A Systematic Review of How Cloud Computing (CC) and the Internet of Things (IoT) Can Contribute Towards Achieving the Sustainable Development Goals (SDGs)

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List of Abbreviations

CC	Cloud Computing
CDP	Committee for Development Policy
GDP	Gross Domestic Product
HDI	Human Development Index
I4.0	Industry 4.0
IoT	Internet of Things
LDC	Least Developed Country
SDG	Sustainable Development Goal
TB	Tuberculosis
UN	United Nations

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Abstract

Technology is driving an industrial revolution. "Industry 4.0" (I4.0) signifies the determination to lead this transition. Moreover, there is growing interest in a developing subject that has the potential to bring about systematic changes and achievement of the Sustainable Development Goals (SDGs) of the United Nations, which represent an extensive strategy designed to promote sustainable solutions for dealing with the primary challenges confronting the global community. This study conducted a comprehensive review of existing literature to determine the potential contributions of two technological enablers, the Internet of Things (IoT) and Cloud Computing (CC), which refers to integrating Industry 4.0 technologies towards achieving SDGs. The review portfolio consists of 100 peer-reviewed articles examining the interconnected or independent relationship between IoT and CC concerning sustainability. The articles were initially reviewed in relation to the technologies associated with Industry 4.0. Subsequently, a more detailed analysis was conducted to identify the extent of their connection to the SDGs. The results indicate that the integration of IoT and CC has a beneficial effect on SDG 12 (Responsible Consumption and Production), SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), SDG 3 (Good Health and Well-being), and SDG 6 (Clean Water and Sanitation), respectively. The particular targets addressed by deploying IoT and CC technologies are revealed and examined. We contend that the IoT-CC nexus is essential for achieving the SDGs as it links cutting-edge technology with innovative business models. This serves as a reference for tech professionals to integrate fields, advancing Industry 4.0 and sustainability. Additional research could further assess the IoT-CC nexus implications and examine its impacts on the SDGs.

Keywords: Internet of Things, Cloud Computing, Industry 4.0, Sustainable Development Goals, Sustainability

1. Introduction

To address urgent global concerns and achieve sustainable development by 2030, the United Nations presented the Sustainable Development Goals in 2015. The seventeen Global Goals cover a wide range of fields, including eradicating poverty, ensuring food security, improving health and well-being, promoting gender equality, developing renewable energy, mitigating climate change, and creating sustainable cities, among many others (Figure 1) (United Nations, 2015). In recent decades, sustainable practices have garnered heightened attention from scholars, corporations, and policymakers (Geels, 2014; Sadhukhan et al., 2020). The increasing momentum of this phenomenon can be attributed to global commitments and initiatives aimed at mitigating greenhouse gas emissions, reevaluating waste management practices, and tackling the challenges of resource scarcity (Caldecott et al., 2016; Jones et al., 2016; Luederitz et al., 2017). According to the European Commission (2015) and Turker and Altuntas (2014), global policies and contracts are increasingly enforcing the integration of initiatives pertaining to sustainability as a mandatory condition for entering into agreements. As a result, adherence to sustainable practices has become a compelling competitive advantage within the marketplace. Silvestre and Ţîrcă (2019) claim that attaining sustainable performance depends on implementing innovative practices. The progress of technology and the emergence of innovative solutions have resulted in far-reaching transformations that extend across various levels, encompassing individuals, businesses, and societies as a whole. This international initiative emphasizes the importance of cross-sectoral and intergovernmental collaboration in achieving fundamental alterations (Breuer et al., 2019). Therefore, the SDGs, consisting of 169 targets, serve as a comprehensive framework to direct policymakers in implementing sustainable approaches.

Figure 1

The 17 Sustainable Development Goals.

Note, From https://de.m.wikipedia.org/wiki/Datei:Sustainable_Development_Goals.svg

1.1. The Rise of Industry 4.0

The fourth industrial revolution is primarily founded on the integration of computing, communication, and control, known as Cyber-Physical Systems (Monostori et al., 2016; Stăncioiu, 2017; Zhou et al., 2015). The effective implementation of this approach heavily depends on the utilization of Big Data Analytics, which encompasses methodologies aimed at extracting meaningful insights from big volumes of data (Aceto et al., 2019).

Figure 2 illustrates the major enablers of the fourth industrial revolution. The Sustainable Development Goals (SDGs) and Industry 4.0 are related because they can be changed and improved by collaboration. While the Sustainable Development Goals (SDGs) address critical global problems, Industry 4.0, with its advanced technologies and data-driven approaches, gives a way to find solutions that are in line with the SDGs.

The origin of the term "Industry 4.0" or "I4.0" can be traced back to November 2011, when the German government introduced its high-tech strategy, which included the concept of "Industrie 4.0" for the year 2020 (Zhou et al., 2015). Since 2011, many other countries have also proposed comparable governmental initiatives (Data Dashboard | Advanced Technologies for Industry. n.d.; Governo de Portugal, n.d.).

Figure 2

The Major Enablers of the Fourth Industrial Revolution.

Note, From https://www.researchgate.net/figure/Nine-pillars-of-Industry-40_fig3_350187480

The nine pillars of technology support the development of fresh types of interrelated technological advancements. According to Hofmann and Rüsch (2017), while each of these pillars can be applied independently, their simultaneous implementation within the framework of Industry 4.0 (I4.0) reveals their true potential. This collaboration leads to innovative technological approaches based on improved data collection and manufacturing techniques. Nevertheless, these technologies offer advantages not only in terms of production but also in their potential to mitigate the generation of waste, minimize adverse environmental effects, and drive the adoption of cleaner manufacturing methods in the industrial sector (Kurniawan et al., 2022; Mohanty et al., 2021). From this standpoint, the advancement of Industry 4.0 has the potential to facilitate a novel improvement that prioritizes resource efficiency, management of waste, and other sustainable procedures (Enyoghasi & Badurdeen, 2021), which are discussed in the Agenda 2030.

The Internet of Things (IoT) and Cloud computing (CC) are two emerging technologies that exhibit the potential to facilitate the achievement of Sustainable Development Goals (SDGs). IoT encompasses a comprehensive network of interconnected devices, such as mobile phones, sensors, actuators, and related technologies that facilitate seamless communication and integration (Burhanuddin et al., 2017; Parashar, 2016). Cloud computing is a model that facilitates the provision of computing resources via the Internet, encompassing computational capabilities, data storage, and software applications. According to Dinh et al. (2013), this functionality allows users to utilize shared computing resources as needed conveniently.

The recognition of the extensive potential of CC and IoT in promoting sustainability and facilitating the achievement of Sustainable Development Goals (SDGs) has been widely acknowledged. Cloud computing possesses the capacity to optimize resource utilization,

reduce energy consumption, and improve collaboration and data-sharing capabilities. Meanwhile, IoT has the potential to enable the seamless monitoring of various processes in real-time, thereby enabling data-driven decision-making and the implementation of intelligent solutions across diverse sectors, including agriculture, healthcare, transportation, and energy (Liu et al., 2019). The combination of these two technological foundations has assumed notable importance. IoT enables the extensive interconnection of devices, leading to unprecedented data collection and exchange (Burhanuddin et al., 2017). In contrast, Cloud Computing offers the essential framework for the storage and analysis of data, providing resources that can be scaled and advanced capabilities for processing data (Dinh et al., 2013). Incorporating these technological facilitators within the domains of IoT and CC facilitates advancing cutting-edge solutions. By leveraging the power of interconnected devices and cloud-based resources, industries can achieve greater operational efficiency, improved decision-making processes, and enhanced productivity (Vassakis et al., 2018). This results in advancements in various fields, including intelligent manufacturing, smart cities, healthcare, and logistics. Hence, the combined implementation of these pillars unlocks the full potential of Industry 4.0, resulting in transformative technology solutions that drive innovation and shape the future of interconnected systems (Hofmann and Rüsch, 2017).

Considering the increasing attention and academic research devoted to these areas, this study conducts a comprehensive examination of the existing literature and provides insights into the potential of Cloud Computing and the IoT to contribute to the Sustainable Development Goals (SDGs).

1.2. United Nations Classification of the Countries

The United Nations (UN) classifies countries into three major groups according to their level of development: developed nations, developing nations, and least developed nations (Nations, 2023; Neshovski, 2023). This classification is predominantly employed for

analytical and statistical objectives, serving as a valuable tool for the United Nations (UN) in its endeavors to foster global development and tackle the distinct challenges encountered by different countries. The following is a comprehensive analysis of each individual category (Nations, 2023; Neshovski, 2023):

1. Developed countries:

Developed nations are distinguished by their sophisticated economies, high standards of living, and robust infrastructure and institutional frameworks. These countries typically exhibit a high per capita Gross Domestic Product (GDP) and provide a broad range of social services comprising healthcare, education, and social welfare. Countries typically characterized by a high Human Development Index (HDI) exhibit a significant overall development level, as determined by multiple variables, including life expectancy, education, and income. The United States, Germany, Austria, Switzerland, and UK are prominent examples of developed countries.

2. Developing countries:

Developing countries, alternatively referred to as emerging economies, are distinguished by their comparatively lower degree of economic development than developed countries. These countries frequently encounter obstacles such as poverty, poor accessibility of educational and healthcare services, and insufficient infrastructure. Although these nations may witness economic growth, their per capita GDP tends to be comparatively lower compared to developed nations. Developing countries comprise diverse countries characterized by varying socio-economic factors, spanning across different regions, including Brazil, India, China, Ecuador, and Mexico.

3. Least developed countries:

The least developed countries (LDCs) classification encompasses particularly vulnerable and poor nations. LDCs encounter significant structural limitations and socioeconomic

difficulties, including elevated poverty levels, restricted human resources, inadequate institutional structures, and reliance on primary sectors such as agriculture. LDCs are classified by the United Nations by applying specific criteria about income levels, human resources, and economic susceptibility. The United Nations Committee for Development Policy (CDP) periodically reviews and updates the list of Least Developed Countries. Some examples of Least Developed Countries are Ghana, Pakistan, and Bangladesh.
The UN classifications of countries participating in the publication of essays were investigated in this research. After that, research publications on how the Internet of Things and Cloud Computing affect Sustainable Development Goals in developed, developing, and least-developed countries were selected.

This study examines the research question, methodology, results (including bibliometric findings), classification of SDGs, and targets addressed in the literature portfolio and concludes with recommendations in the sections that follow.

2. Research Question

The swift advancement of human life in a highly consumer-driven environment has led to an increased depletion of natural resources over time. Moreover, the way these resources are utilized is undergoing rapid transformations, thereby highlighting the critical research inquiry of ensuring sustainable practices (Timčenko et al., 2017). In this context, the Sustainable Development Goals align seamlessly with the Internet of Things (IoT) paradigm, while Cloud Computing has emerged as a paramount platform for storing and analyzing data collected from IoT devices. This facilitates the flawless integration of applications reliant on virtualization technologies and data-intensive computations. Cloud computing and the Internet of Things are two emerging technologies of Industry 4.0 that are quickly developing and extensively used (Stergiou et al., 2018). Moreover, these two technologies play a crucial

role in gathering, organizing, and analyzing large volumes of data that can be used to develop long-term solutions (Alam, 2021).

The research question, " A systematic review of how the integration of Cloud Computing (CC) and the Internet of Things (IoT) contribute towards achieving the Sustainable Development Goals (SDGs)," is strategically selected to investigate how much in scientific literature these technologies and SDGs are studied and to what extent these technologies address the SDGs.

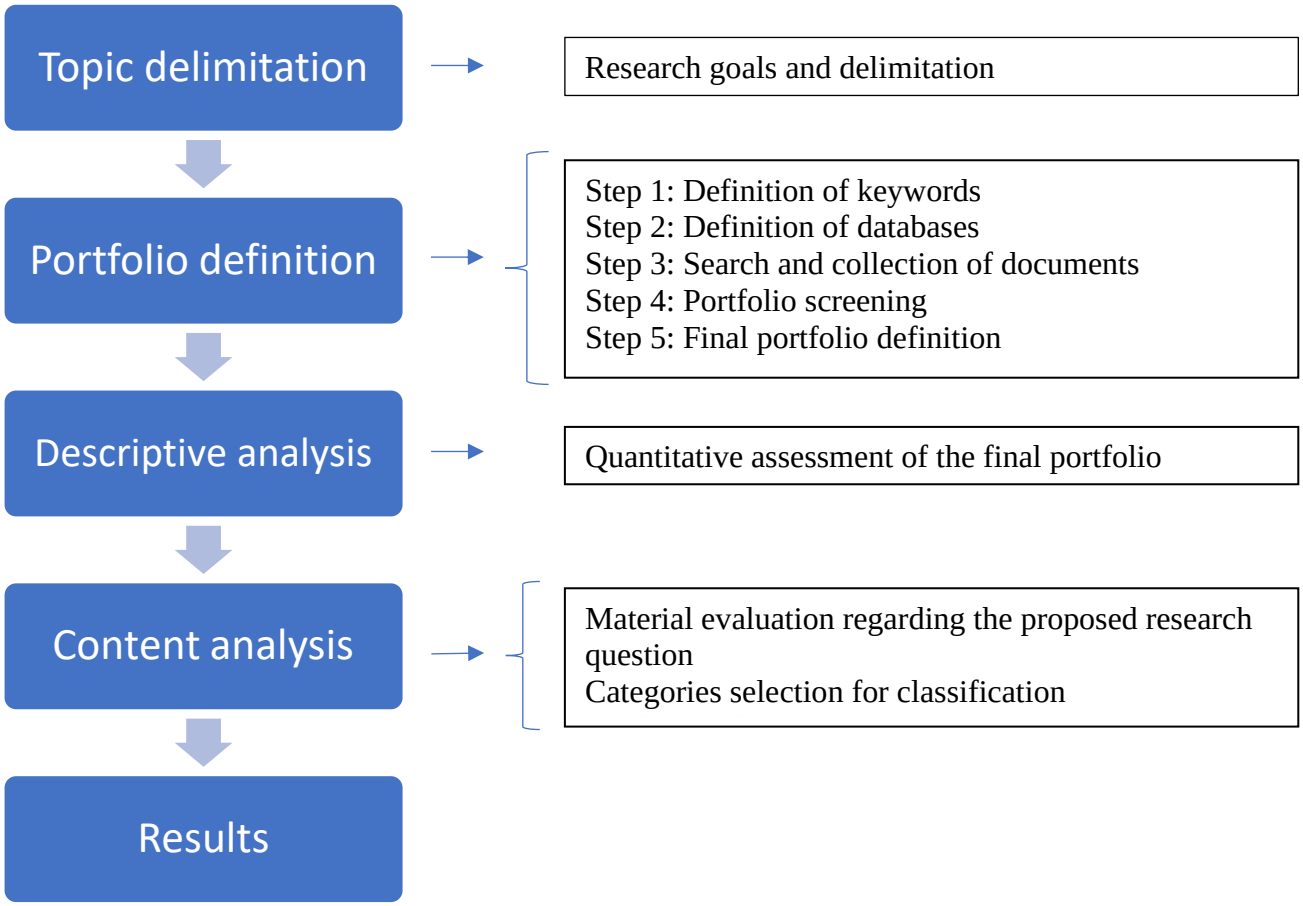
3. Methodology

A literature review offers a thorough and all-encompassing examination of literature pertaining to a particular subject matter, hypothesis, or approach and integrates previous studies to reinforce the framework of knowledge (Paul & Criado, 2020).

The primary objective of this study is to explore peer-reviewed articles, specifically those published between 2016 and 2023, that delve into the subject of Industry 4.0 technologies (the Internet of things and Cloud Computing) and the Sustainable Development Goals (SDGs). The review was conducted by implementing the sequential processes suggested by Barros et al. (2019) and Coutinho et al. (2019). The approach employed for the literature review is outlined in Figure 3.

Figure 3

The Literature Review Process.



Note, From Barros et al. (2019) and Coutinho et al. (2019).

3.1. Topic delimitation

The present study's research question pertains to the analysis of articles included in this review, which investigate the extent to which IOT and CC contribute to achieving the United Nations Sustainable Development Goals. The inclusion criteria for this study involved peer-reviewed articles published between 2016 and 2023. Since all the subjects covered are considered emerging topics, temporal boundaries needed to be established for this research. This study was executed in April 2023 and encompassed those articles that have been released up to that time.

3.2. Portfolio definition

Step 1: Keywords definition

This study centered on examining the correlation between the Internet of Things (IoT) and Cloud Computing (CC) and the Sustainable Development Goals (SDGs). The study also examined the reciprocal integration of the Internet of Things and Cloud Computing technologies to promote sustainable practices. The keywords employed for the two searches are as follows:

Internet of Things, IoT, Cloud Computing, CC, SDG, sustainable development, sustainability, Industry 4.0.

Regarding the few articles that are published in languages other than English, keywords in the same language were used to broaden the scope of the study and obtain more data out of the collected articles.

Steps 2 and 3: Definition of database and collection of studies

The research methodology was established by initially reviewing relevant data sources. The peer-reviewed journals are mostly associated with diverse publishing groups, such as Elsevier, Springer, and Emerald.

Step 4: Screening the portfolio

After conducting the search, duplicate entries were eliminated. The process of filtering was conducted by reviewing the abstract, introduction, result, and conclusion of all papers. The final portfolio was composed by selecting articles that referred to the research question.

Step 5: Final definition of portfolio

The publications were converted onto spreadsheets and systematically arranged according to the designated criteria to facilitate result extraction and assessments of contents.

3.3. Descriptive analysis

To provide a comprehensive description of the final portfolio, a quantitative analysis was undertaken. Then, the documents were categorized into three distinct types of studies:

those that center on the correlation between the Internet of Things (loT) and the SDGs, those that concentrate on the association between Cloud Computing (CC) and the SDGs, and those that reference the relation of both loT and CC with the SDGs.

3.4. Content Analysis

An in-depth analysis of the ultimate portfolio applies to the outcomes of the current study. IoT and CC implemented technologies, and the corresponding methodologies executed within Sustainable Development Goals have been identified and categorized. After analyzing the portfolio's contents, the significant SDGs and targets addressed by the integration of IoT and CC were determined. It was subsequently feasible to clarify how the interaction of IoT and CC facilitates the realization of particular SDG objectives.

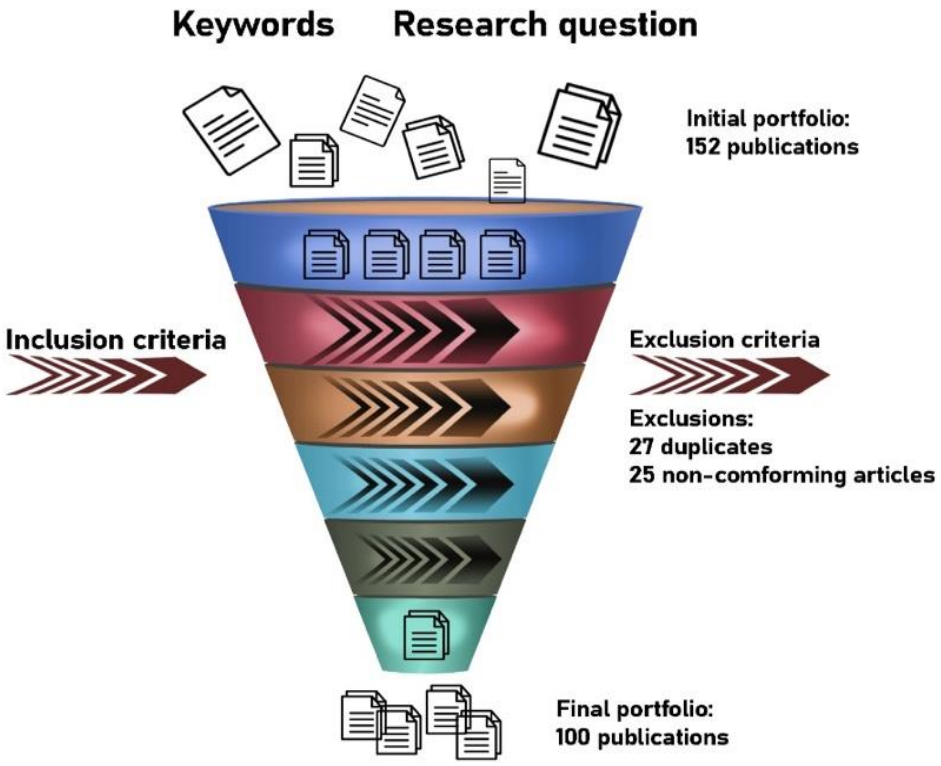
4. Results

The initial literature search included a total of 152 publications. The research portfolio was derived through a selection process, as illustrated in Figure 3. An overall of 27 studies were removed from the analysis on account of duplication., and 25 papers were eliminated throughout the entire text-reading process. Following the implementation of the evaluation protocol, 100 articles were selected. It's worth pointing out that both IoT and CC are very new areas of study (Blair et al., 2016; Humayun, 2020), and researchers have begun to examine the covert connections among these domains just recently (Díaz et al., 2016; Hashem et al., 2015). This study showcases a compilation of contemporary research and resolutions investigating Sustainable Development Goals (SDG) by merging the IoT and CC. The subsequent analysis involves an examination of bibliometric outcomes and publication trends. This is accompanied by the evaluation of the results of the Internet of Things (IoT) and Cloud Computing (CC) technologies presented in this research. The subsequent segment of this paper points out the

Sustainable Development Goals (SDGs) and targets that are distinctly and significantly impacted by solely the IoT or CC, as well as the combination of IoT and CC.

Figure 4

Review Screening Process.

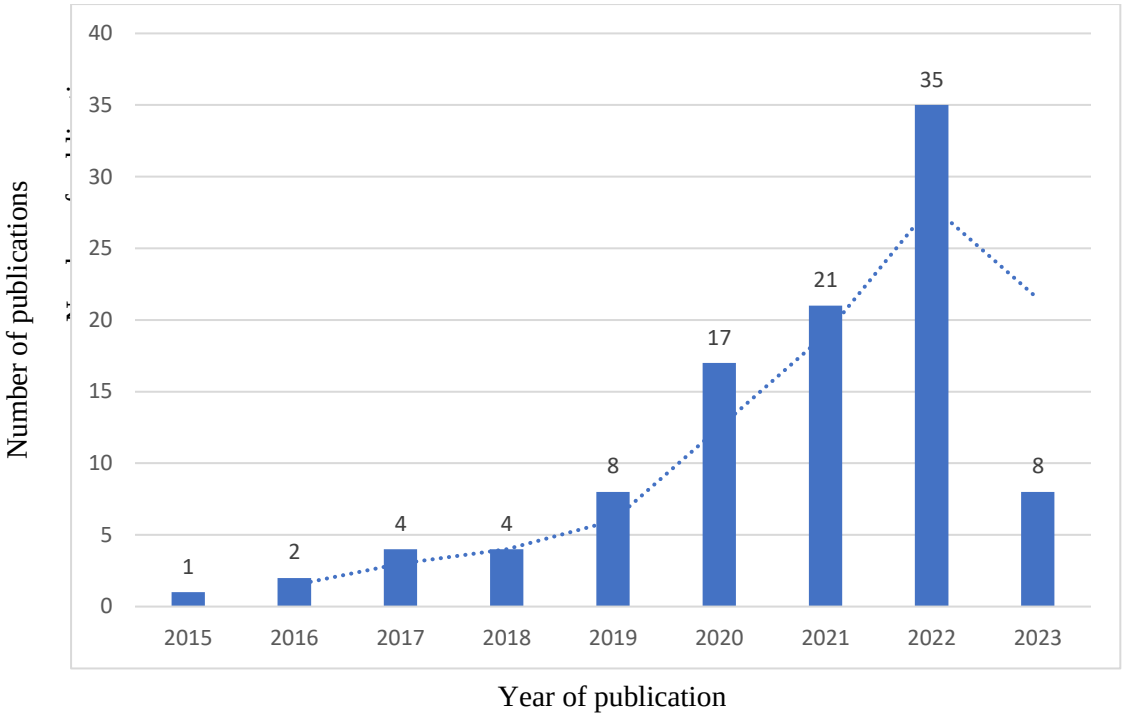


4.1. Bibliometric Results

This study analyzed the publications by examining the chronological progression of articles that specifically addressed the intersection of IoT and CC technologies with sustainability issues. Additionally, the distribution of these publications across peer-reviewed journals was examined. Figure 5 illustrates the topic's development over time.

Figure 5

Distribution of publications over the years.



The findings indicate that the initial endeavor to establish a connection between either of the two fundamental themes of this study and the Sustainable Development Goals (SDGs) was undertaken by Rose et al. (2015). The authors argue that the Internet of Things can substantially contribute to realizing the SDGs set forth by the United Nations. By leveraging IoT technologies, various development challenges can be addressed effectively. For instance, sensor networks can be used for environmental monitoring, disease detection, and resource management, thereby impacting areas beyond resource conservation. The data derived from IoT applications can also support local research efforts and encourage academic talent to stay within their countries. In the context of food security, IoT-enabled "smart agriculture" techniques can improve the sustainability and productivity of the entire food supply chain. The IoT is being deployed globally to address pressing development issues, from poverty alleviation to water and sanitation management. The declining costs of sensors and connectivity technologies and improved data communications have facilitated the spread of IoT interventions in development. Examples include secure and efficient vaccine transportation, monitoring livestock health, optimizing soil conditions for agriculture, and

providing off-grid electricity through solar cells. However, challenges related to infrastructure, technical capacity, and regulatory environments need to be addressed to maximize the impact of IoT in achieving the SDGs. In 2016, two research studies were published in the discussed scientific field, indicating a growing level of interest in the subject. Falzon and Raviglione (2016) emphasize the potential of digital technology, particularly the Internet of Things, to contribute to the achievement of the United Nations' Sustainable Development Goals in the context of tackling tuberculosis (TB) and public health concerns. It states that the implementation of the "End TB Strategy" requires new approaches that align with the SDGs and involve broad-scale action on poverty and determinants of tuberculosis. The article mentions the potential of digital technologies, such as the Internet of Things and big data, to personalize medicine, promote equity, human rights, and patient empowerment, and improve operational intelligence and decision-making. The research conducted by Timčenko et al. (2016) states that Cloud Computing has the potential to contribute to sustainability and emphasizes the importance of open data in the sustainability assessment framework, suggesting that the framework heavily relies on access to open data. The number of publications increased in 2017, 2018, and 2019, with the focus being mainly on the nexus of IoT and CC and its positive impact on Sustainable Development Goals (Bonilla et al., 2018; Leitner et al., 2019; Timčenko et al., 2017). Since 2020, there has been a significant increase in the number of publications addressing pathways toward a more sustainable and efficient industry and society. Ahad et al. (2020) suggested using Cloud Computing and the Internet of Things to develop a sustainable smart city where data is automatically organized, regulated, and evaluated. The year 2021, with 21 published articles, appears to have marked a turning point in the integration of IoT and CC. However, the growing awareness of the subject matter in the year 2022 suggests that the intersection of the IoT and CC represents a developing area of academic research with wide-ranging practical implications and

significant opportunities for expansion, particularly as the world gradually turns into new modes of manufacturing, utilization, and technological advancement. In 2022, there were 35 related publications, 22 of which focused on the IoT-CC nexus and its impact on numerous Sustainable Development Goals. The article published by Gairola and Kumar (2022) emphasizes that the amalgamation of the Internet of Things with Cloud Computing has the potential to influence the capacity of developed countries to attain the SDGs, including the socio-economic sustainable development, healthcare, safety, and environmental monitoring in various industries. Since the review was done in April 2023, the portfolio consisted solely of studies published during the year's first quarter.

The analyses presented, encompassing the sequential advancement of publications, dispersion of publications throughout different years, and the incorporation of current publications, converge to provide valuable insights for the purpose of addressing the research question.It provides a comprehensive viewpoint on the scholarly interaction pertaining to the Internet of Things (IoT), Cloud Computing (CC), and their potential impact on the Sustainable Development Goals (SDGs). Moreover, it indicates how interest in this field is growing, how IoT and CC are becoming more important to SDGs, how early researchers laid foundations, how a growing body of literature focuses on the positive contributions of IoT-CC integration to specific SDGs, and how this field is still evolving and help us understand the relationship between these technologies and SDGs.

The collected studies were published in various scientific publications spanning from technical and quantitative scientific journals to ecological and sustainability-related articles, as both IoT and CC contain alternatives and approaches that may be utilized in a number of industries and areas. The findings of this review demonstrate that IoT and CC are the targets of researchers from multiple disciplines, suggesting the significance of the topics and the variety of objectives that may be achieved by solutions developed within this framework.

The number of publications connected to each individual technology and its impact on sustainability is presented in Table 1. Among the 100 selected articles, it was found that the "CC" technology has been the subject of 12 publications, while "IoT" has been the focus of 34 publications. Notably, the "IoT-CC Nexus" has garnered the highest number of publications, with a total of 54.

The data suggests that the technological innovation known as Cloud Computing has the least number of published articles. This observation implies that researchers, academics, or industry professionals may have allocated fewer resources or attention to exploring the specific applications, implications, or advancements of Cloud Computing. It could also indicate that researchers and scholars have not extensively covered this specific area of technology as much as other topics, leading to a smaller body of literature on the subject. It can be concluded that there are opportunities for additional research and investigation in the area of Cloud Computing's influence on achieving sustainable development goals.

Table 1

IoT, CC, and IoT-CC nexus and their corresponding number of publications.

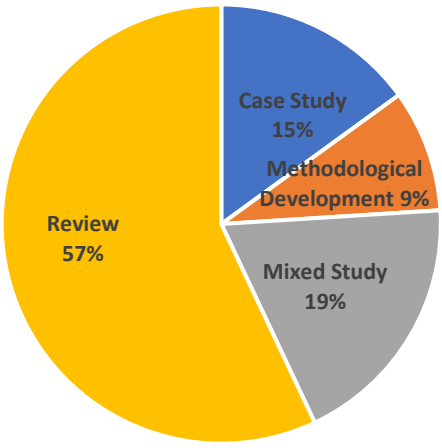
Technology	Number of Publications	Publications Proportion
CC	12	12%
IoT	34	34%
IoT-CC Nexus	54	54%

Figure 6 displays the distribution of article classifications. Upon analyzing the distribution, it is apparent that a significant proportion of the articles within the selected portfolio are classified as reviews, constituting 57% of the overall publications. The main objective of these review articles is to integrate the current knowledge and present a comprehensive view

of the research areas on the Internet of Things, Cloud Computing, and sustainability. Case study articles constitute 15% of the studied publications, with a total of 15 papers. These articles primarily aim to analyze real-world cases and examples related to the application of IoT and CC concepts in the context of sustainability. Methodological development articles account for 9% of the selected portfolio. These publications focus on proposing new frameworks, business models, or methodological approaches (Mbuagbaw et al., 2020) that contribute to the advancement of the IoT-CC-sustainability field. The emphasis of these papers lies in exploring novel methods and techniques to address the challenges and opportunities in the integration of IoT and CC for sustainable practices. Mixed study articles represent 19% of the selected articles. These papers integrate the exposition of case studies with either a methodology development or a literature review, typically in the form of a proposed framework (Onwuegbuzie & Collins, 2007). By integrating multiple research approaches, mixed study articles aim to comprehensively understand the interplay between IoT, CC, and sustainability, considering both practical insights and theoretical advancements.

Figure 6

Distribution of article classifications.



The analysis of the article classification reveals that the majority of the selected publications in the IoT-CC-sustainability domain are focused on theoretical advancements, as reflected by the high proportion of literature review articles. However, practical applications through case studies and methodological development articles also contribute significantly to the research landscape. The results suggest that researchers in this field are inclined to investigate the theoretical implications of IoT and CC principles and their impact on sustainability. Examining the classification of articles offers helpful insights on the study of IoT, CC, and sustainability. This examination plays a significant role in addressing the research question and suggests that the combination of IoT and CC is being actively investigated in theoretical settings. This exploration has the potential to provide actual contributions to SDGs by introducing innovative solutions. Furthermore, the existence of articles focused on methodological development suggests continuous attempts to create new models and approaches, showcasing the research community's commitment to progressing in this area. The variety of article classifications demonstrates the diverse aspects of research on IoT-CC-sustainability. This includes both real-world applications and theoretical progress, which together enhance our comprehension of how these technologies can support and have an impact on the Sustainable Development Goals (SDGs).

The research paper extracted the authors' affiliations with multiple countries, revealing that Europe holds the first place regarding the number of published resources (Figure 7) and that Germany is dominant in the list, with 17 out of the 100 selected papers. India ranks second with a total of 10 articles. Spain and the United States are ranked next, having contributed to nine. Figure 8 illustrates that the primary research contributions originate from authors based in Germany and India.

Figure 7

Distribution of papers across the world.

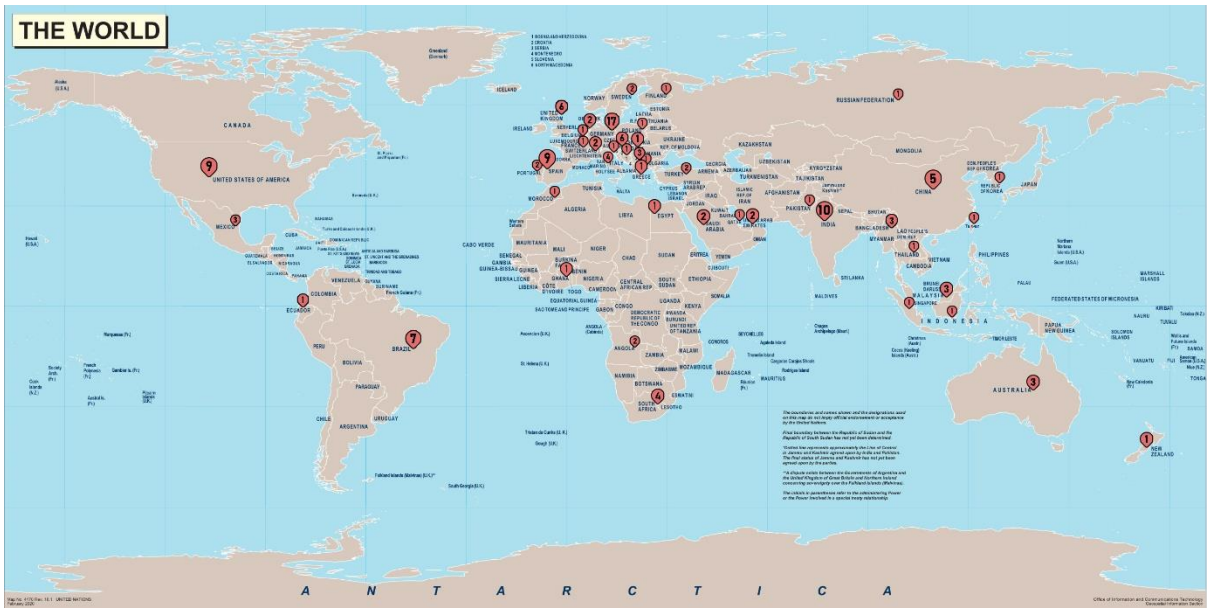


Figure 8

Distribution of papers across the world.

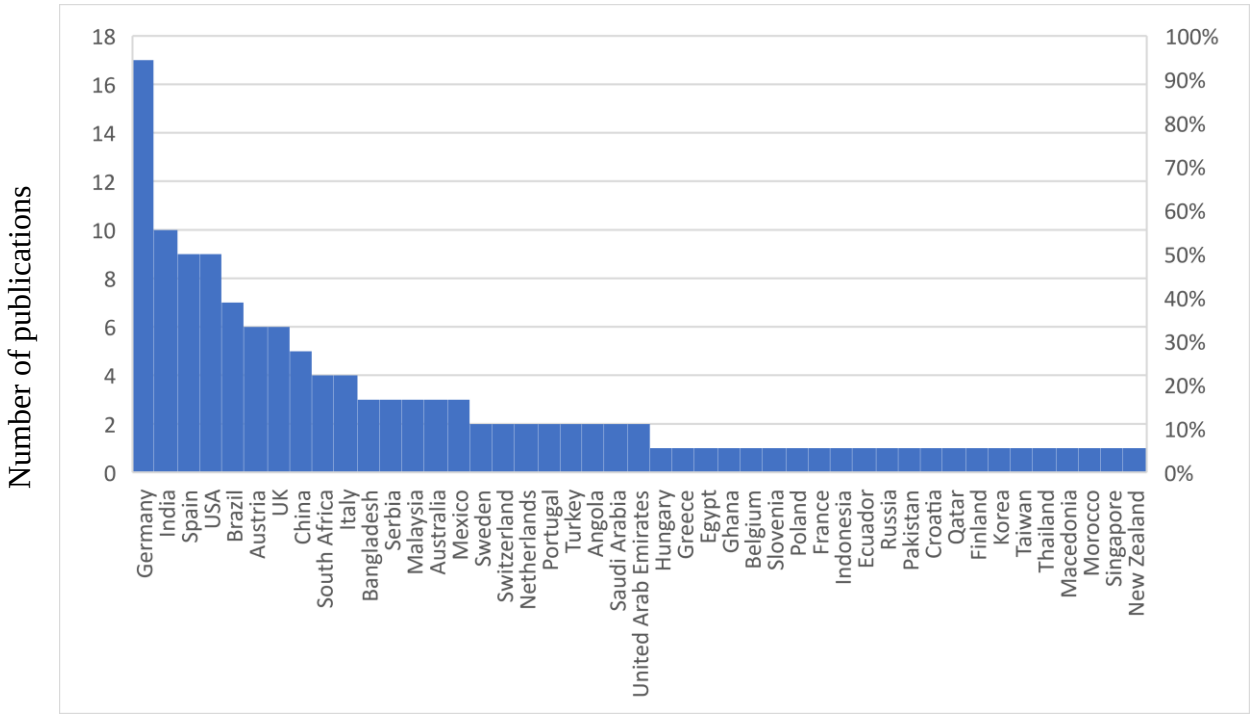


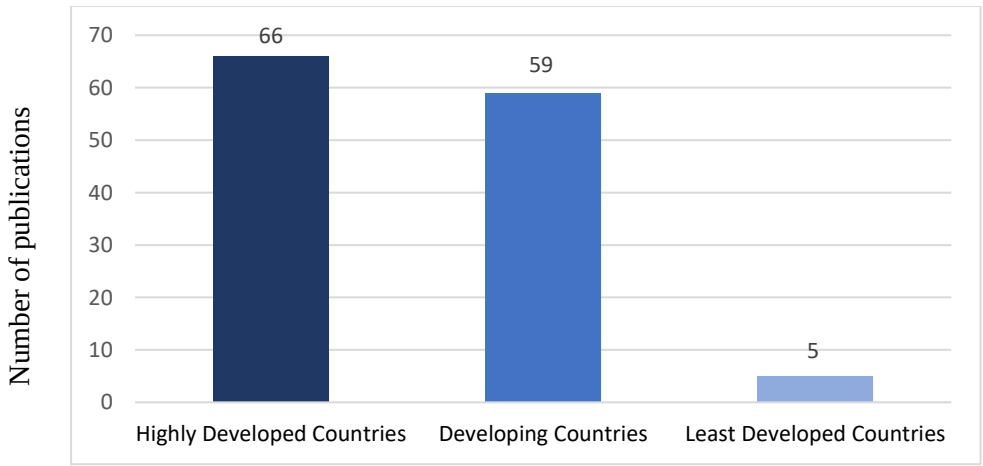
Figure 8 displays the primary research contributions made by different countries like Germany and India. It offers important insights into how research efforts are distributed globally in the field of integrating Cloud Computing (CC) and the Internet of Things (IoT) concerning sustainability and the Sustainable Development Goals (SDGs). The information points out the global aspect of research in this field, showing that many countries have taken an active role in studying the probable impact of CC and IoT on achieving SDGs. This offers a wider and more inclusive perspective on the subject.

This paper examined the distribution of countries dedicated to publications according to the United Nations classifications. Then, the research papers investigating the influence of the Internet of Things and Cloud Computing on achieving Sustainable Development Goals in developed, developing, and least-developed countries were identified. The data provided offers insights into the number of papers published within this particular research field, thereby illuminating the research productivity and contributions of countries within each category in addressing global sustainability challenges.

Figure 9 shows the distribution of papers on the impact of IoT and CC on the SDGs.

Figure 9

Distribution of papers across the developed, developing, and least developed countries.



Developed countries lead with the highest number of publications, with 66 scholarly papers addressing the sustainability concerns and solutions. These nations have made noteworthy contributions in integrating and leveraging IoT and Cloud Computing to address sustainability challenges due to their sophisticated technological infrastructure, research capabilities, and well-established educational institutions.

Developing countries exhibit remarkable research endeavors, as evidenced by the publication of 59 papers. These countries progressively acknowledge the significance of IOT and CC to developing sustainability. They are actively making contributions to the global database of knowledge. Their research output demonstrates their commitment to leveraging technology for positive societal and environmental impact.

The least developed countries, facing multiple socio-economic challenges, present a limited research output with only 5 papers. However, their involvement in this research area signifies a growing recognition of the potential of IoT and CC in addressing SDGs despite the constraints they face. This exemplifies a remarkable commitment to utilizing technology for positive transformation and emphasizes the significance of cultivating extensive cooperation across different global contexts.

These findings indicate that to promote inclusive and sustainable development, it is essential to ensure knowledge-sharing and collaboration among countries at different stages of development. Encouraging research partnerships, capacity-building initiatives, and resource allocation can help bridge the research gap, allowing for a more equitable distribution of knowledge and the advancement of sustainable development on a global scale.

4.2. Classification of the Sustainable Development Goals

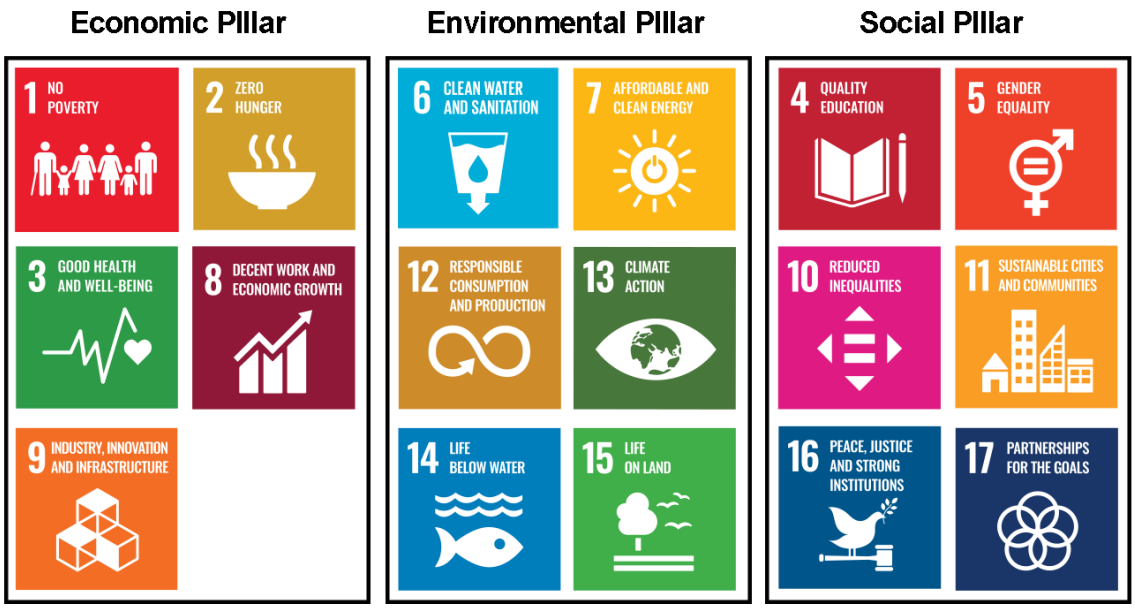
The Sustainable Development Goals (SDGs) framework, consisting of a comprehensive array of 169 targets, aims to be achieved by 2030 to establish a harmonious equilibrium

among the fundamental dimensions of sustainable development: economic, social, and environmental (Kostoska & Kocarev, 2019) (Figure 10).

These significant initiatives require active involvement and cooperation on an international level, expanding their influence on a range of countries, including developed, developing, and least developed countries. This collaborative effort imposes considerable responsibility on nations to direct their efforts towards achieving substantial improvements in equity and sustainability, resolving inequalities, and promoting comprehensive progress across various socio-economic contexts.

Figure 10

17 SDGs in three categories: economic, environmental, and social.



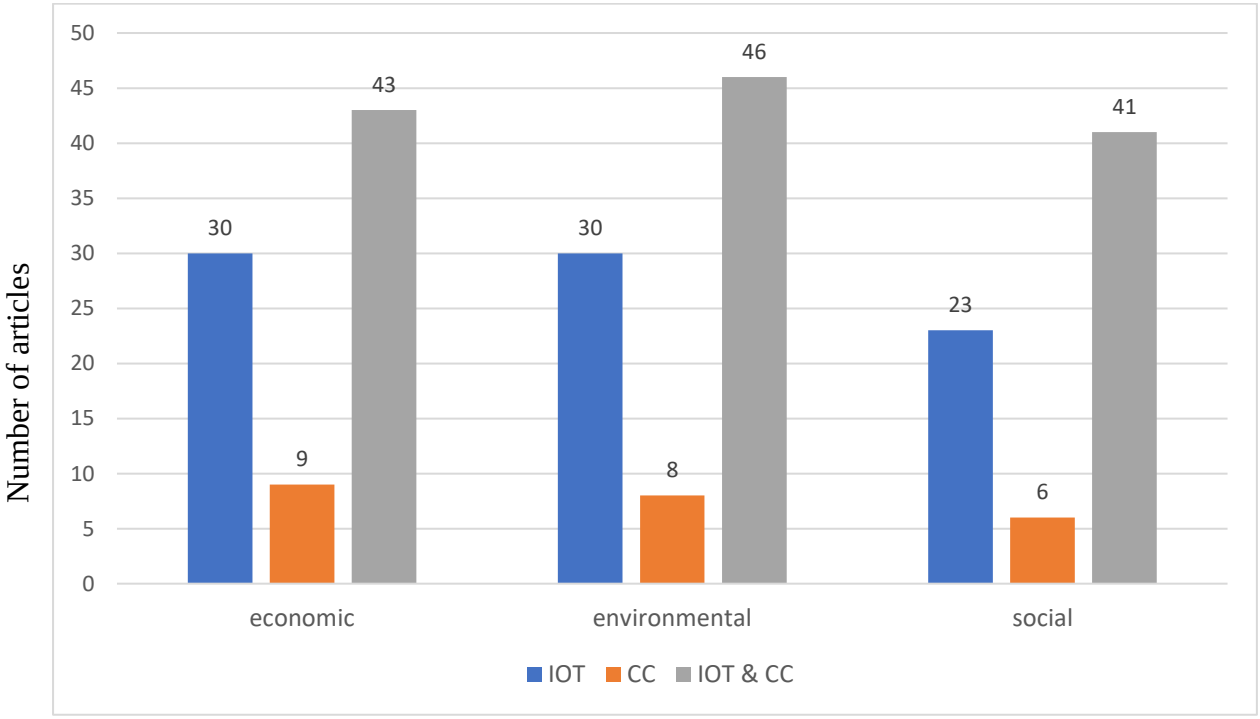
Note, From https://www.mdpi.com/2071-1050/11/7/1961

The extensive utilization of Internet of Things (IoT) and Cloud Computing (CC) technologies has resulted in substantial changes across several industries by enabling efficient data management, real-time monitoring, and advanced data analysis. This study evaluated the effects of the Internet of Things (IoT) and cloud computing (CC) on economic,

environmental, and social sustainability. The evaluation was carried out by thoroughly analyzing the selected literature. Understanding these contributions can offer valuable insights for decision-makers and stakeholders to utilize these technologies for sustainable development effectively. Figure 11 illustrates the impact of the Internet of Things (IoT), Cloud Computing, and the IoT-CC-nexus on economic, environmental, and social sustainability.

Figure 11

IoT and Cloud Computing contribution to economic, environmental, and social sustainability.



4.2.1 Economic Sustainability

Focusing on the economic dimension, 30 articles address the ways in which IoT technologies can drive economic sustainability, presenting valuable insights into the potential applications and benefits across various sectors. Furthermore, the inclusion of 9 articles provides a deeper understanding of how Cloud Computing can contribute to economic

advancements. Additionally, 43 articles explore the nexus of IoT and Cloud Computing, revealing the synergies and integrated approaches that can improve economic sustainability efforts. This assessment suggests a higher emphasis on the integrated utilization of the Internet of Things and Cloud Computing in order to achieve economic sustainability, compared to their individual applications. The findings indicate that the integration of the Internet of Things and Cloud Computing technologies can lead to promoting economic sustainability by facilitating more efficient use of resources, reducing costs, boosting productivity, and enabling innovative business models (Bisht et al., 2022; Bonilla et al., 2018; Engels, 2022; Patyal et al., 2022; Timčenko et al., 2017).

4.2.2 Environmental Sustainability

Within environmental research studies, a set of 30 articles pertaining to the IoT and 8 articles related to Cloud Computing have been identified. These articles mostly showcase the potential of IoT and CC in addressing environmental sustainability challenges, such as resource management, energy efficiency, and environmental monitoring. The inclusion of 46 articles that explore the nexus of IoT and CC within the environmental dimension further emphasizes the importance of integrated solutions to tackle complex environmental issues. The existing body of literature indicates that utilizing these technologies can facilitate monitoring environmental conditions, enhance energy efficiency, optimize waste management processes, and promote sustainable practices. As a result, these advancements can mitigate adverse ecological effects and preserve valuable resources (Ahad et al., 2020; Camodeca & Almici, 2021; Dhanaraju et al., 2022; Engels, 2022; Feroz et al., 2021; Gimpel, 2022; Kolesnichenko et al., 2021; Patyal et al., 2022; Wurm et al., 2021).

4.2.3 Social Sustainability

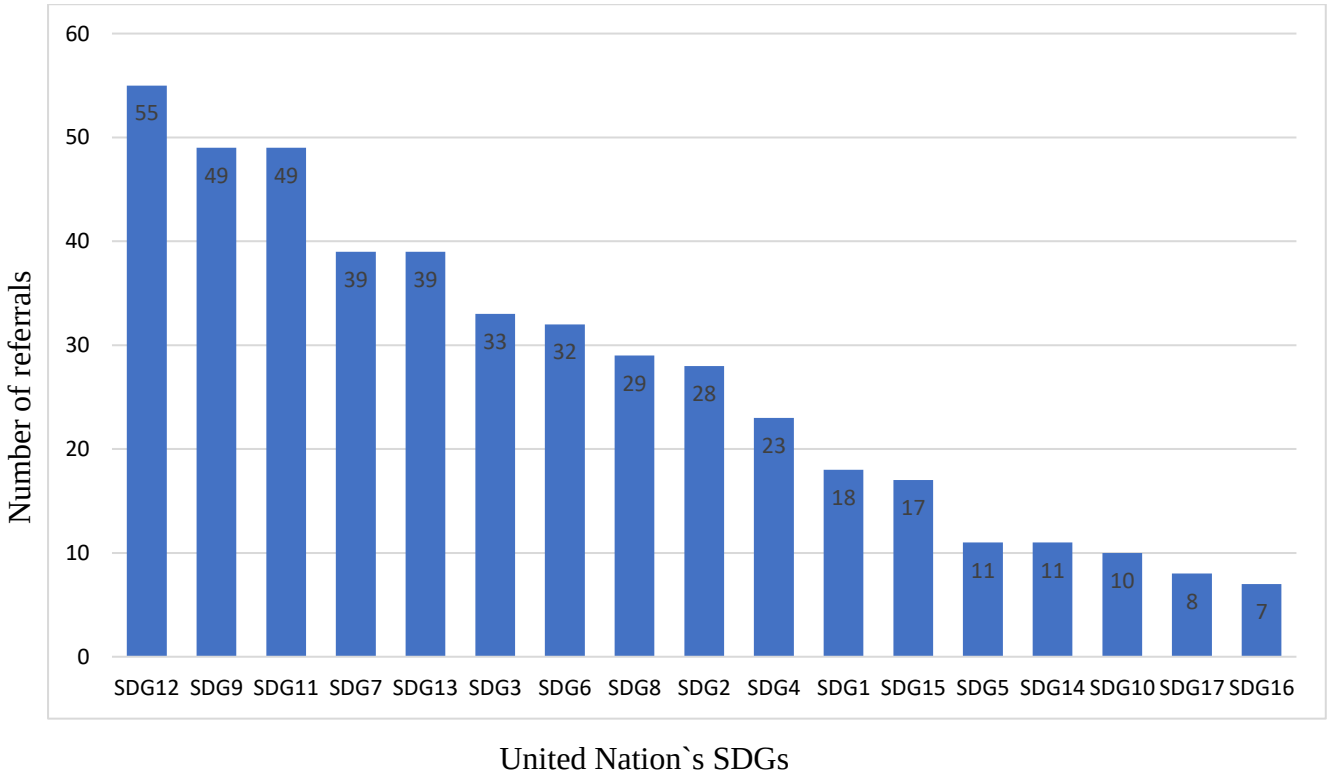
The social implications of IoT and CC have been explored through the analysis of 23 IoT-related articles and 6 articles focusing on Cloud Computing. These articles highlight the

role of IoT and CC in promoting social development, inclusivity, and improving the quality of life for individuals and communities. The inclusion of 41 articles that explore the nexus of IoT and CC within the social dimension provides a comprehensive understanding of the multifaceted impact of these technologies on social sustainability. The findings indicate that IoT and CC technologies have the potential to contribute to social sustainability by improving healthcare services, enhancing public safety and security, fostering community engagement, and enabling inclusive access to resources and information (Camodeca & Almici, 2021; Engels, 2022; Fritzsche, 2022; Grijalvo Martín, 2020; Hung & Chen, 2023; Kolesnichenko et al., 2021; Patyal et al., 2022; Zengin et al., 2021).

The prominence of IoT and Cloud Computing in addressing various SDGs has been assessed by analyzing the frequency of SDGs mentioned in the articles (Figure 12). The results reveal the most frequently addressed SDGs, highlighting their potential for advancing sustainable development through IoT and Cloud Computing technologies.

Figure 12

Frequency of SDGs being mentioned.



The following SDGs were frequently mentioned across multiple studies:

- SDG12: Responsible Consumption and Production
- SDG9: Industry, Innovation, and Infrastructure
- SDG11: Sustainable Cities and Communities
- SDG7: Affordable and Clean Energy
- SDG13: Climate Action
- SDG3: Good Health and Well-being
- SDG6: Clean Water and Sanitation

The results indicate that specific goals are more prominently linked to these technologies compared to others. SDG12, "Responsible Consumption and Production," emerged as the most frequently mentioned SDG, with 55 mentions. This indicates that IoT and Cloud Computing have the potential to significantly impact the optimization of resource consumption and waste management, thus promoting sustainable production and consumption patterns. According to Boulouard et al. (2022), the implementation of the Internet of Things and Cloud Computing has emerged as a crucial technique within the context of Industry 4.0, facilitating advancements in production efficiency and sustainability. These technologies enable real-time data capture and reduce computing and storage requirements in digitally enhanced production processes.

SDG9, "Industry, Innovation, and Infrastructure," and SDG11, "Sustainable Cities and Communities," were mentioned 49 times. This indicates the significant impact of the Internet of Things (IoT) and Cloud Computing in improving industrial operations, promoting infrastructure growth, and fostering sustainable practices in urban areas. According to Kolesnichenko et al. (2017), these technologies present potential opportunities for enhancing efficiency, connection, and the general quality of urban living.

SDG7, "Affordable and Clean Energy," and SDG13, "Climate Action," garnered 39 mentions each. This suggests that IoT and Cloud Computing are perceived as instrumental in addressing energy challenges, enabling the integration of renewable energy sources, and facilitating climate change mitigation and adaptation efforts. According to Hildebrandt and Landhäußer (2017), technological advancements and increased data processing capabilities provide a tremendous opportunity for addressing climate change and achieving sustainability. Another significant SDG is SDG3, "Good Health and Well-being," which received 33 references. This highlights the potential of IoT and CC for improving healthcare services. The significance of cloud computing in conjunction with emerging technologies like IoT has been recognized as necessary in enhancing public health systems worldwide and making contributions toward achieving sustainable development objectives (Latif et al., 2017). SDG6, "Clean Water and Sanitation," and SDG8, "Decent Work and Economic Growth," were addressed 32 and 29 times, emphasizing the impact of these technologies on water management and economic development. Big data collected from different sensors connected via IoT can be saved to the cloud and accessed for additional research and analysis, as well as for artificial intelligence or machine learning. The data can be used for many purposes, including monitoring water quality and assessing contaminants (Pandey et al, 2022). These findings provide valuable insights for policymakers, researchers, and practitioners seeking to utilize these technologies to address global sustainability challenges. Further research and practical implementation are needed to unlock the full potential of IoT and Cloud Computing in advancing the SDGs.

The frequency with which Sustainable Development Goals (SDGs) are cited in publications serves as a measure of the analysis performed in this study to discover common topics and areas where IoT and Cloud Computing technologies are thought to have an

important impact. This measure is justified by its capacity to show the level of importance and emphasis placed on certain SDGs in the context of IoT and CC research.

The study intends to highlight which goals are more prominently associated with these technologies by analyzing how frequently each SDG is referenced, providing useful insights into the areas where IoT and CC have the potential to make significant contributions. This research helps researchers, policymakers, and practitioners better understand areas where these technologies will help to progress sustainable development. While the frequency measure might not reflect the full range of each SDG's significance, it does provide a quantitative perspective on the frequency of certain goals in the discourse surrounding IoT, CC, and sustainability, which can be a useful starting point for further research and policy development.

4.3. SDG addressed in the literature portfolio

By analyzing a wide range of research articles, this study identifies the United Nations' Sustainable Development Goals (SDGs) most frequently associated with IoT and Cloud Computing, emphasizing the potential of these technologies in achieving sustainable development objectives.

The 2030 Agenda for Sustainable Development defines 17 SDGs that address global challenges and promote sustainable development across various sectors. By identifying the frequently mentioned SDGs within the selected articles, this study offers valuable insights into the specific goals that benefit from the integration of IoT and Cloud Computing technologies (Table 2).

Table 2

SDGs mostly affected by IoT and Cloud Computing strategies.

No	Ref.	SDGs addressed
1	(Rose et al., 2015)	SDG1, SDG3, SDG6, SDG7, SDG12, SDG13
2	(Falzon & Raviglione, 2016)	SDG3, SDG6, SDG7, SDG9, SDG11, SDG12, SDG13, SDG14, SDG15
3	(Timčenko et al., 2016)	SDG6, SDG7, SDG9, SDG11, SDG12, SDG13
4	(Liaw et al., 2017)	SDG3, SDG8
5	(Hildebrandt & Landhäußer, 2017)	SDG2, SDG3, SDG6, SDG7, SDG11, SDG12, SDG13
6	(Latif et al., 2017)	SDG3
7	(Timčenko et al., 2017)	SDG8
8	(Orr et al., 2018)	SDG4
9	(Wahl et al., 2018)	SDG1, SDG3
10	(Bonilla et al., 2018)	SDG7, SDG9, SDG12, SDG13
11	(Scheuch-Schmid, 2018)	SDG12
12	(Tariq, 2019)	SDG11
13	(Diederich, 2019)	SDG9, SDG13
14	(Daú, et al., 2019)	SDG3, SDG6, SDG11
15	(Kostoska & Kocarev, 2019)	SDG3, SDG4, SDG7, SDG13
16	(Berg, 2019)	SDG1, SDG2, SDG7, SDG8, SDG11, SDG12
17	(Leal Filho, 2019)	SDG9, SDG12
18	(Leitner & Stiefmueller, 2019)	SDG4, SDG5, SDG9, SDG11, SDG17
19	(Monteiro et al., 2019)	SDG9, SDG11, SDG12
20	(Oláh et al., 2020)	SDG7, SDG9, SDG12, SDG13
21	(Achar, 2020)	SDG6, SDG7, SDG11, SDG12, SDG13
22	(Renda & Laurer, 2020)	SDG1, SDG7, SDG9, SDG11
23	(Islam et al., 2020)	SDG2, SDG6, SDG7
24	(Fatimah et al., 2020)	SDG3, SDG6, SDG8, SDG12, SDG13
25	(Li et al., 2020)	SDG6, SDG11
26	(Wu et al., 2020)	SDG1, SDG2, SDG3, SDG4, SDG5, SDG6, SDG7, SDG8, SDG9, SDG10, SDG11, SDG12, SDG13, SDG14, SDG15, SDG16, SDG17
27	(Schluep, 2020)	SDG9, SDG13
28	(Aguilar & Kuffer, 2020)	SDG1, SDG3, SDG9, SDG13
29	(Hoosain et al., 2020)	SDG7, SDG12
30	(Ahad et al., 2020)	SDG11, SDG12
31	(Grijalvo Martín et al., 2020)	SDG3, SDG4, SDG5, SDG8, SDG9, SDG10, SDG11
32	(Karges & Vollmer, 2020)	SDG4, SDG12
33	(Nagel, 2020)	SDG12

Table 2

SDGs mostly affected by IoT and Cloud Computing strategies (continued).

No	Ref.	SDGs addressed
34	(Salam, 2020)	SDG1, SDG2, SDG3, SDG4, SDG6, SDG7, SDG8, SDG9, SDG10, SDG11, SDG12, SDG13, SDG14, SDG15, SDG16
35	(Rodríguez-Abitia et al., 2020)	SDG4, SDG5
36	(Gensch et al., 2021)	SDG8, SDG11, SDG12, SDG13
37	(Martínez et al., 2021)	SDG4, SDG7, SDG11
38	(Verdejo Espinosa et al., 2021)	SDG3, SDG4, SDG7, SDG17
39	(Režek Jambrak et al., 2021)	SDG1, SDG6, SDG8, SDG11, SDG12, SDG13, SDG14
40	(López-Vargas et al., 2021)	SDG2, SDG3, SDG4, SDG6, SDG7, SDG8, SDG9, SDG11, SDG12, SDG13, SDG14, SDG15
41	(de Villiers et al., 2021)	SDG2, SDG6, SDG7, SDG9, SDG11, SDG12, SDG13, SDG15
42	(Dalal, 2021)	SDG2, SDG3, SDG6, SDG9, SDG11, SDG13, SDG14, SDG15
43	(Ugwuanyi et al., 2021)	SDG6, SDG9, SDG11
44	(Bohra & Bordoloi, 2021)	SDG2, SDG3, SDG6, SDG7, SDG8, SDG9, SDG11, SDG12, SDG13, SDG14, SDG15, SDG17
45	(Adjei et al., 2021)	SDG12
46	(Jamwal et al., 2021)	SDG9, SDG12, SDG13
47	(Mabkhot et al., 2021)	SDG7, SDG9
48	(DAYIOĞLU & Turker, 2021)	SDG2, SDG6, SDG7, SDG8, SDG12
49	(Kolesnichenko et al., 2021)	SDG1, SDG2, SDG3, SDG4, SDG5, SDG6, SDG7, SDG8, SDG9, SDG10, SDG11, SDG12, SDG16
50	(Khan et al., 2021)	SDG1, SDG9, SDG10
51	(Zengin et al., 2021)	SDG7, SDG8, SDG9, SDG11, SDG12, SDG13
52	(Feroz et al., 2021)	SDG11, SDG12
53	(Nurgazina et al., 2021)	SDG3, SDG6, SDG8, SDG9, SDG11, SDG12
54	(Camodeca & Almici, 2021)	SDG1, SDG2, SDG3, SDG4, SDG5, SDG7, SDG8, SDG9, SDG10, SDG12, SDG16
55	(Pagliarin et al., 2021)	SDG11
56	(Wurm et al., 2021)	SDG12
57	(Carbon et al., 2021)	SDG2, SDG7, SDG9, SDG12
58	(Sun & Wang, 2022)	SDG2, SDG12
59	(Thakur et al., 2022)	SDG7, SDG11
60	(Mahdad et al., 2022)	SDG2, SDG9
61	(Bachmann et al., 2022)	SDG1, SDG2, SDG3, SDG4, SDG5, SDG6, SDG7, SDG8, SDG9, SDG10, SDG11, SDG12, SDG13, SDG14, SDG15, SDG16, SDG17
62	(Wu et al., 2022)	SDG1, SDG4, SDG5, SDG8, SDG10, SDG11, SDG14, SDG15, SDG16
63	(Mhlanga, 2022)	SDG11, SDG12, SDG13
64	(Sidek et al., 2022)	SDG8, SDG9, SDG11, SDG12

Table 2

SDGs mostly affected by IoT and Cloud Computing strategies (continued).

No	Ref.	SDGs addressed
65	(Obaideen et al., 2022)	SDG2, SDG6, SDG7, SDG12, SDG15
66	(Arshad et al., 2022)	SDG1, SDG2, SDG3, SDG9, SDG11, SDG12, SDG15
67	(Tasnim & Ahad, 2022)	SDG3, SDG6, SDG7, SDG8, SDG9, SDG11, SDG12, SDG13, SDG17
68	(Kaufmann & Petzlberger, 2022)	SDG11
69	(Verde et al., 2022)	SDG9, SDG11, SDG15
70	(Ghorbanpour et al., 2022)	SDG2, SDG6, SDG9, SDG13
71	(Dhanaraju et al., 2022)	SDG2, SDG7, SDG12, SDG15
72	(Pandey et al., 2022)	SDG6
73	(Patyal et al., 2022)	SGD3, SDG6, SDG7, SDH9, SDG12, SDG13
74	(Bisht et al., 2022)	SDG1, SDG8, SDG12, SDG13
75	(Fabricio et al., 2022)	SDG9
76	(Costa et al., 2022)	SDG2, SDG9
77	(Kee et al., 2022)	SDG7, SDG9, SDG11
78	(Sultana & Tamanna, 2022)	SDG4
79	(Fritzsche et al., 2022)	SDG4, SDG10, SDG13
80	(Engels, 2022)	SDG3, SDG9, SDG12, SDG13
81	(Gimpel, 2022)	SDG9, SDG11, SDG12, SDG13
82	(Heizung, 2022)	SDG2, SDG3, SDG4, SDG6, SDG7, SDG8, SDG9, SDG11, SDG12, SDG17
83	(Marcher & Wieser, 2022)	SDG13
84	(Maslowski, 2022)	SDG3, SDG4, SDG5, SDG6, SDG7, SDG8, SDG9, SDG11, SDG12, SDG13, SDG15
85	(Boulouard et al., 2022)	SDG1, SDG2, SDG4, SDG5, SDG6, SDG8, SDG9, SDG12, SDG13, SDG14, SDG15
86	(Zaman, 2022)	SDG9, SDG11, SDG12
87	(Leal Filho, 2022)	SDG2, SDG11, SDG12
88	(Bellini et al., 2022)	SDG1, SDG2, SDG3, SDG4, SDG5, SDG6, SDG7, SDG8, SDG9, SDG10, SDG11, SDG12, SDG13, SDG14, SDG15, SDG16, SDG17
89	(Gairola & Kumar, 2022)	SDG4
90	(Ashir et al., 2022)	SDG6, SDG7, SDG8, SDG9, SDG11, SDG12
91	(Calvo et al., 2022)	SDG3, SDG7, SDG9, SDG11, SDG13
92	(Wolfert & Isakhanyan, 2022)	SDG2, SDG3, SDG6, SDG9, SDG12, SDG13, SDG15
93	(Gao et al., 2023)	SDG3,SDG9, SDG11
94	(Tabuenca et al., 2023)	SDG3, SDG4
95	(Chen et al., 2023)	SDG7, SDG9, SDG11, SDG12, SDG13

Table 2

SDGs mostly affected by IoT and Cloud Computing strategies (continued).

No	Ref.	SDGs addressed
96	(Tyagi et al., 2023)	SDG2,SDG3, SDG7, SDG8, SDG11
97	(Guerrero-Ulloa et al., 2023)	SDG3, SDG8, SDG13
98	(Bhat et al., 2023)	SDG1, SDG8
99	(Hung & Chen, 2023)	SDG12
100	(Hayashi et al., 2023)	SDG2 SDG,9

4.4. Targets addressed in the literature portfolio

The Sustainable Development Goals (SDGs) were officially established by the United Nations in September 2015. This framework comprises a total of 17 goals and 169 targets. These goals and targets aim to incorporate aspects of sustainable development into nations' broader economic, environmental, and social frameworks (Salvia et al., 2019). As technology continues to advance, the Internet of Things and Cloud Computing have emerged as powerful tools with the potential to considerably impact the achievement of the SDGs. This study encompasses a number of targets from different SDGs, highlighting the diverse areas where IoT and Cloud Computing can make a significant difference (Table 3).

By synergizing cutting-edge technology with sustainability aspirations, this study emphasizes the opportunity for IoT and Cloud Computing to drive innovation and facilitate progress within the complex domain of sustainable development. Through their interconnected nature, these technological enablers have the capacity to influence not only the achievement of specific targets but also the overall integration and balance of the SDGs framework, fostering a more harmonious and interconnected global pursuit of a more equitable, prosperous, and sustainable future.

Table 3

Targets transformed by IoT and Cloud Computing strategies.

No	Ref.	Targets addressed
1	(Falzon & Raviglione, 2016)	Target 6.3 Target 7.2 Target 9.4 Target 11.6 Target 12.2 Target 13.1 Target 14.2 Target 15.1
2	(Aguilar & Kuffer, 2020)	Target 11.7
3	(Rodríguez-Abitia et al., 2020)	Target 4.4
4	(Verdejo et al., 2021)	Target 17.9 Target 17.12 Target 17.13 Target 17.19
5	(Obaideen et al., 2022)	Target 6.4
6	(Verde et al., 2022)	Target 11.7

The targets addressed in Table 3 include improving water quality, increasing the share of renewable energy, upgrading infrastructure for sustainability, reducing environmental impacts in cities, achieving sustainable resource management, strengthening resilience to climate-related hazards, conserving marine and terrestrial ecosystems, promoting inclusive public spaces, enhancing skills development, facilitating international cooperation, removing trade barriers, enhancing macroeconomic stability, and developing comprehensive measurements of progress on sustainable development.

Each target is examined in the context of how IoT and Cloud Computing can advance progress and realize the associated sustainable development objectives. This research considers the potential benefits and challenges associated with the integration of these technologies, providing insights into how they can promote data-driven decision-making,

optimize resource management, enhance infrastructure sustainability, support inclusive urban spaces, strengthen resilience, and foster international cooperation.

The targets identified within the literature portfolio are as follows:

-Target 4.4: Substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship (United Nations, 2015).

IoT and Cloud Computing can enhance educational opportunities and skills development through e-learning platforms, virtual laboratories, and remote access to educational resources. These technologies support the acquisition of technical and vocational skills, promoting employment and entrepreneurship (Kolesnichenko et al., 20201; Rodríguez-Abitia et al., 2020).

-Target 6.3: Improve water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials (United Nations, 2015).

This target emphasizes the need to protect water resources and reduce pollution. IoT can play a crucial role by enabling real-time monitoring of water quality, identifying sources of pollution, and facilitating proactive measures to improve water management through the applications of sensor networks to environmental challenges (Achar et al., 2020; Khan et al., 2021; Pandey et al., 2022; Rose et al., 2015).

-Target 6.4: Deals with water scarcity and refers to two main indicators: water use efficiency and water stress (United Nations, 2015).

IoT and Cloud Computing can help address water scarcity by enabling efficient water consumption through real-time monitoring, smart irrigation systems, and leak detection. These technologies provide insights into water consumption patterns and support effective water management strategies (Achar et al., 2020; Khan et al., 2021; Rose et al., 2015).

-Target 7.2: Increase the share of renewable energy in the global energy mix (United Nations, 2015).

IoT and Cloud Computing can support integrating and optimizing renewable energy sources by enabling smart grid management, energy monitoring, and demand-response systems. These technologies can enhance energy efficiency and facilitate the transition toward a sustainable energy mix (Bonilla et al., 2018; Mabkhot et al., 2021).

-Target 9.4: Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies (United Nations, 2015).

IoT and Cloud Computing can contribute to sustainable infrastructure and industry by enabling smart buildings, efficient resource management, predictive maintenance, and supply chain optimization. These technologies improve operational efficiency, reduce resource consumption, and promote the adoption of clean technologies (Kolesnichenko et al., 2021; Mabkhot et al., 2021; Patyal et al., 2022).

-Target 11.6: Reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality, municipal, and other waste management (United Nations, 2015).

IoT and Cloud Computing enable smart city solutions, such as air quality monitoring, waste management optimization, and traffic management. These technologies can help cities reduce environmental impacts, improve public health, and enhance overall sustainability (Feroz et al., 2021; Khan et al., 2021).

-Target 11.7: Provide universal access to safe, inclusive, and accessible green and public spaces, particularly for women and children, older persons, and persons with disabilities (United Nations, 2015).

IoT and Cloud Computing can support the development of smart, inclusive, and sustainable urban spaces. These technologies enable the monitoring and management of public spaces, improving safety, accessibility, and resource utilization (Khan et al., 2021; Kolesnichenko,2021).

-Target 12.2: Achieve sustainable management and efficient use of natural resources (United Nations, 2015).

IoT can contribute to sustainable resource management by providing real-time data on resource consumption, enabling efficient use of resources, and supporting decision-making for sustainable practices (Bachmann et al., 2022; Oláh et al., 2020; Režek et al., 2021; Sun & Wang, 2022; Wu et al., 2022). Cloud Computing facilitates data analysis and collaboration, enhancing resource management efforts (Ghorbanpour et al., 2022; Wahl et al., 2018; Wu et al., 2020).

-Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries (United Nations, 2015).

IoT-based sensors and monitoring systems can provide early warning systems, weather forecasting, and disaster management solutions (Renda & Laurer, 2020; Sultana & Tamanna, 2022). Cloud Computing supports the storage, processing, and analysis of large-scale data for effective disaster response and resilience-building (Ahad et al., 2020; Grijalvo et al., 2020; Kee et al., 2022; Mabkhot et al., 2021).

-Target 14.2: Sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including strengthening their resilience and taking action for their restoration (United Nations, 2015).

IoT devices and networks can monitor and collect data on marine and coastal ecosystems, supporting conservation efforts, monitoring pollution levels, and protecting biodiversity,

while Cloud Computing enables the analysis and sharing of this data, facilitating effective management and restoration actions (Režek et al., 2021).

-Target 15.1: Ensure conservation, restoration, and sustainable use of terrestrial and inland freshwater ecosystems (United Nations, 2015).

IoT technologies, such as remote sensing devices and sensor networks, can contribute to monitoring and managing terrestrial and freshwater ecosystems. Cloud Computing allows for data analysis and decision support, promoting sustainable conservation and restoration practices (Khan et al., 2021; Rose et al., 2015).

-Target 17.9: Enhance international support for implementing effective and targeted capacity-building in developing regional countries to support national plans for implementing all the sustainable alternative development goals through interregional cooperation (United Nations, 2015).

Cloud Computing plays a vital role in supporting international cooperation and capacity-building efforts. It enables sharing of knowledge, resources, and best practices across regions, facilitating the implementation of sustainable development goals (Wahl et al., 2018; Wu et al., 2020).

-Target 17.12: Remove trade barriers for least developed countries, realize timely implementation of duty-free and quota-free market access, and simplify preferential rules of origin to facilitate market access (United Nations, 2015).

Cloud Computing can streamline trade processes, provide a platform for secure data sharing, and enable efficient supply chain management. These technologies reduce trade barriers and facilitate market access for least-developed countries (Wu et al., 2020).

-Target 17.13: Enhance global macroeconomic stability through policy coordination and coherence (United Nations, 2015).

Cloud Computing can support global policy coordination and coherence by facilitating data sharing, analysis, and decision-making among different stakeholders. These technologies enhance collaboration, promote transparency, and contribute to macroeconomic stability (Li et al., 2020).

-Target 17.19: Further develop measurements of progress on sustainable development, complementing gross domestic product, and supporting statistical capacity-building in developing countries (United Nations, 2015).

Cloud Computing can provide the infrastructure and tools for data storage, analysis, and reporting, supporting the development of comprehensive measurements of progress on sustainable development. These technologies strengthen statistical capacity and monitor the effectiveness of sustainable development efforts (Fabricio et al., 2022; Zengin et al., 2021).

It is important to note that these technologies' specific implementation and effectiveness are different across different regions and contexts. By understanding the opportunities and challenges associated with the integration of IoT and Cloud Computing in the context of specific SDG targets, policymakers, organizations, and stakeholders can make effective decisions and utilize these technologies to drive sustainable development and address major global challenges. Furthermore, it is crucial to address privacy, security, equitable access, and environmental sustainability challenges to fully leverage the potential of IoT and Cloud Computing in advancing sustainable development (Rani et al., 2021).

However, the quantity of the identified targets within the studied literature portfolio is limited, which indicates potential research gaps and a need for further investigation into the specific applications of IoT and Cloud Computing in achieving SDG targets. Future studies should explore the underrepresented SDG targets more deeply to better understand how IoT and Cloud Computing can be used effectively to address sustainable development challenges, ensuring a more inclusive approach to attaining the SDGs.

5. Conclusion and Recommendations

The integration of Internet of Things (IoT) and Cloud Computing (CC) technologies has the potential to significantly contribute to achieving the United Nations' Sustainable Development Goals (SDGs). The findings of this literature review revealed that the IoT-CC nexus can positively impact SDG 3 (Good Health and Well-Being), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). This research highlights the importance of utilizing cutting-edge technologies like IoT and CC to address global challenges related to healthcare, clean water, renewable energy, industry innovation, sustainable cities, responsible consumption, and climate action. However, further research is needed to explore and understand the specific applications of these technologies to unrepresented SDG targets for a more comprehensive approach to sustainable development.

The bibliometric results of this study give us useful insights into how publications in the field of IoT, CC, and sustainability have progressed. It's clear that there's a growing interest in this area, as an increasing number of publications are being released over time. The way articles are spread out among different classifications shows that much of the research has a theoretical focus. This means the research is less focused on how it can be applied in the real world. The way research contributions have been spread worldwide shows how important this topic is on a global level. Both developed and developing countries are actively working to deal with sustainability challenges. In order to promote inclusive and sustainable development, it is important to encourage collaboration between countries at different levels of development. This collaboration helps bridge knowledge gaps and encourages the use of technology for positive change.

The study's findings provide several recommendations for future research to address the

existing gaps and improve the integration of sustainability approaches. The following recommendations offer a comprehensive understanding of how to enhance sustainability strategies:

- Exploring Cloud Computing's potential for SDGs: The study highlighted a notable lack of attention to Cloud Computing compared to IoT, suggesting that future studies should prioritize in-depth investigation of Cloud Computing's applications, implications, and advancements for achieving sustainable development goals.
- Tackling overlooked SDG targets: Future research should explore how the Internet of Things and Cloud Computing can effectively address underrepresented targets to discover their potential in overcoming distinct sustainability challenges and closing existing knowledge gaps.
- Diverse regional contexts: To fully comprehend the impact of diverse regional contexts on SDGs, research should extend to diverse countries and regions. This will reveal adaptable applications within varied socio-economic contexts, enriching the approach to sustainable development goals.
- Ethical and privacy considerations: To ensure responsible IoT-CC integration, more research is needed on ethical and privacy dimensions. Investigating challenges and safeguards will enhance understanding of their responsible deployment towards sustainable development goals.
- Balancing IoT-CC-sustainability research: The IoT-CC-sustainability research domain should achieve a balance between practical applications (case studies) and theoretical advancements (reviews and methodological articles) for a deeper understanding of operational implications, broader sustainability impact and more comprehensive exploration.

- Exploration of additional Industry 4.0 enablers: It is recommended that a comprehensive exploration of additional Industry 4.0 enablers be undertaken to gain deeper insights into their impact on Sustainable Development Goals (SDGs), thereby enhancing our understanding of the potential contributions these enablers can make toward global sustainability objectives.
- The literature's limitations: The study provides valuable recommendations for future research to improve sustainability measures. However, it is important to recognize the literature's limitations, which include potential biases, inadequate theoretical research, and a reliance on measures like SDG frequency.
- Research in a broader scope, encompassing various types of documents and sources: It is strongly recommended that future research adopt a broader scope that encompasses diverse document types and sources. To advance knowledge and innovation effectively, it is essential to expand the horizons of research beyond peer-reviewed literature.

Addressing these knowledge gaps would result in a complete understanding of how the Internet of Things (IoT) and cloud computing may successfully contribute to achieving sustainable development goals and accelerate the transition to Industry 4.0 objectives.

In conclusion, the integration of the Internet of Things and Cloud Computing has the potential to revolutionize sustainable practices and contribute significantly to achieving the Sustainable Development Goals by 2030. We can build a more sustainable and prosperous future for the global community by embracing this technological nexus and encouraging further research and collaboration.

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Appendix A

Table A.1.

Sustainable Development Goals.

SDG 1	No poverty
SDG 2	Zero hunger
SDG 3	Good health and well-being
SDG 4	Quality education
SDG 5	Gender equality
SDG 6	Clean water and sanitation
SDG 7	Affordable and clean energy
SDG 8	Decent work and economic growth
SDG 9	Industry, innovation and infrastructure
SDG 10	Reduced inequalities
SDG 11	Sustainable cities and communities
SDG 12	Responsible consumption and production
SDG 13	Climate action
SDG 14	Life Below water
SDG 15	Life on land
SDG 16	Peace, justice and strong institutions
SDG 17	Partnerships for the goals

*Note,*From UN, 2015. Transforming our world: the 2030 Agenda for Sustainable Development. United Nations, A/RES/70/1, Agenda items 15 and 116, 1-35.

Appendix B

Figure B.1.

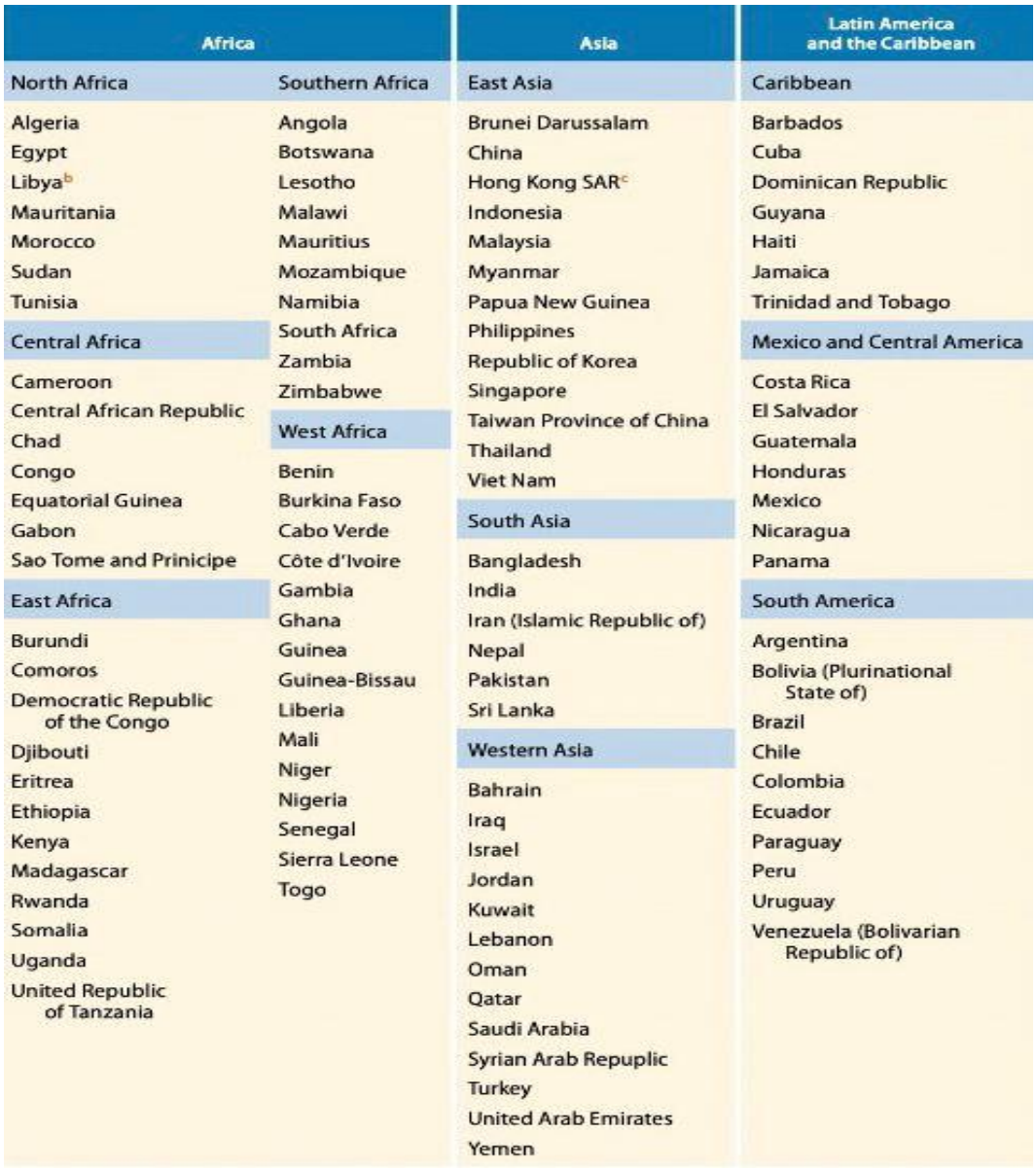
The developed countries.

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				

Note,From https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf

Figure B.2.

The developing countries.



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	

Note,From https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf

Figure B.3.

The least developed countries.

Africa		East Asia	South Asia	Western Asia	Latin America & the Caribbean
Angola	Madagascar	Cambodia[a]	Afghanistan[a]	Yemen	Haiti
Benin	Malawi	Kiribati[a]	Bangladesh		
Burkina Faso	Mali	Lao People's Democratic Republic[a]	Bhutan[a]		
Burundi	Mauritania	Myanmar	Nepal		
Central African Republic	Mozambique	Samoa[a, b]			
Chad	Niger	Solomon Islands[a]			
Comoros	Rwanda	Timor Leste[a]			
Democratic Republic of the Congo	Sao Tome and Principe	Tuvalu[a]			
Djibouti	Senegal	Vanuatu[a]			
Equatorial Guinea	Sierra Leone				
Eritrea	Somalia				
Ethiopia	South Sudan[a]				
Gambia	Sudan				
Guinea	Togo				
Guinea-Bissau	Uganda				
Lesotho	United Republic of Tanzania				
Liberia	Zambia				

Note,From https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf