Lecture Notes on Data Engineering
and Communications Technologies 105

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AI and IoT for Sustainable Development in Emerging Countries

Challenges and Opportunities

Springer

Lecture Notes on Data Engineering and Communications Technologies

Volume 105

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ISSN 2367-4512 ISSN 2367-4520 (electronic)
Lecture Notes on Data Engineering and Communications Technologies
ISBN 978-3-030-90617-7 ISBN 978-3-030-90618-4 (eBook)
https://doi.org/10.1007/978-3-030-90618-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Artificial intelligence and Internet of Things have introduced themselves today as must-have technologies in almost every sector. Ranging from agriculture to industry and healthcare, the scope of applications of AI and IoT is as wide as the horizon. Nowadays, these technologies are extensively used in developed countries, but they are still at an early stage in emerging countries.

As these countries were more affected by the COVID-19 pandemic, both healthcare-wise and economy-wise, the need to adopt new solutions to sustainable development challenges has become more crucial than ever.

The idea behind this book is to focus on solutions based on AI and IoT that can face the challenges of the emerging countries. We will shed the light on different sectors such as agriculture, industry, transportation, environment, energy, healthcare, etc. We will discuss the challenges that the emerging countries face in these sectors and provide AI and IoT-based solutions to them. We will also introduce success stories featuring the implementation of AI- and IoT-based solutions and their impact on the lives of people in developing countries.

This book will be divided into five parts. The first part will introduce AI and IoT as actors that can help address the sustainable development challenges in general with some case scenarios as examples. The other sections will go in depth and spot the light on AI and IoT and their role to play in each of the most important sectors of everyday life. They will also expose how researchers from emerging countries applied AI and IoT to approach sustainable development challenges taking into consideration the specificities of their own countries.

First part, containing five chapters, starts in Chapter "Achieving Sustainable Development Goals Through Digital Infrastructure for Intelligent Connectivity," by spotting the light on Sustainable Development Goals (SDGs) set by the UN to be achieved by 2030 and the impact that COVID-19 had on these SDGs by increasing intelligent connectivity levels and gaining better access to education, health, work, and entertainment despite the pandemic. Chapter "Implementation of Intelligent IoT" introduced the concept of "artificial intelligence-enabled Internet of Things," better known as "AIoT." It provides an overview on "intelligent" IoT devices, as well as why and how to implement them. Chapter "Cyber Security Challenges for Smart Cities"

discusses the interconnectivity of intelligent devices at its widest levels, "Smart Cities," and how it can be secured. Chapters "Efficient Machine Learning Technique for Early Detection of IoT Botnets" and "AI-Based Smart Robot for Restaurant Serving Applications" are introductory use case scenarios where researchers from emerging countries, Algeria and Pakistan, take the best of both AI and IoT to provide better solutions to everyday life situations, such as communication security on the one hand and restaurant serving on the other hand.

Second part spots the light on the innovations of emerging countries researchers when it comes to facing the environment and energy optimization challenges. On a microscopic level, Chapter "A Novel Deep Learning Architecture Based IoT Time-Series for Energy Consumption Forecasting in Smart Households" introduces a deep learning-based IoT system able to predict energy consumption in smart households. On a macroscopic level, Chapter "Performances of CPV Optics in Morocco" measures the performances of Concentration Photovoltaic systems adopted in Morocco as a means to produce solar-based electrical energy, while Chapter "Artificial Intelligence Based on Particle Swarm Optimization for Optimal Wind Turbine Power Control Using Doubly Fed Induction Generator" introduces an approach to optimize wind turbine power control based on artificial intelligence. When it comes to environment, Chapters "A Comparative Study Between NARX and LSTM Models in Predicting Ozone Concentrations: Case of Agadir City (Morocco)" and "Spatiotemporal Prediction of $PM_{2.5}$ Concentrations Based on IoT Sensors" introduce two IoT and machine learning-based approaches to predict the concentration of ozone components (and pollutants) in both Morocco and Taiwan, respectively. This part also introduces the role of artificial intelligence and Internet of Things in smart precision agriculture as the authors in Chapter "Comparative Study Between Different Recommendation Systems in Smart Agriculture" provide a comparative analysis on recommendation systems and their role as a means to optimize agricultural yields.

Third part focuses on Industry 4.0 and Transportation in developing countries and provides an overview on different approaches to address their challenges. Chapter "Configuration Security for Sustainable Digital Twins of Industrial Automation and Control Systems in Emerging Countries" goes through the configuration security techniques used for sustainable Digital Twins in emerging countries, and suggest a new approach, based on a combination of artificial bee colonies and support vector machines, that will be able to optimize attack predictions. Chapter "An Empirical Investigation on Lean Method Usage: Issues and Challenges in Afghanistan" addresses the challenges facing the application of Lean method in Afghan software development companies, while Chapter "Optimization of the Effects Oscillation Welding: Sinusoidal and Triangular Beam During Laser Beam Welding of 5052-H32 Aluminum Alloy" provides a regression-based model to predict the tensile strength of aluminum alloys. When it comes to transportation, the authors in Chapter "The Internet of Things Solutions for Transportation" provide an overview of AI- and IoT-based solutions for transportation as well as their challenges while going through use cases of large companies that have adopted these solutions. Chapter "A Novel

GAN-Based System for Time Series Generation: Application to Autonomous Vehicles Scenarios Generation" proposes a novel GAN-based system for time series generation able to generate various autonomous driving scenarios, toward a fully automatic framework of self-driving testing. Road accidents are also in the spotlight in this section, as in Chapter "Fuzzy Set Theory-Based Approach for Mining Spatial Association Rules: Road Accident as a Case Study," where the authors introduce a new approach on analyzing road accidents in a specific area and determining their main causes. This approach combines the best of artificial intelligence-based recommendation systems with fuzzy set theory applied on spatial association rules for a better performance. Chapter "A Mobile Application for Real-Time Detection of Road Traffic Violations" also proposes a machine learning-based solution for road accidents in Mauritius. This solution is able to detect infringements, warn the wrongdoers, and report them to the authorities.

COVID-19 has brought the attention on the importance of health care as a crucial sector, especially in emerging countries where the pandemic had a greater impact. Part Four will focus on different attempts of researchers from these countries to take the best of AI and IoT to face healthcare-related challenges. The authors in Chapter "IoT Based Health Monitoring System and Its Challenges and Opportunities" spot the light on some of these challenges, especially when it comes to monitoring infected or elderly patients. They proposed an IoT-based health monitoring system that connects through GSM networks as a means to overcome connectivity problems in emerging countries. Chapter "Wireless Body Sensor Networks: Applications, Challenges, Patient Monitoring, Decision Making, and Machine Learning in Medical Applications" presents the works of an Iraqi team that also provides a solution to the health monitoring issue by introducing wireless body sensor networks (WBSN). In this chapter, they present this technique, its architecture, challenges, healthcare application, and their requirements. Since the amount of data transferred through WBSNs can be important, the same team introduces in Chapter "A Novel Lossless EEG Compression Model Using Fractal Combined with Fixed-Length Encoding Technique" a means to optimize connectivity in these networks by compressing EEG signals, and thus reducing the size of data sent. Along with the connectivity of the healthcare-oriented systems comes their security, a challenge addressed in Chapter "Securing the Hyperconnected Healthcare Ecosystem" where the authors propose a holistic cybersecurity platform that tackles privacy and security risks in an automated fashion to foster the development of innovative applications within the healthcare ecosystem. Optimizing the yields of healthcare-oriented IoT devices also implies a better energy consumption. This urged the authors of Chapter "Design of an Efficient Rectenna for RF Energy Harvesting for IoT Medical Implants" to design an efficient rectenna for radio frequency harvesting for IoT medical implants. Researchers from emerging countries have put quite some efforts to increase the role of AI in the healthcare sector, and the remaining chapters of this part will spot the light on them. In Chapter "Multi-class Classification for the Identification of COVID-19 in X-Ray Images Using Customized Efficient Neural Network," the authors used AI to detect COVID-19 positive cases based on X-Ray images, while the authors of "Chapters A Review: Recent Automatic Algorithms for the Segmentation of Brain Tumor

MRI" and "Oncology with Artificial Intelligence: Classification of Cancer Using Deep Learning Techniques" suggest new deep learning-based approaches to detect cancer cells. Chapter "IoT Based Machine Learning and Deep Learning Platform for COVID-19 Prevention and Control: A Systematic Review" proposes a systematic review of several efforts to apply deep learning to enhance the prevention and control of the COVID-19 disease.

The increasing connectivity and the necessity to stay online made the exploitation of big data in general and social media in particular a concern to emerging countries as well. Part Five will go through efforts of researchers from these countries to take the best of big data and social media. In Chapter "Digital Transformation and Costumers Services in Emerging Countries: Loan Prediction Modeling in Modern Banking Transactions," the authors present a baking system that predicts loan repayment or default based on customer's digital data. Chapter "A k-Mean Classification Study of Eight Community Detection Algorithms: Application to Synthetic Social Network Datasets" proposes a new approach for community detection in social media, while Chapter "Topic Modeling for Short Texts: A Novel Modeling Method" offers an AI-based technique to better rank topics in short texts. "Chapters Prediction and Analysis of Moroccan Elections Using Sentiment Analysis" and "Analysis of COVID-19 Trends in Bangladesh: A Machine Learning Analysis" provide new approaches to analyze the sentiments of social media users regarding hot topics in their countries, such as the general elections in Morocco or the COVID-19 disease in Bangladesh.

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Meknes, Morocco — Mariya Ouaissa
Meknes, Morocco — Mariyam Ouaissa
Fes, Morocco — Sarah El Himer

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AIoT and Challenges for Sustainable Development

Achieving Sustainable Development Goals Through Digital Infrastructure for Intelligent Connectivity

T. P. Fowdur, M. Indoonundon, M. A. Hosany, D. Milovanovic, and Z. Bojkovic

Abstract We are at the beginning of the decade to achieve the targets of the UN Sustainable Development Goals (SDGs) by 2030 and achieving these targets appear even more challenging as the world is still struggling to cope with COVID-19. The COVID-19 pandemic has in fact seriously comprised several SDGs such as SDG 1 (No Poverty) in which significant progress was being made. For the first time in two decades, poverty levels are being projected to grow as a result of the COVID-19 pandemic. However, COVID-19 has also propelled the adoption of digital technologies to much higher rates. In particular, intelligent connectivity (IC), which combines 5G with Artificial Intelligence (AI), the Internet of Things (IoT) and other emerging technologies, has allowed individuals to access several life-saving and enhancing services such as education, health, food supplies, work and entertainment, during the pandemic. The adoption of intelligent connectivity is being increasingly popular, propelled by new requirements created by Covid-19 and fueled by an exponentially growing mobile industry. This chapter gives a detailed overview of how intelligent connectivity and other emerging digital technologies are contributing to all the 17 SDGs.

Keywords 5G · AI · UN · SDGs · Intelligent connectivity · Cloud · IoT

1 Introduction

The UN General Assembly introduced the Sustainable Development Goals (SDGs) in its resolution 70/1 in 2015, with the target year being 2030 [1, 2]. The goals encompass

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Z. Boulouard et al. (eds.), *AI and IoT for Sustainable Development in Emerging Countries*,
Lecture Notes on Data Engineering and Communications Technologies 105,
https://doi.org/10.1007/978-3-030-90618-4_1

Fig. 1 The sustainable development goals (SDGs) (Source: [6])

three major community development dimensions which are environment protection, social diversity and economic growth [3]. The SDGs have been set by the community which includes government, private sector and academia and they have become one of the most widely adopted standard systems for achieving sustainable community development. The 17 SDGs, given in Fig. 1 are a continuation of the Millennium Development Goals (MDG) which consisted of 8 goals, set in 2000 with 2015 being the target year [4, 5]. The SDG framework is linked to several human rights but can be differentiated from them by their emphasis on people, planet, prosperity, peace, and partnership [6].

The SDGs are very ambitious and broad [7] and can seem impossible to achieve. Nevertheless, they are pursued to encourage innovative approaches to make progress [8]. Intelligent Connectivity, which is the combination of several technological enablers such as Artificial intelligence (AI), mobile communications (5G), Internet of Things (IoT), Cloud and Blockchain, is considered to be the most impactful technology which can help achieve SDGs. These main parts are briefly described as follows:

5G: 5G has incorporated three main service sets namely: (i) Enhanced Mobile Broadband (eMBB) to provide data rates of upto 10 Gbps, (ii) Ultra-Reliable Low-Latency Communication (URRLC) for applications requiring extremely low error rates (high reliability) and low latency and (iii) Massive Machine Type Communications (mMTC) to support high device density with low power consumption [9].

Cloud: Includes services such as Software-as-a-Service, Infrastructure-as-a-Service, and Platform-as-a-Service which provide the necessary applications, processing power and storage requirements to run and scale AI and data analytics [10].

AI: Allows data analytics to be performed with diverse machine learning algorithms for different applications which can even be real-time or near real-time. The analytics

can take the form of predictions, classifications, pattern discovery and decision making processes [10].

IoT: Consists of a network of items composed of sensors that can communicate via the Internet. The sensors collect data to feed AI systems and other network elements such as controllers or even robots, implement the instructions received from AI systems [11].

Blockchain: Blockchain, also known as Distributed Ledger Technology (DLT), cryptographically associates data blocks, permanently logs transactions and links them to the next data block. It creates a reliable continuous data stream [12] and can thus be used as a key enabling technology for multiple types of AI applications and analytical tools.

Intelligent Connectivity is still in its infancy but is expected to bring innovations, boost productivity, and speed up the development of novel business models which will significantly impact socioeconomic development [13]. 5G technology will provide enhanced internet connectivity which is expected to lead to an economic output of $3.6 trillion and the creation of 22.3 million jobs by 2035 [14], translating into $13.2 trillion global economic value across industries. A third of this economic output is composed of manufacturing whereas another third is composed of wholesale and retail, construction, information and communications, and public services [14]. However, the first trillions of dollars will need to be invested into the development of 5G networks globally. Companies aim at becoming first movers into the 5G market but first, cooperation will be required to accelerate 5G's development.

A global reduction in greenhouse gas (GHG) emissions that is tenfold more than the global carbon footprint of the mobile industry, has been achieved by the adoption of mobile technology. People around the world rely mainly on mobile technology to obtain digital access, leading to over five billion subscribers of mobile services and around four billion mobile internet users worldwide. Mobile technologies have introduced several economic, social and environmental advantages by easing access to digital services and expanding connectivity and they have also contributed to all 17 SDGs [15].

In this chapter, the impact of Intelligent Connectivity on each SDG will be described with several use cases in countries and organizations across the world.

2 Impact of Intelligent Connectivity on SDGs

In this section an in-depth analysis on how intelligent connectivity can contribute to the 17 SDGs is provided. Table 1 provides a global view of the relative impact of the different technological enablers of IC on the 17 SDGs for some selected use cases that will be presented in the following sub-sections.

Table 1 Relative impact of technological enablers in selected intelligent connectivity use cases for sustainable development goals (SDGs)

SDG	5G mobile communications	Artificial intelligence (AI)	Internet of things (IoT)	Cloud computing (CC)	Blockchain (BC)
1	+	+	+		
2	+	+	+		
3	+	+			
4	+	+	+		
5		+	+		
6	+		+		
7	+	+			+
8	+	+	+		
9	+	+	+	+	
10	+	+			
11	+	+			
12	+		+		
13	+		+		
14	+	+	+		
15	+	+	+		
16		+			
17	+				

2.1 SDG 1: No Poverty

People earning less than $1.25 per day are considered to be extremely poor. The aim of this SDG is to eradicate such extreme poverty globally by 2030 and also to guarantee that all men and women, including the vulnerable ones, have the same rights to economic resources. Furthermore, they will have access to basic necessities, natural resources, property ownership, inheritance, novel technology and financial services such as microfinance [16].

Mobile technology is an essential contributor to SDG 1 as it drives sustainable economic growth by supporting households to overcome poverty and by providing humanitarian assistance. Since 2015, the number of mobile users among the world's poorest 40% (composed of 1.9 billion people) has increased by 200 million [15]. Furthermore, mobile helps in improving efficiency and productivity in other sectors. It allows companies to reach non-local customers, allowing the former to expand and create jobs for the local population.

Even the general use of mobile helps to curb poverty. The increased availability of mobile phones in Peru has decreased poverty prevalence by 8% and has reduced acute poverty by 5.4% points [17]. The deployment of mobile broadband networks

in Nigeria in 2010 to 2016 has created new jobs and reduced extreme poverty by 7% points [18].

In Low-to-Middle Income Countries (LMIC), the financial exclusion gap has been reduced with the help of mobile money. From 2015 to 2019, there has been an increase of 460 million registered mobile money accounts which adds up to more than 1 billion registered accounts. Mobile money allows users to easily access financial services and to seamlessly manage their cash flow, build working capital and handle financial risks. Access to mobile money in Kenya was found to have lifted out of poverty some 200,000 households (2% of Kenya's households). In rural Uganda, it was observed that mobile money could smoothen consumption and curb poverty [19].

Furthermore, M-KOPA, a Ugandan based company, has combined digital micro-payments technology with IoT connectivity to make financial management more accessible. They used an advanced asset financing platform which they built themselves to invest $400 million in financing which allowed one million customers to gain access to high-quality energy-efficient appliances, solar lighting, smartphones and loans amongst others [20].

The World Bank and the UN rely significantly on research and data to keep track of the progress towards their goal of eliminating poverty [21]. The difficulty to collect data itself is considered to be a consequence of poverty as per the Decentralized AI Alliance (DAIA) [22]. As per DAIA, location plays an important role in the eradication of poverty. Traditional household surveys which help keep track of the number and location of poor people are expensive to many nations and are thus not regularly conducted [22]. One solution to this issue is the use of AI. Recently, a team at Standford University has conducted a study where they used powerful machine learning algorithms high-power satellite imaging analysis to detect poverty in Nigeria, Tanzania, Uganda, Malawi and Rwanda. The accuracy of the algorithm's predicted data was verified using accurate survey data [23]. Furthermore, AI can be used to obtain essential information such as the nearest water sources, agricultural fields and marketplaces in high poverty regions [22, 24].

2.2 SDG 2: Zero Hunger

The main aim of this SDG is to end hunger, enhance nutrition, establish food security, and encourage sustainable agriculture [25]. Mobile technology plays an important role for SDG 2 as it leads to better nutritional knowledge, improved agricultural practices, and household food security. Production of agricultural supplies is made more efficient by mobile devices, satellites, drones and other state-of-the-art solutions [15]. 5G is expected to improve yields and quality of crops through the precise monitoring of the weather and soil which will help to tailor the application of pesticides and fertilizers. The Internet of Vehicles (IoV) could enhance food distribution by determining the optimal routes and monitoring the temperature of the food being

transported. Additionally, the market and shop lives of crops can be increased by implementing the use of mobile refrigeration [26].

Intelligent Connectivity can help in the combat against hunger through the following measures [27]:

- *Yield boost from harvesting and storage*—The UN's Food and Agriculture Organization (FAO) indicated that up to 40% of food production may be lost before reaching the market, especially in developing countries. Proper cost-effective monitoring, which can be provided by IoT networks can be used to identify the optimal harvesting and storage methods for vulnerable crops.
- *Enhancement of the existing distribution network*—The World Bank estimated that in South and South-East Asia, during the storage and transport of food, around 90% of calories are wasted. The productivity and efficiency of food distribution networks can be improved through viable commercialized IoT and AI technologies which may provide monitoring facilities and provide real-time access to food distribution data.
- *Support for cost-effective real-time data tracking and tracing of the cold-chain infrastructure*—This allows food that needs to be preserved at cold temperatures to be monitored on a 24/7 basis and ensures that an alarm is generated in case that anomalies are detected by sensors and location trackers. This leads to reduced food wastage, improved food quality and safety of commonly contaminated food.
- *Waste minimization by improving food purchase habits in rich countries*—Tracking of food quantity and quality can be done by using smart refrigerators. These refrigerators have useful features such as intelligently recommending purchase orders, generating alerts if abnormalities are detected and suggesting the amount of food to be purchased based on usage patterns [27].

Additionally, AI can significantly boost agricultural techniques by enabling the use of self-driving farm equipment and efficient farm monitoring and management equipment. AI can also help in developing different genetically modified crops which are less vulnerable to diseases and pests. Researchers utilize sensors, drones and robots for collecting data which can help increase the production of heat and drought-resistant crops which are crucial in famine-stricken nations [22, 23].

2.3 SDG 3: Good Health and Wellbeing

SDG 3 aims at guaranteeing healthy lives and upholding the well-being of everyone [28].

Mobile health solutions allow affordable health care to be delivered at a high quality. Mortality rates due to childbirth and pregnancy can be reduced by making information more accessible and by getting people connected to healthcare. For example, in Cameroon where less than 60% of the women population receive proper health care, access to mobile apps and messaging solutions has improved the care given to pregnant women. The GiftedMom startup has designed an application [29]

that allows pregnant women and mothers to connect to health specialists and has provided support to more than half a million mothers since 2020. The startup has also collaborated with 45 hospitals in Cameroon and helped in the prevention of early deaths. Since December 2019, over 250,000 women have obtained critical health details through the startup. Many of these women were nursing mothers who earned less than $3 a day [30].

With high capacity 5G networks, people will have the ability to use connected wearables for monitoring their heart rates, temperature, stress levels, location and blood pressure. Any detected health anomalies may trigger emergency alerts to notify the wearer or even a rescue team. Such facilities may benefit health insurance programmes and give rise to predictive healthcare and personal security solutions. Clinicians can use machine learning-aided smart platforms to identify medical data patterns. They can then act earlier and advise patients to take preventive measures. Low latency 5G networks may become the enablers of telemedicine services such as teleconsultation and telesurgery. Telesurgery is still in its infancy due to network and robotic limitations even though the first telesurgical operation was carried out in 2001 [26].

Moreover, the COVID-19 pandemic has triggered a significant adoption of Intelligent Connectivity in dealing with the virus. For example, frontline staff are using AI-enabled thermal cameras to check the temperature of patients instead of using manually operated forehead thermometers. These cameras provide quicker and more accurate temperature measurements and help protect the frontline staff from contracting the virus. Furthermore, the use of intelligent chatbots, drones, robots and telemedicine equipment have become more common as they allow doctors to work remotely, keeping them safe from the risk of infections. One such example is a chatbot built by the Centers for Disease Control and Prevention (CDC) to attend to people who have COVID-19 symptoms and thus accelerate the detection of COVID-19 cases. For individuals with more serious symptoms, an online triage system was set up by the US to locate potential COVID-19 cases easier. Heath personnel at the National University Hospital in Singapore utilize a chat assistant app to stay in touch with dynamic information about the pandemic. In hospitals, the spread of the virus is predicted by using AI-based tracking with advanced graphical analytics to provide essential insights on the pandemic. This tool also allows authorities to understand if a local lockdown is required or if any actions can be taken to help stop the spread of the virus. Furthermore, hospitals may be notified of potential virus infections by AI applications that track the movement of mobile devices [31–36].

AI is largely contributing to the vaccine creation process, especially by identifying essential genome sequences, and is also speeding up the vaccine testing phase. In the UK, BenevolentAI helped to identify approved drugs that may be used to inhibit the spread of COVID-19. The company derived contextual relationships between drugs, diseases and genes using AI to come up with vaccines recommendations [31–36].

2.4 SDG 4: Quality Education

The aim of this SDG is to ensure that everyone obtains access to quality education and to encourage lifelong learning [37].

Mobile technology and mobile networks play an essential role in SDG 4. They provide education access to educators, scholars, and professionals irrespective of their location. Services such as educational management have become more accessible via mobile networks [15].

During the COVID-19 pandemic, technology has helped scholars to attend classes remotely via online education platforms according to a study by Mhlanga and Moloi [24]. In their study, it was also concluded that the shift from face-to-face teaching to online delivery increases access to education by eliminating space constraints [38]. Eneza Education is one such education project which incorporates AI to assist the tutoring of millions of students in rural areas such as Kenya, Ghana and Côte d'Ivoire. Such projects make education more encompassing, equal and foster lifelong learning prospects globally [22].

E-learning has proved to be crucial during crises like the COVID-19 pandemic. The pandemic has at some point deprived 90% of students of access to their schools [39].

There has been a significant rise in the usage of video conferencing and communication platforms such as WhatsApp, Skype and Microsoft Teams for e-learning purposes due to the outbreak of COVID-19. Teachers in some schools in Bhutan use online messaging platforms such as WhatsApp and WeChat to deliver homework to students who are expected to answer back with an image of their answers for assessment. In Bulgaria, 65,000 teachers were able to connect to 700,000 students to deliver videos and webinars with the help of an e-learning platform launched in March 2020. 90% of the students were able to obtain 6 h of distance learning per day via this platform [15, 40].

Furthermore, AI applied to Learning analytics may provide useful statistics on education and AI can also be used for teaching. The current Intelligent Tutoring Systems (ITS) have great potential in the education sector but also have some limitations which may eventually be overcome through technology progresses [41, 42]. Another application is in automated attendance systems. For example, in South Africa, IoT has interconnected the students to automate their attendance tracking using biometric features [3].

2.5 SDG 5: Gender Equality

The aim of this SDG is to achieve gender equality and empower all women and girls [43].

Gender equality can be improved by mobile technology in societal, financial and administrative spheres. In addition to women, mobile technology also benefits their

communities, businesses and the broader economy. Mobile allows women to have access to life-improving facilities such as financial, health and job related services [15]. One prime example of mobile technology which enhances women safety is the Salvatio Push. It is an IoT wearable device that allows women to notify their community about their location at a push of a button if they are in a life-threatening situation so that rescue can be received [44, 45].

The Indian government funded IoT-based solutions for ensuring women's safety on public transports in 2017. The Abhaya Passenger project is one of India's approaches to ensuring women's safety by equipping 100,000 rickshaws with IoT devices linked to the Abhaya Passenger app which is available for download to the public. Through these devices, the live GPS locations of the rickshaws are tracked and the relevant information about the auto driver which may be required in cases of emergency is provided to the passenger [46]. The drivers are provided with a Radio Frequency Identification (RFID) card which needs to be swiped in the vehicle to start the vehicle. Once a vehicle is started, the police or traffic control room is alerted so that proper tracking can be performed. The driver's details are made available by scanning a QR code attached to the vehicle, using the Abhaya Passenger app [47]. The integration of 5G and AI to this project could also further enhance the prospects of this project.

2.6 SDG 6: Clean Water and Sanitation

The purpose of this SDG is to guarantee that water and sanitation are made available to all and are sustainably managed [48].

Mobile technology provides reliable links for communication and payment between utilities or authorities and the clients, hence improving various aspects of water delivery and sanitation. It also provides remote and affordable billing solutions and the logistics for collecting and non-sewered sanitation services is greatly facilitated [15].

Financial losses made by water and sanitation providers can be reduced through mobile-enabled solutions such as digital payments and smart meters and hence allows the providers to upgrade their distribution network. One such example is the Safe Water Network which was able to significantly increase its per-liter payment collection rate in more than 90% of its stations by digitalizing processes [49]. The implementation of mobile money in Tanzania was able to increase payments to the water utility threefold while lowering waiting times for water collection from 3 h to 10 min [50]. SOIL, which is an ecological sanitation provider in Haiti was able to reduce its collection costs from $1.10 to $0.05 by implementing mobile payments [49].

IoT-based smart water infrastructure can provide leakage detection services, geographic information system (GIS) management facilities, and network optimization which can be useful in the context of improper water infrastructure and thus improve water supply and drainage plans. iWesla which is a smart water project developed in Spain allowed abnormal water consumption to be detected by using sensors

and an alerting system, saving up to 50% of water consumption. Early detection of such anomalies also helps avoid damage caused by leaks or open taps [51, 52].

2.7 SDG 7: Affordable and Clean Energy

The purpose of this SDG is to guarantee access to affordable, reliable, sustainable and modern energy for all. There are around 759 million people who do not have access to dependable and reasonably priced electricity supply services [53].

Advancements and breakthroughs in AI, blockchain, advanced materials for solar panels, and battery technology (specifically lithium-ion batteries [54]) make renewable energy mini-grids potentially the cheapest solution to provide electricity to 290 million people [55].

Wind farms have become a more important source of carbon-free electricity over the past decade since the cost of turbines has been reduced. However, they are an unreliable source of energy due to the variable nature of wind. To address this issue, DeepMind and Google used machine learning algorithms to predict the wind power output 36 h ahead by using historical turbine data and weather forecasts on a 700 megawatts wind power grid. This prediction can then be used to plan the optimal hourly delivery commitments to the power grid one day in advance. To date, the value of wind energy has been boosted by around 20% by machine learning compared to the scenario with no time-based commitments to the grid [56].

Mobile money was able to unlock a wide section of the solar off-grid customer base and provides services related to energy and appliances for consumers in the low-income category. Mobile-enabled solutions can reduce the cost of mini-grid connections and solar home systems and provide essential information to off-grid providers about consumer behaviors and thus improve service delivery. For instance, smart-meter driven mini-grid power generation and consumption provides a better overview of the grid and allows better decisions to be made about the dimensioning of the grid. The International Energy Agency estimates that mini-grids can eventually supply electricity to more than 450 million people (equivalent to 80% of people in Sub-Saharan Africa who still lack access to electricity) and can lead to $300 billion in investment by 2030 [57].

2.8 SDG 8: Decent Work and Economic Growth

The purpose of this SDG is to support sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all [58].

Due to the COVID-19 pandemic, digital transformation has become a priority for all sectors which need to maintain business operations amidst lockdowns and social distancing. The pandemic has brought ICT to the forefront as a critical enabler

of business continuity. Companies in sectors that had already adopted higher bandwidth broadband and cloud services can continue to operate properly even during lockdowns. Organizations in these sectors are also able to operate more effectively through AI and IoT solutions [31]. ITU conducted studies that showed that a 10% boost in mobile broadband penetration leads to a wider 1.5–2.5% increase in GDP. Upgrades from 2 to 3G and 4G mobile networks also have a positive impact on the economy [59]. Almost 5% of the global GDP was generated by mobile technologies and services in 2019, which is equivalent to $4.1 trillion of economic value added [60]. Furthermore, it is estimated that 5G technologies will contribute $2.2 trillion to the global economy between 2024 and 2034. 5G will initially be very beneficial to crucial sectors such as utilities and manufacturing (particularly in China) and financial and professional services (especially in MENA and North America) [15].

5G networks' capabilities will provide a major contribution in powering business resilience and recovery. The initial use cases of 5G which aim at providing broadband connectivity, support augmented and virtual reality services and enable high-quality media transmission might not look worthwhile in the era after COVID-19, but are essential for 5G's widespread deployment and will lead to new essential use cases. 5G use cases such as e-shopping and robot deliveries are expected to grow quickly. Japan already started using robot delivery services in 2019. 5G has enabled several novel robot delivery use cases to be introduced after COVID-19 in many countries. Additionally, governments are encouraging new supply models that limit the propagation of the virus and promote a highly partitioned workforce by providing incentives. During the pandemic, startups in Japan have developed robots for medical use and contactless deliveries. Nations that do not invest heavily in a 5G network will fall behind from the benefits of its revolutionary applications [31].

2.9 SDG 9: Industry Innovation and Infrastructure

The aim of this SDG is to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation [61].

A fourth industrial revolution is set to be driven by Intelligent Connectivity whereby computers and robots optimize the manufacturing and maintenance processes in flexible factories. The IoT, enhanced with AI and cloud computing, is one of the key enablers of Industry 4.0. In this context, 5G networks will use edge computing and network slicing with efficient spectrum utilization to provide ultra-reliable low latency communication (URLLC) which may be applied to logistics or remote control of Automated Guided Vehicles in production plants, factories or mines [26].

With real-time information capture and remote control of machinery, factory-wide connectivity will improve the factory's efficiency and allow manufacturers to provide more value to customers. Industry 4.0 will feature self-optimizing production facilities which can address events, such as technical issues, supply shortages and

new customer requirements. 3D printing of objects will be available on-demand to allow the repair of broken equipment [26].

IoT, AI, cloud computing, M2M, mobile broadband and big data analytics are essential elements of Industry 4.0, which improve production efficiency and sustainability [15, 59]. Services like object tagging and internet-to-object communication are also essential for real-time data capture, while cloud computing allows computing and storage power to be reduced for digitally enhanced production [62].

The two most significant methods 5G will contribute to SDG 9 are by [13]:

(1) Supporting faster and effective inspections through predictive intelligence:

One specific example is Bright Machines [63] which manages a cloud-based software for the planning, simulation and implementation of the setup and tutorials used to establish, reconfigure and run any quantity of physical production lines for assembly. This software is applied in a North American factory and the key benefits of this software over traditional ones are:

- Reduced parts per million (PPM) defect rates by 88%.
- Increased unit production per hour by 33%.
- Reduced assembly-line staff by 50%.

(2) Improving operational value:

A specific example is the Nokia factory in Oulu [64]. The Nokia factory managed machine and device telecommunications through Ethernet cables which added significant costs in rewiring work. Using Omron LD Autonomous Intelligent Vehicles, material flow is automated. Material is delivered from storage to the production line, without any human intervention. Dynamic consumer demands result in short product cycles which force production lines to be rearranged over short notices. With 5G's high throughput, low delay and large capacity, autonomous mobile devices may automatically deliver components to the exact location required based on communication with production line equipment.

2.9.1 SDG 10: Reduced Inequalities

The aim of this SDG is to reduce inequality within and among countries [65].

The ICT sector can help reduce inequality both between and within countries by providing access to information and knowledge to the less fortunate population—including women and girls or those who have disabilities [66].

For example, people with disabilities can more easily navigate in 5G covered regions. Blind people can be equipped with smart 5G connected devices which can provide accurate real-time audio feedback to help navigate independently [67].

With a high throughput network, people with disabilities can rely on data-driven solutions to become independent. Advances in technologies such as facial recognition will allow them to identify people, objects and important places in their surroundings. Deaf people and any person who needs to communicate using sign language

rely significantly on video chat apps to communicate but high latency networks are huge hurdles to them. 5G is expected to satisfy their crucial need for low latency communications [67].

Smart home services enabled by 5G networks are also helpful to people with disabilities who wish to live independently. They are given the possibility to use their smartphone to control their environment, such as to switch on appliances, adjust temperature or operate a door.

People with disabilities can also rely on wearable devices such as smartwatches to track and improve their health. Moreover, wearable GPS devices, allow people with intellectual disabilities to be located and tracked. The quality of life of disabled people will be enhanced with emerging technologies as follows [67]:

- They will be more informed and in communication with the world.
- They will have access to the same education as students without disabilities.
- It will have an opportunity to live and work independently.

Mobile operators use their technical know-how and infrastructure to increase impact at scale for forcibly displaced persons (FDPs) and their host communities. At the end of 2019, around 79.5 million people were forcibly displaced, among which 26 million were refugees. At least 93% of refugees around the world live in regions that have a 2G or 3G coverage [68] and connection to a mobile network can provide crucial support to these populations by providing them with the means to contact relatives and peers, access information platforms, translation applications and mobile money services [69]. Operators are also cooperating with humanitarian organizations to better understand people in need. For instance, Safaricom has partnered with the UN Refugee Agency (UNHCR) and the GSMA to research how people with disabilities use mobile devices for enhancing their lives [70].

2.9.2 SDG 11: Sustainable Cities and Communities

The aim of this SDG is to render cities and human habitats safe, sustainable, inclusive, and resilient [71].

Smart city is an area where technological advances will play a major role. It is estimated that around 66% of the world's population will settle in cities by 2050 according to the UN [72]. Countries are addressing socio-economic issues in sectors such as the energy, healthcare and security sectors by converting fast-expanding urban areas into smart cities.

Buildings and cities are already becoming smarter, more sustainable and safer with the help of mobile connectivity. 5G will accelerate such developments by its support for dense networks of sensors and actuators which will enable organizations, municipalities and individuals to monitor and control their property remotely using the appropriate platforms. Orange is planning to allow consumers to link their smart devices to its Livebox wireless router and also intends to launch a Protected Home service which aims at ensuring home security smartly via video surveillance, with the collaboration of Groupama [26].

AI can be combined with the highly reliable 5G networks to implement the real-time location, video and biometric data analysis. Furthermore, cloud-based facial recognition systems can be applied to high-resolution surveillance cameras to identify and locate law offenders in real-time [73].

Intelligent Connectivity is expected to help address transportation issues. For example, data collected from sensors and actuators on streetlights, highways, vehicles and parking areas will be delivered to a centralized transportation system on the cloud using Intelligent Connectivity. These data will then be processed to extract traffic insights which traffic controllers can use to advise drivers about the optimal and safest route to their destination. Cars could communicate with streetlights on the road they are driving so that only the segments of the road which the driver will require visibility are illuminated, hence saving energy. Technology convergence potentially helps reduce traffic congestion and even mortality rates by optimizing the transportation system [74]. Recently, Bosch conducted research that concluded that by 2025, connected vehicles will reduce traffic accident injury cases by 350,000 yearly and can save around 11,000 lives [75].

2.9.3 SDG 12: Responsible Production and Consumption

The purpose of this SDG is to guarantee sustainable consumption and production patterns [76].

The planet's resources such as fresh water, land, fossil fuels and other minerals are under increasing pressure due to the world's population explosion. According to the United Nations Development Programme (UNDP), lowering the ecological footprint is essential to achieve sustainable development [77]. Lowering the ecological footprint implies achieving sustainable consumption and manufacturing of resources by reducing the use of natural resources, toxic materials, and emissions of pollutants and waste, while satisfying basic consumption needs [78]. As agriculture is one of the most water-consuming economic activities globally, major changes will be required to achieve this SDG. Technology and newer IoT solutions in agriculture play a major role in improving the quantity and the quality of harvests. Since unpredictable weather conditions can affect crops and reduce yields, digital applications and infrastructure tools aid farmers to adjust their decisions on the optimal time to plant and the most suitable crop varieties to choose to achieve higher productivity. Furthermore, they predict the optimal amount of water and agrochemicals that are necessary, contributing to more sustainable agriculture [79]. They can also help monitor and analyze consumption patterns to raise awareness about the risk of unsustainable manufacturing and consumption of soil [52].

Moreover, smart vehicles connected to a 5G network could easily identify the optimal routes and allow food in transit to be remotely monitored, thus increasing the efficiency of food distribution. Furthermore, crops can be delivered with longer market and shop lives with the help of mobile refrigeration. Policymakers may rely on reliable wireless connectivity which will be available to everyone to sensitize people about green transportation options for routine purposes [26]. In 2019, around