique	1988
Burkina Faso	1971	Myanmar	1987
Burundi	1971	Nepal[4]	1971
Cambodia	1991	Niger	1971
Central African Republic	1975	Rwanda	1971
Chad	1971	São Tomé and Príncipe[2]	1982
Comoros	1977	Senegal	2000
Democratic Republic of the Congo	1991	Sierra Leone	1982
Djibouti	1982	Solomon Islands[3]	1991
Eritrea	1994	Somalia	1971
Ethiopia	1971	South Sudan	2012
Gambia	1975	Sudan	1971
Guinea	1971	Timor-Leste	2003
Guinea-Bissau	1981	Togo	1982
Haiti	1971	Tuvalu	1986
Kiribati	1986	Uganda	1971
Lao People's Democratic Republic[4]	1971	United Republic of Tanzania	1971
Lesotho	1971	Yemen	1971
Liberia	1990	Zambia	1991
Madagascar	1991		

** The list will be updated when new decisions by the General Assembly become available.*

Source: List of least developed countries (as of 18 December 2023).

https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/ldc_list.pdf.

Appendix – 6

Table A5 - *Contribution of CC, IoT, CC-IoT Nexus, and AI to SDG Categories.*

SDG Categories	CC	IoT	CC & IoT	AI
Economic	9	30	43	78
Environmental	8	30	46	77
Social	6	23	41	66

Table A5 presents data from 2 research papers, firstly it draws data for AI from the literature portfolio of this paper, and additionally, also has data on CC, IoT, and CC-IoT which has been retrieved from another similar study *'Examining the role of IOT and cloud computing in achieving sustainable development goals'* by Abaee et al. (2024). This is the classification of number of SDG Category and one of the industry 4.0 technology related studies that are published, which address the sustainable development goals under the Economic, Environmental and Social categories. This data has been graphically presented in Figure 11, to show the frequency of SDGs that are addressed under each category/pillar of SDG, by each of the technologies, i.e., CC, IoT, CC-IoT Nexus and AI.

Appendix - 7

Table A6 - *Frequency of SGDs being mentioned in literature Portfolio.*

SDGs	***Frequency of SDGs addressed***
SDG-1	4
SDG-2	6
SDG-3	33
SDG-4	18
SDG-5	6
SDG-6	8
SDG-7	30
SDG-8	38
SDG-9	66
SDG-10	9
SDG-11	50
SDG-12	47
SDG-13	49
SDG-14	1
SDG-15	9
SDG-16	14
SDG-17	9

Table A6 shows the number of times each SDG is addressed, in the studies included in the literature portfolio of this paper. This data has been graphically represented in Figure 12.

Appendix – 8

Table A7 - *Frequency of Targets being addressed in the literature portfolio.*

SDG Targets	Frequency
9.5	19
9.4	16
3.8	15
13.2	11
7.3	10
7.2	9
11.6	8
4.4	7
12.5	7
3.4	6
16.6	6
13.3	6
13.1	6
12.2	4
17.6	4
8.2	4
11.3	3
9.1	3
3.d	3
10.2	3
11.2	3
16.7	2
2.4	2
12.4	2
7.1	2
3.3	2
11.b	2
5.1	2
2.3	2
16.1	2
8.5	2
2.1	1
1.5	1
2.2	1
1.4	1

Table A7 - *Frequency of Targets being addressed in the literature portfolio (Continued).*

SDG Targets	Frequency
8.3	1
4.1	1
6.6	1
5.2	1
6.1	1
6.2	1
10.3	1
16.a	1
14.1	1
14.2	1
15.1	1
15.2	1
16.3	1
17.9	1
11.1	1
17.8	1
16.4	1
16.2	1
11.5	1
11.7	1
1.1	1
6.3	1
1.2	1
16.5	1
3.6	1
12.1	1
4.5	1
8.1	1
9.3	1
9.2	1
8.6	1
4.3	1
4.a	1
7.a	1
13.b	1
12.6	1

Table A7 shows frequency of SDG Targets being addressed in literature portfolio of this paper. This data has been analyzed from Table 3 and has been presented graphically in Figure 13.