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Future Landscape, Challenges, and The Role of the Internet of Things (IoT) in Empowering Sustainable Development Goals (SDGs) in Pakistan

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***Abstract*– The fast development and adoption of smart IoT (Internet of Things)-based technologies has created new opportunities for technological growth in many areas of life. The major purpose of IoT technologies is to simplify procedures in numerous industries, boost system efficiency, save time and money, and, eventually, improve quality of life. Today, digitization has a significant impact on the future of humanity, industries, and everything else around us. As a result, digital technologies have gained popular attention. This problem impacts even emerging countries like Pakistan. This article will look at how digital technologies, such as IoT, may assist poor nations meet their Sustainable Development Goals. This notion is explained with instances from Pakistan. As a developing country, Pakistan confronts various hurdles in its quest for technical advancement and sustainability. To fully capitalize on the potential of sophisticated technologies that are meant to bring about real sustainability, Pakistan would need to adopt operational strategies and solutions to cope with these difficulties while minimizing risks and maximizing benefits.**

***Index Terms*– IoT Future, Challenges, Digital Technologies, Sustainability, Sustainable Development Goals, Artificial Intelligence and Pakistan's Digital Transformation**

I. INTRODUCTION

THE Sustainable Development Goals (SDGs) are the 2030 agenda adopted by United Nations members in 2015. The Sustainable Development Summit created seventeen global objectives to address the social, economic, and environmental difficulties in attaining Global Sustainable Development. Developed countries quickly adopt digital technology, however poor countries such as Pakistan still have the potential for progress in this field. Pakistan was the first to embrace it; it is a plan for people, the earth, and prosperity. These 17 goals have 169 targets for balancing the three pillars of sustainable development: social, economic, and environmental. UN agencies in Pakistan have been working closely with the government in a range of subject areas, contributing to the document's outcomes and, ultimately, Pakistan's achievement of the SDGs.

The Sustainable Development Report 2023, commonly known as the SDG Index, ranks Pakistan 128th (Fig. 1) out of 166 nations in progress toward achieving the Sustainable Development Goals (SDGs). Pakistan's SDG Index score is 59.0, lower than the worldwide average of 69.2. The SDG Dashboard for Pakistan indicates uneven outcomes across all 17 SDGs. Goals such as "climate action" and "quality education" have made significant progress, whereas "zero hunger", "good health and well-being", "affordable and clean energy", "access to water and sanitation", "industry, innovation and infrastructure", and "sustainable cities and communities" have made less progress (Fig. 2).

Despite these problems, Pakistan presents itself as a highly appealing market. Of Pakistan's 228 million people, 100 million are under the age of 25, indicating a vast population of youthful brains. Now, digitization is the major driver that may help Pakistan achieve its SDGs. Pakistan has a huge chance to accomplish its SDGs through the use of artificial intelligence (AI) and the Internet of Things.

In the age of digital technology, IoT is described as "things that are connected to the internet." The Internet of Things seeks to enable any connected item to identify, detect, network, and process other things across a network to achieve certain objectives. New business models for IoT deployment demand high connection, privacy, security, coverage, reliability, and low latency. Digitalization has a significant impact on numerous businesses and individuals, acting as a vital driver for developing technologies such as Big Data, Robotics, the Internet of Things (IoT), and others.

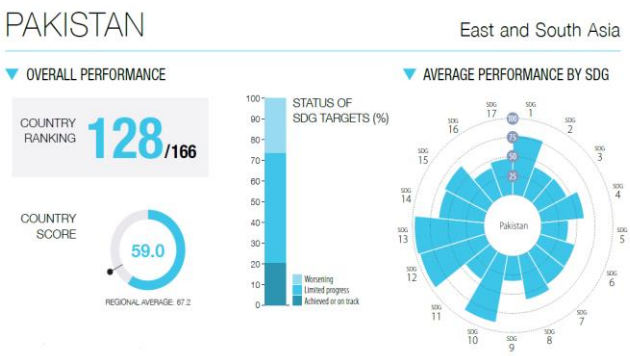

Fig 1. Pakistan SDGs Performance Report 2023 [source: sdgpakistan.org]

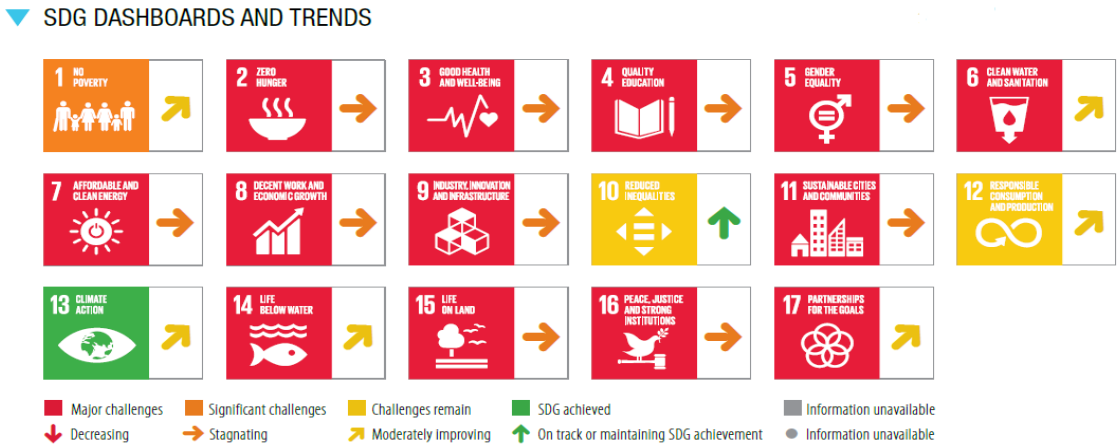

Fig. 2. SDG Dashboard [source: sdgpakistan.org]

According to an IoTAnalytics.com report, there will be 16.7 billion IoT-connected devices worldwide in 2023, 16% up from the previous year. This is why the IPv4 system, which uses 32-bit addresses, restricts the amount of unique identities (it can only support 4 billion). In contrast to IPv4, IPv6 addresses are 128-bit. It also has auto-configuration, security, and a number of mobility options. IPv6 is the next-generation network layer protocol. IPv6 supports all IoT standards (CoAP, MQTT, 6LoWPAN, and RPL) and includes IPSec, which is a set of security protocols for encryption, authentication, and integrity.

In Pakistan, sustainability has arisen as a significant problem, with the dynamic growth of IoT offering different benefits; nevertheless, this quick development must be monitored and analyzed to avoid negative environmental effects and guarantee wise resource usage. Every day, criminals and intruders target Internet of Things devices. According to one survey, 70% of IoT devices are extremely vulnerable to assault. As a result, an effective technique is needed to safeguard internet-connected devices from hackers and intruders.

According to Statista, the IoT industry in Pakistan is expected to produce $7 billion to $16 billion in yearly revenue between 2024 and 2028. Currently, 40+ startups are available in Pakistan that provide IoT-based services both domestically and globally. In January 2023, the PTA directed that all telecommunications providers use the IPv6 protocol to deliver internet services. The PTA made this decision to develop the IoT business in Pakistan.

Future IoT goals include smart living, smart objects, smart health, smart cars and transportation, low-carbon products, smart supply chains, smart cities, smart energy consumption monitoring systems, and smart asset tracking systems (Ring Fencing), among others. In the future, the Internet of Things will drastically change our lifestyles and economic methods. In ideal conditions, people and devices will be able to communicate at any time, from any location, with any device, and over any network or service. The primary purpose of IoT is to improve the planet for future generations.

Despite these limitations, the IoT industry in Pakistan is expected to develop significantly, with estimates indicating considerable revenue creation and the rise of multiple startups providing IoT-based services. The major purpose of this essay is to look at how digital technologies such as IoT might assist poor nations like Pakistan accomplish their Sustainable Development Goals. The Table I lists some of the goals on which we will focus in this study report.

This article examines how digital technology, namely IoT, contributes to Pakistan's Sustainable Development Goals.

- This article analyzes recent technological issues in the IoT.
- The study also addresses future social concerns.

Table I: SDGs Group by IoT Sectors

No.	Goals	IoT Sector
1	SDG-2: Zero Hunger	Agriculture and Farming
2	SDG-3: Good Health and Well-being. SDG-6: Clean Water and Sanitation.	Health, Water, Sanitation, and Livelihoods Education.
3	SDG-7: Affordable and Clean Energy. SDG-9: Industry, Innovation, and Infrastructure.	Efficient use of energy resources, and 4th Industrial Revolution.
4	SDG-11: Sustainable Cities and Communities.	Smart City

II. RELATED WORK

Some current IoT and SDG-related work by various individuals. The major SDGs research is conducted globally; however, we have located two to three research publications in Pakistan on irrigation, digitalization, and smart cities. Following investigation, we discovered that the key issue is the economy and infrastructure for smart solutions. Out of 18 references, 11 are research papers and the remaining 7 are articles from various websites.

Table II: Related Research Papers

No.	Year	Title	Author	reference	Proposed work	Limitations	Technology	SDG
1	2024	IoT, Applications & Challenges: A Comprehensive, Review	Abhishek Khanna., Samreet Kaur	[1]	Presenting its views on how IoT implementation in the world can increase the quality of life and quality of services.	Generic IoT Challenges	IoT	Nill
2	2023	FoodTech startups: Technological solutions to achieve SDGs	Iramaia Angelica Neri Numa	[19]	Adopting new technologies to revolutionize the food sector for SDG-2	Limited to SDG-2 (No Hunger) Not discussing about its effect on health issues (SDG-3)	IoT, Blockchain, Big Data	SGD-2 (No Hunger)
3	2023	The Role of Digital Technologies in Facilitating Sustainability in Developing Countries: A Case of Pakistan	Shazia Nadir Ali, and Dr. Rao Aamir Khan	[3]	Proposing a work of digitalization in Pakistan and how it can help Pakistan in achieving SDGs, and a better economy.	How do digital technologies (digitalization) affect SDGs in Pakistan? Not specific to IoT. Mostly about AR, VR, ML, AI, quantum computing	Artificial Intelligence and Machine Learning	All SDGs
4	2023	Smart cities and sustainable development goals (SDGs): A systematic literature review of co-benefits & tradeoffs	Ayoob Sharifi	[17]	Focusing on the relationship between Smart cities and SDGs, and how to implement smart city solutions to achieve SDGs	Limited to smart city (positive and negative impact on SDGs)	IoT and Wireless Technology	All SDGs
5	2022	An overview of smart irrigation systems using IoT	Muhammad Ramadan	[16]	Proposing a smart irrigation system with IoT to achieve SDG-6	Limited to SDG-6. Environmental impact of irrigation system in general	AI, IoT, LoRa, and MQTT	SDG-6
6	2021	Impact of Internet of Things (IoT) as Persuasive Technology	Shagufta Faryad., Hira Batool., Muhammad Asif., Affan Yasin	[5]	They have discussed how IoT helps people and things to communicate and, to analyze which factors influence the acceptance and rejection of particular behaviors and the core motivators that persuade people to do something or to avoid something.	Specific to IoT and its connectivity	IoT	Nill
7	2020	Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends and Prospects for Emerging 5G-IoT	Kinza Shafique., Bilal A. Khawaja	[2]	Proposing how 5G technology and its standards can enhance the implementation and sustainability of IoT and QoS.	IoT-Based Smart Applications. Impact of 5G technology on IoT	5G, IoT, HetNets, QoS	Nill
8	2020	Challenges and Opportunities of the Internet of Things for Global Development to Achieve the United Nations Sustainable Development Goals	Ascensión López Vargas	[15]	They are proposing a low-cost solution for IoT4D to achieve SDGs globally. Also, discussed some global issues of IoT implementation.	Not specific to any country. Potential and challenges of IoT in achieving SDGs. low-cost IoT systems	IoT4D	All
9	2020	Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future	Sandro Ni_zeti_c	[14]	It highlights the different fields of life and how IoT can help improve the quality of life globally (especially in the environmental and health sectors). Plus, digitalization affects different economic sectors	Only discussed 7 SDGs. Focus on global activity. Mostly focus on the energy sector (efficient use of energy resources)	IoT, 4IR (4th Industrial Revolution)	SGD-2, 3, 5, and 6
10	2017	A comparative study of LPWAN technologies for large-scale IoT deployment	Kais Mekki	[18]	About LPWAN IoT technology	Limited to LPWAN	LPWAN, and IoT	Nill

Table III: SDGs Progress Comparison

SDG Goal	Description	Progress in Pakistan	Progress in other countries
2	Zero Hunger	Pakistan confronts food security difficulties, with over 18% of its people undernourished.	Several countries have made progress in eliminating hunger, with the global incidence of malnutrition falling from 14.7% in 2000 to 8.9% by 2020.
3	Good Health and Well-being	Due to access and infrastructural problems, Pakistan's healthcare system suffers from high rates of infant and maternal death (55.7 per 1,000 live births) and maternal mortality (276 per 100,000 live births).	Global life expectancy increased from 66.8 years in 2000 to 72.6 years in 2019, indicating that other nations have made considerable strides in improving healthcare outcomes and access.
6	Clean Water and Sanitation	Only 30% of Pakistan's population has access to well-run sanitary facilities, while about 21% people has the lack of access to clean water resources.	The fact that 4.2 billion people worldwide lack access to securely managed sanitation services and 2.2 billion people lack access to safely managed drinking water highlights the continued difficulties in attaining universal access to clean water and sanitation.
7	Affordable and Clean Energy	By 2030, Pakistan wants to generate 30% of its power from renewable sources; however, at the moment, fossil fuels make up the majority of the country's energy mix, with renewables making up just 4%.	Over 26% of the world's power generated in 2018 came from renewable sources, marking a more than twofold increase in the capacity of renewable energy worldwide since 2010.
9	Industry, Innovation, and Infrastructure	Pakistan wants to boost GDP growth to 6.5% by 2025, with investments in innovation and infrastructure development to help achieve this goal.	While advanced economies are spending money on research and infrastructure, which propels technological breakthroughs and economic expansion, access to these resources is still uneven around the world.
11	Sustainable Cities and Communities	By 2030, it is expected that 50% of Pakistan's population will live in cities, creating difficulties for infrastructure development, sustainable urban planning, and access to essential services.	Numerous nations are allocating resources towards sustainable urban development, with programs emphasizing the enhancement of green spaces, public transit, air pollution reduction, cheap housing, and essential services accessibility in metropolitan areas

Table IV: IoT Connection in Pakistan

IOT CONNECTIONS\YEARS	2018	2019	2020	2021	2022	2023	2024
SMART FINANCING	139.5	45.66	61.88	64.51	64.13	68.95	73.42
SMART CITIES	523.9	205.8	336.9	391.6	431.1	511.9	597.9
OTHERS	12.72	4.16	6.27	7.62	8.7	10.43	12.37
INDUSTRIAL	1,452.00	510.8	754.3	863	915.9	1,034.00	1,185.00
OTHERS	73.07	26.19	43.84	55.05	64.02	79.03	94.17
CONSUMER	3,458.00	1,218.00	1,799.00	2,052.00	2,190.00	2,473.00	2,811.00
AUTOMOTIVE	210.1	89.48	155.9	200.4	236	289.7	343.5
HEALTH CARE	73.07	26.19	43.84	55.05	64.02	79.03	94.17

Table V: IoT Projects to Achieve SDGs

SDGs	which area IoT can Improve?	How (Proposed Projects)
SDG 7 (Affordable and Clean Energy)	energy efficiency and reduce energy consumption	Smart Energy Management System by NUST is an IoT-based system
SDG 9 (Industry, Innovation, and Infrastructure)	industrial processes, promote innovation, and enhance infrastructure development	Smart Manufacturing by the Pakistan Institute of Engineering and Applied Sciences (PIEAS) is an IoT-based project
SDG 11 (Sustainable Cities and Communities)	urban planning, transportation, and waste management	Smart City Solutions by the Lahore University of Management Sciences (LUMS) is an IoT-based project
SDG 13 (Climate Action)	monitor and reduce greenhouse gas emissions	Smart Agriculture by the University of Agriculture, Faisalabad (UAF) is an IoT-based project
SDG 15 (Life on Land)	monitor and protect biodiversity	Smart Forest Monitoring by the Pakistan Forest Institute (PFI) is an IoT-based project
SDG 6 (Clean Water and Sanitation)	monitor water quality and ensure that clean water is available	The Smart Water Management project by the Pakistan Council of Research in Water Resources (PCRWR) is using IoT to monitor water quality and ensure that clean water is available to all. The "Smart Waste Management" project by the Sindh Solid Waste Management Board (SSWMB) is using IoT to optimize waste collection and reduce waste.
SDG 3 (Good Health and Well-being)	healthcare services in remote areas	"Sehat Kahani" project uses IoT to connect patients with doctors

III. DIGITAL TRANSFORMATION IN PAKISTAN

Digital technologies are projected to cause transformational changes over the planet. Even in a developing country like Pakistan, the technical environment has changed dramatically as the country seeks to establish itself in global markets. The Internet of Things (IoT) is an important idea in the realm of digitalization. Artificial intelligence (AI) is important to realizing the full promise of the Internet of Things (IoT), enabling real-time data analysis and decision-making. AI-powered insights enable IoT devices to adapt and improve operations autonomously, enhancing efficiency and efficacy in a wide range of sectors, including smart cities and industrial automation AI integration inside the Internet of Things. IoT enhances data interpretation, predictive analytics, and autonomous decision-making, accelerating disruptive possibilities in industries such as smart cities, healthcare, and manufacturing, among others. As Pakistan's digital progress continues, its importance grows by the day. The worldwide artificial intelligence industry is anticipated to approach $125 billion by 2025.

Table VI: Different Reports

Source	*Report*	*Year*
Statista.com	Pakistan's IoT industry is predicted to produce $7.41 billion by 2024. IoT is predicted to dominate the industry, with a market volume of $3.00 billion the same year.	2023
CAGR	Moving forward, revenue is predicted to expand at a 22.12% annual rate with a market volume of $3.00 billion the same year. with a market volume of US$16.48 billion by 2028.	2024-2028
Data Reportal	Pakistan had 111 million internet users at the start of 2024, with an internet penetration of 45.7%.	2024
Ookla's	research shows that the median mobile internet connection speed over cellular networks is 16.67 Mbps. The median fixed internet connection speed is 13.06 Mbps.	2024

Pakistan's usage of IoT is increasing as the government promotes smart city programs to improve infrastructure and citizen services.

Role of IoT in facilitating SDG's

IoT can assist with practically all of the 17 goals, but here are a couple that will have a substantial impact:

- *Zero Hunger (SDG-2)*

According to research by, World Food Program (WFP) worldwide hunger has increased since 2014. In 2020, an estimated 768 million people were chronically hungry, and this figure is predicted to climb to 828 million by 2022. However, Pakistan provided a strong impetus to attain this milestone. Pakistan's progress toward zero hunger undernourishment fell by 4.2%, from 20.2% in 2015 to 16% in 2019. Pakistan's objective is to quadruple agricultural productivity by the end of 2030 and establish a sustainable food production system (SDGs Brochure 2023) to eradicate hunger at its source. According to the research from sdgindex.org, Pakistan is in the red zone (major issues remain), as seen in Fig. 3.

Future Infrastructure:

Smart farming enables farmers to boost production, minimize food waste, and enhance food storage and distribution while boosting output. Sensors can monitor weather, soil, and crop conditions in real time. Monitoring alone may help save billions of gallons of water and gigawatts of power by reducing waste and enhancing agricultural production.

Table VII: IoT Projects

Project/ Source	*Country*	*Purpose*
Agrisource DATA	Africa	Africa-based start-up that utilizes IoT and AI for agricultural analytics, claims to have saved 772 million liters of water over the previous six years while increasing average production by about 9%.
Digital Dera	Pakistan	Agri-Tech start-up by Agriculture Republic introducing low-cost and affordable technologies in Pakistan.
Taza-Tech	Pakistan	Building digital products like agricultural value chains, empowering formers, suppliers, and retailers.

Monitoring the environment for proper temperature and humidity levels may considerably decrease waste during storage and transit. Real-time information enables remedial action, resulting in less food waste. Another use for IoT is livestock monitoring. Cowlar.com is an IoT start-up that helps farmers monitor the health of their animals and limit disease transmission.

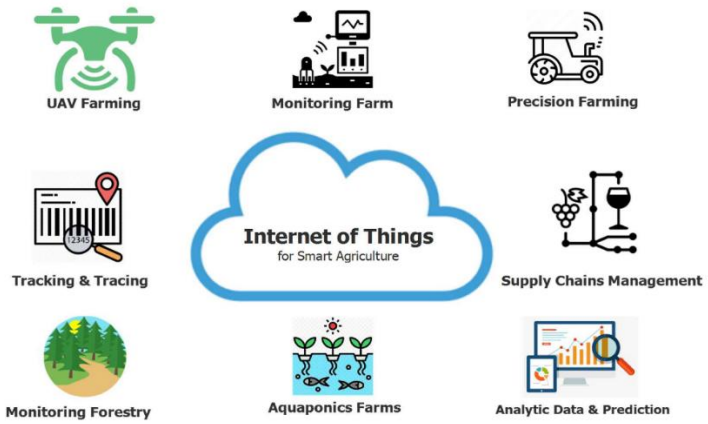

Fig. 3. Smart Agriculture [Source: vitality.io]

- *Good health and well-being (SGD-3)*

The world's population is aging, and the elderly's well-being is a worry. According to the World Bank, about ten percent of the world's population is over 65. In many wealthy nations, it is already at 20%. In such cases, care must be transferred from hospitals to homes. This is where linked health with IoT may help you get great treatment from the comfort of your own home. IoT gadgets, such as motion sensors, fall detection, and

panic buttons, enable caretakers to remotely monitor the elderly. IoT-based healthcare may enhance services by collecting massive volumes of patient data (big data) to make proactive and predictive choices, as well as provide future insights.

Table VIII: SDG-3 Progress

Area of progress	*Progress*	*Report year*
Number of Moms Died	32.6% reduced	2007-2019
Professional Health Staff	10% increased	2013-2018
Vaccination	11.5% increased	2013-2018
Drinking Water	51% improved	2022
Hygiene	85% improved	2022
Sanitation	Low efficiency	2022
Waste Water	38% increased	2022
Water Quality	-	-
Ecosystem	33% growth	2016

The SDGs 2021 annual report lists Pakistan's issues as having insufficient funding, unavailable data, inadequate stakeholder participation, etc. One of the strategies they are attempting to put into practice for future advancement in the next years is the supply of new machinery and enhancements to the current IT infrastructure.

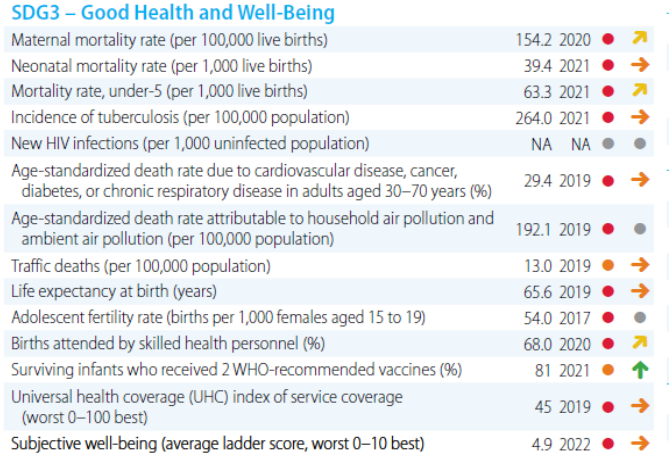

Fig 5. SDG-3 Report [source: Pakistan SDGs Performance Report 2023]

Future Infrastructure:

IoT can assist in the prompt availability of data to health department authorities so they can take appropriate action to accomplish its goals (in health to lessen the elements listed in the above graphic). Hospitals are implementing IP cameras, wearable health monitoring devices (smart watches), and other ambient sensors to obtain the most recent data. People are encouraged to maintain their health via wearables, especially smartwatches. In the 13 weeks after buying a smartwatch, people's step counts rise by an average of 2,000, per study.

One of the main health concerns is air pollution. To respond appropriately and quickly air quality must be measured at the hyper-local scale. Hyper-local pollution data may be collected by mounting Internet of Things (IoT) sensors for Air Quality Monitoring on cars. Another method to get data without spending money on hundreds of sensors in permanent places is to install Internet of Things air quality sensors in vehicles equipped with GPS systems.

A UK-based business called Manxtechgroup.com (MTG) tested mobile hyper-local air quality monitoring devices on the Isle of Man, providing economical, precise readings. Pakistan's healthcare IoT market is expected to reach US $369 million by 2024, according to satista.com, as the major hospitals and clinics are now integrating wearables and smart devices to enhance patient monitoring and healthcare delivery.

Pakistan is developing an agenda titled "Leaves no one behind" in preparation for the future implementation of SDG-3. SDG3 is the whole system used in Pakistan. Pakistan has been keeping an eye on how each system is doing, in reaching the SGD-3 targets, but they haven't yet used any IoT technology because the data for the majority of the years is lacking. SDG3 may be achieved more quickly due to the use of IoT in healthcare, which enables remote monitoring, personal healthcare, medical device integration, and even disease therapies [15].

- *Clean water and Sanitation (SDG-6)*

UNICEF and WHO estimate that 1.2 million people die annually from drinking contaminated water and that one in three people globally lack access to clean drinking water. Pakistan has seen improvements in both national and provincial access to sanitation and clean water (SDG-6). In Baluchistan, the availability of better drinking water grew by 17% between 2015 and 2020.

Table IX: Improved Drinking Water Usage Index (2000-2022)

Safely managed drinking water	*Improved drinking water*
34-50%	90-94%

Table X: Sanitary condition [source: sdg6data.org]

Services	*National*	*Urban*	*Rural*
Safely managed service	-	-	40%
Basic service	70%	85%	25%
limited	10%	12.5%	12.5%
unimproved	15%	12.5%	12.5%
Open defection	5%	-	10%

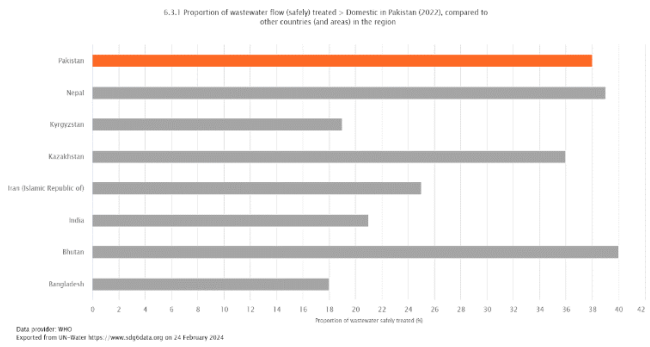

Fig. 10. Water quality and waste flow [source: sdg6data.org]

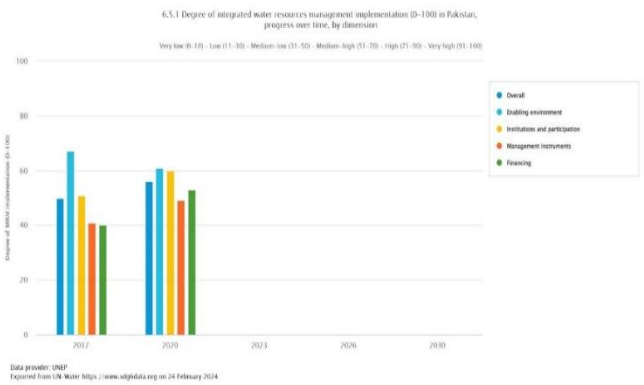

Fig. 11. Water Resource Management [source: sdg6data.org]

Data on water resource management from 2021 to 2023 are missing, even though this index is crucial for regulating the flow of water throughout Pakistan's many areas.
By cutting down on water waste, keeping an eye on water quality, and supplying flowing water through creative solutions, IoT may make a substantial contribution to the clean water objective.

Table XI: Water Projects

Project	*Country*	*Purpose*
eWATER	Sub-Saharan Africa	eWATER is a water operator that makes use of mobile money, the Internet of Things (IoT), and Near Field Communication (NFC) technology to manage the 24/7 provision of affordable, clean water.
NB-IoT	UK	Vodafone UK and SES Water have worked together to create an NB-IoT-based technology that will help save water that leaks.

The project's short-term objective is to reduce leakage, which accounts for around 23% of the water that runs via subterranean pipes, by 15% in five years and more than half by 2045 [11].

Future Infrastructure:

By the end of 2030, IoT-powered smart sanitation solutions hope to increase waste collection and management efficiency in Pakistan's efforts to improve water quality, encourage local participation in water and sanitation management, restore and protect the water-related ecosystem, etc. through smart irrigation systems [16]. An Internet of Things (IoT)-based cost-effective system for real-time water quality monitoring has been the subject of experimental research. The general goal of the experiment was to build and test online data transfer, online data monitoring, and recording for analysis [12].

The Smart Water Quality Management (SWQM) system is being developed by the Pakistan Council of Research in Water Resources (PCWR). It is an efficient and economical design that uses Internet of Things technology to monitor the quality of drinking water. Such initiatives can readily accomplish their objectives if the government assists.

- *Affordable and clean energy (SDG-7)*

Worldwide pollution levels are increasing, with energy being a key contributor to pollution. There are initiatives in place to provide inexpensive, sustainable energy. Pakistan has shown its commitment to the environment by increasing its share of renewable energy (SDG-7) by more than four times between 2015 and 2019. Between 2014 and 2015, 47% of Americans relied on clean fuel for cooking, a rise from 41.3 %.

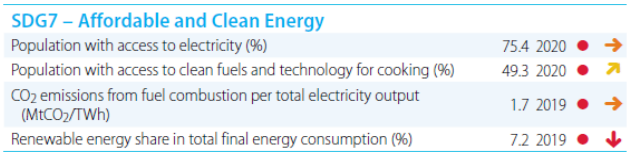

Fig. 13. SDG-7 Report [source: Pakistan SDGs Performance Report 2023

Concerns have been raised by some regarding the dependability of renewable energy. IoT, AI, and ML technologies together save operating costs and increase dependability. Renewable energy has helped smart networks because it increases the dependability of the energy supply by mixing traditional and renewable energy sources.

Future Infrastructure:

Field equipment maintenance, like that of wind turbines, is expensive and time-consuming. IoT devices gather data and transmit it to the cloud, where artificial intelligence (AI) algorithms match previous data with real-time sensor readings to assess if the equipment is operational. To ascertain whether repairs are necessary, field technicians and power plant staff can remotely view the data. Reducing operating expenses may be achieved by switching to prescriptive maintenance. Edge IoT devices are another type of advanced IoT system. These devices are capable of processing sensor data and controlling machinery without the need for human interaction.

Table XII: Energy Projects

Project	Country	Purpose
Smart Energy Management System	Pakistan	study in January 2023, they suggested developing an Arduino module, GSM, and current sensor smart energy meter project.
Solar Power Monitoring system	Pakistan	The University of Faisalabad has also suggested an Internet of Things-based solar power monitoring system.
AIoT-EE&C	Pakistan	A project called AIoT-EE&C (Artificial Intelligence & IoT for Energy Efficiency and Conservation) in buildings was suggested by the National Energy Efficiency and Conservation Authority. This will help them choose which technologies are most suited for the unique demands of each building
Isles of Scilly (UK) and Hitachi worked together in 2015 to cut the island's dependency on fossil fuels	Isles of Scilly (UK)	To achieve the objectives, the island council implemented Hitachi's IoT platform to distribute renewable energy and track carbon emissions as well as placed 400 kW of solar panels on residential and administrative buildings. 77% of homes in Europe will have smart electric meters by 2024 and reduce cost by 40%.

In addition to balancing load and offering users features like precise billing, peak time, and actual consumption, the smart

meters will enable planners to leverage real-time data and analytics.

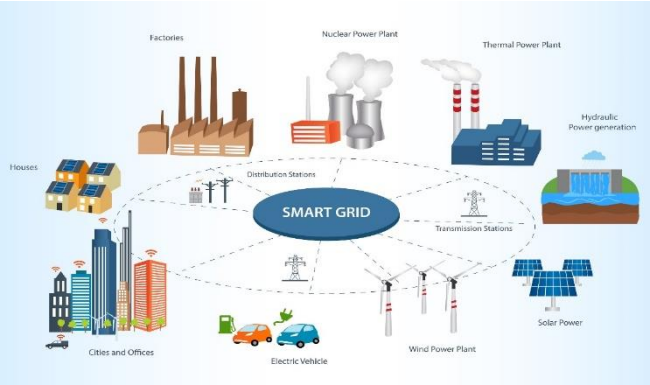

Fig.15. Smart Grid System

- *Industry, innovation and infrastructure (SDG-9)*

Among the main objectives for 2030 are the development of resilient and sustainable industry and infrastructure as well as the encouragement of innovation. In terms of the SDG-9 aims (industry, innovation, and infrastructure), Pakistan achieved some progress.

The share of small-scale industries in total industrial value-added rose to 10.5% in 2019–2020 from 8.4% in 2014–2015, notwithstanding the overall negative consequences of COVID-19. It comes as no surprise that infrastructure or industry are involved in 35–40% of IoT initiatives at the moment. IoT may support this objective in a variety of ways.

For the past six years, Edraak Systems has been utilizing cutting-edge technology to empower industry in order to achieve SDG objective 9. Thus, they are methodically transforming the business from an analog to a smart industry by utilizing cutting-edge technology for customized IoT and AI solutions. 4.0.

SDG9 – Industry, Innovation and Infrastructure	Value	Year	Rating	Trend
Rural population with access to all-season roads (%)	68.0	2022	●	●
Population using the internet (%)	21.0	2021	●	→
Mobile broadband subscriptions (per 100 population)	46.5	2021	●	↑
Logistics Performance Index: Quality of trade and transport-related infrastructure (worst 1–5 best)	2.2	2018	●	↓
The Times Higher Education Universities Ranking: Average score of top 3 universities (worst 0–100 best)	36.5	2022	●	●
Articles published in academic journals (per 1,000 population)	0.2	2021	●	→
Expenditure on research and development (% of GDP)	0.2	2019	●	↓

Fig. 16. SDG-9 Report [source: Pakistan SDGs Performance Report 2023]

Connected data-gathering systems are offered by US-based startup Arch Systems, which is focused on Industry 4.0. Real-time factory data is collected by the systems using sensors, which provide comprehensive metrics for manufacturing optimization. Predictive maintenance is made possible by the systems, which also take actionable insights from this data. This increases uptime by allowing manufacturers to switch from preventative to predictive maintenance.

Future Infrastructure:

IoT has the potential to provide a number of intriguing services for the automobile sector, including better navigation, collision prevention, preventative maintenance, and variable degrees of vehicle autonomy.

Connected activities in factories may save expenses, increase productivity, and use less energy. Pakistan ought to have shifted toward industry 4.0—the incorporation of intelligent agent technology into industrial processes—in order to accomplish target 9. Pakistan must adopt the newest technologies at the industrial level as the globe moves toward the Fourth Industrial Revolution (IoT, AI, ML, IA, etc.). Both the economy and manufacturing costs will grow as a result.

The continuous automation of conventional manufacturing and industrial processes via the use of cutting-edge smart technologies like artificial intelligence, machine learning, and the Internet of Things (IoT) is driving the fourth industrial revolution. This revolution also contributes to a reduction in the rate of CO2 emissions.

Fig 18. Industrial IoT Stats [source: statista.com]

- *Sustainable cities and communities (SDG-11)*

The globe is getting increasingly urbanized. By 2030, more than 60% of people on Earth are predicted to reside in cities. In developing nations like China, Indonesia, and India, there is a rapid urbanization trend. Seventy percent of the carbon emissions come from cities. In order to combat the threat posed by climate change, sustainable cities are essential. IoT helps create sustainable cities by matching infrastructure and services to the demands of the populace.

Pakistan made minimal headway; according to SDG 11 on sustainable cities and communities, the percentage of urban residents living in slums, informal settlements, or subpar housing fell from 45% in 2014 to 38% in 2018. Twenty miles north of Atlanta is a city that exemplifies sustainability: Peachtree Corners. The city is equipped with cameras, sensors, linked roadways, smart buildings, and other intelligent equipment. On the roadways around Peachtree Corners, Bosch is testing machine learning-enabled intelligent video analytics, teleoperated scooters, driverless cars, and autonomous package delivery. Singapore has elevated the idea of a smart city to a new plane. The world's first comprehensive national digital twin was just finished in Singapore. With the use of Bentley Systems' technologies, the nation's reality mesh, building, and transportation models were created more quickly from unprocessed GIS, LiDAR, and imaging data.

Future Infrastructure:

It is possible to incorporate IoT and other digital transformation technologies into the infrastructure of entire cities. In addition to saving time and gasoline, intelligent traffic lights can adjust to changing traffic circumstances. When connected smart bins get full, they may notify the appropriate authorities, enabling garbage collection to change from following a set schedule to occurring on a need-based schedule. Networks of security cameras can contribute to city safety. Cutting back on the use of fossil fuels is another essential step in creating a cleaner, more sustainable world.

The installation of networked charging stations has been spearheaded by Europe, which has expedited the uptake of electric vehicles.

Challenges of IoT in facilitating SDGs

Several obstacles prevent Pakistan from effectively utilizing IoT to support the Sustainable Development Goals (SDGs). Among these difficulties are:

Table XIII: Major Challenges in Pakistan

Major Challenges in Pakistan	Description
Lack of Research	Without extensive research projects, people would not be as aware of the unique potential and difficulties that come with incorporating IoT into different industries, such as urban development, healthcare, and agriculture, to fulfill SDGs. Research is essential and helps to guarantee the effective implementation and expandability of IoT solutions that support Pakistan's SDGs.
Literacy Rate	Pakistan has a 62.3% literacy rate; nonetheless, the majority of its graduates prefer to pursue other fields. The agriculture industry accounts for 23% of the country's GDP. The majority of farmers lack formal education, and the adoption of IoT in agriculture is moving extremely slowly
Cost-Effective Solutions	The cost of implementation may not always fit within a former's budgetary limits, and the first investment for a person to develop IoT initiatives in the agriculture sector becomes problematic. Its security and sustainability become problematic, as they do for any system that uses a network and gathers data from several sources. The cost of deploying IoT technologies may be unaffordable. Large-scale adoption of IoT technologies and devices is difficult, especially in environments with limited resources
Connectivity	There is a lack of standards for implementing IoT protocols but In Feb. 2022 PTA announced to provide Framework (LWPAN) for SRD and IoT services. Lack of skilled professionals to implement such technology in the health sector. Overall, most of the health sector in Pakistan is based on manual systems (paperwork) it's a challenge to move towards digital systems, it takes a lot of time. Due to this manual system, there is a gap in communication between different departments of the health sector.
Lack of Financial System	The overall SDGs goals project is delayed due to one of the key factors "Funds". Access to basic banking services is limited in developing countries.
Security and Privacy	IoT devices gather and send enormous volumes of data, and privacy and security issues are brought up. Ensuring the privacy and security of data created by IoT devices is a major concern in Pakistan, where data protection laws and regulations may be deficient or insufficiently implemented.
Energy Problems	Pakistan has a major energy problem and consistent connectivity is difficult.
Environmental Problems	There is worry about how the Internet of Things devices may affect the environment through energy consumption and the production of e-waste. The growth of IoT devices without sufficient steps to limit their environmental impact might worsen current issues in Pakistan, where environmental sustainability is already a significant concern.
Regulation and Policies	In the adoption of IoT technologies, lack of defined regulatory frameworks and regulations controlling their deployment and usage. To fully utilize IoT in achieving SDGs, Pakistan must implement strict laws and policies that address concerns such as data privacy, cybersecurity, and environmental sustainability.
IT Infrastructure	One of Pakistan's biggest problems is the absence of suitable infrastructure, which includes dependable internet access and a consistent supply of energy in many areas. IoT device deployment and operation become challenging in the absence of strong infrastructure, which reduces the devices' ability to effectively serve the SDGs.

To effectively deploy and utilize IoT in Pakistan to facilitate the Sustainable Development Goals, it will be necessary for government agencies, private sector stakeholders, civil society organizations, and international partners to work together to address these challenges.

IV. CONCLUSION

Thus, progress and sustainability can coexist. When used with the proper intention, technology can assist us in achieving the Sustainable Development Goals for 2030. With no doubt one of the key drivers of digital transformation, IoT has the potential to completely redefine sustainability. The World Economic Forum (WEF) released a set of recommendations in 2018 about the Internet of Things' role in guaranteeing a sustainable future in an effort to increase corporate understanding of this. For the sake of our future, we genuinely hope that the world will surpass its sustainability targets.

The quantity of networks that have been created or installed worldwide has kept increasing. In 62 countries, 128 operators have been listed by GSA as having released or implemented at least one LTE-M or NB-IoT technology as of 2020. In recent years, Pakistan has begun to implement its NB-IoT. In November 2019, Telenor published its first NB-IoT website. In 2020, Zong 4G successfully concluded an NB-IoT network experiment. By enhancing the functionality and efficiency of the industrial and civic infrastructures, NB-IoT will open the door for the growth of Pakistan's digital ecosystem. NB-IoT is poised to revolutionize local industries with its capacity to provide high-penetration, low-power, low-cost, and low-data-rate communication, as well as a massive machine-type communication (mMTC).

The GOP is strengthening its support for IoT development in policy. The IoT has been given the 920 MHz to 925 MHz spectrum by PTA/FAB. In addition, PTA is prepared to develop a regulatory framework for the Internet of Things that will include pertinent regulatory needs such as spectrum

management, licensing, privacy and security, data protection, and standards for network standards.

Both consumer and industrial IoT are being used in Pakistan to a very limited extent. An overview of IoT applications in Pakistan is provided by Ignite, the national technology fund of Pakistan backed by MoIT & T. Ignite funds IoT-based initiatives that attempt to address some of the requirements of the nation in sectors including IT, Energy, and Healthcare.

REFERENCES

[1]. Abhishek Khanna., Samreet Kaur. (2024). Internet of Things (IoT), Applications and Challenges: A Comprehensive, Review: Springer, Published: 28 May 2020. Volume 114.

[2]. Kinza Shafique., Bilal A. Khawaja., Farah Sabir., Sameer Qazi., Muhammad Mustaqim. (2020). "Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends and Prospects for Emerging 5G-IoT" Scenarios: Review IEEE ACCESS Volume 8 published: Jan 28, 2020. Page: 23022-23040.

[3]. Shazia Nadir Ali, Dr. Rao Aamir Khan (2023), "The Role of Digital Technologies in Facilitating Sustainability in Developing Countries: A Case of Pakistan". Published in: 2023 IEEE 12th IDAACS. Added to IEEE: 21 Dec, 2023.

[4]. Mirza Abdur Razzaq., Sajid Habib., Muhammad Ali., Saleem Ullah. (2017). Security Issues in the Internet of Things (IoT): A Comprehensive Study: ResearchGate, Published in: International Journal of Advanced computer Science and Applications (IJACSA), volume 8, No.6, 2017.

[5]. Shagufta Faryad., Hira Batool., Muhammad Asif., Affan Yasin. (2021). "Impact of Internet of Things (IoT) as Persuasive Technology": Review ResearchGate, Published in International journal of Information Technology and Computer Science, December 2021.

[6]. Statistics of Internet of Things-Pakistan by Satistica.com

[7]. Article: "PTA Instruction Operators to Complete Transition to IPV6, 20 Jan, 2023". By pta.gov.pk

[8]. Article: "State of IoT 2023 by IoT-Analytics.com". by iot-analytics.com.

[9]. Article: "How can IPv6 foster innovation and creativity in the design and development of IoT solutions?" By Dr. Imed Romdhani Associate Professor of Networking at Edinburgh Napier University, Powered by AI and the LinkedIn community.

[10]. Article: "Internet of Things and Pakistan's Agriculture Sector" by Zahra Niazi, May 2022. Center of Aerospace and Security Studies.

[11]. Article: "IoT Key to Meeting Sustainable Development Goals 2030", a blog by Mohit Agarwal, at Counterpointresearch.com

[12]. "IoT-Based Water Quality Monitoring System for Safe Drinking Water in Pakistan" by Abdul Rauf Memon; Saadia Kulsoom Memon; Abdul Aziz Memon; Tayab Din Memon, published in 2020 3rd International Conference on Computing Mathematics and Engineering Technology (iCoMET), Date of Conference: 29-30 January 2020, Date Added to IEEE Xplore: 23 April 2020,

[13]. Article: "Artificial Intelligence &IoT for Energy Efficiency& Conservation (AIoT- EE&C) in Buildings" by NEECA (National Energy Efficiency and Conservation Authority).

[14]. Sandro Nizetic, "Internet of Things (IoT): Opportunities, issues, and challenges towards a smart and sustainable future" 2020, Journal of Cleaner Production. Volume 274, 20 November 2020, 122877

[15]. Ascensión López Vargas, "Challenges and Opportunities of the Internet of Things for Global Development to Achieve the United Nations Sustainable Development Goals" (2020), IEEE ACCESS: 2020.2975472. Published: 2020. Volume 8 2020.

[16]. "An overview of smart irrigation systems using IoT" by Muhammad Ramadan, Energy Nexus, Received 27 January 2022; Received in revised form 5 July 2022; Accepted 23 July 2022.

[17]. "Smart cities and sustainable development goals (SDGs): A systematic literature review of co-benefits and trade-offs" by Ayoob Sharifi, Published by Elsevier Ltd. Cities 146 (2024) 104659, Received 1 March 2023; Received in revised form 30 October 2023.

[18]. "A comparative study of LPWAN technologies for large-scale IoT Deployment", Kasi Mekki, 2405-9595/c 2018 The Korean Institute of Communications and Information Sciences (KICS). Publishing Services by Elsevier B.V. This is an open-access article under the CC BY-NC-ND license 4.0.

[19]. FoodTech startups: Technological solutions to achieve SDGs (2023) by Iramaia Angelica Neri Numa. Received 29 March 2023; Received in revised form 24 May 2023; Accepted 8 June 2023, 2949-8244/© 2023 Elsevier B.V. All rights reserved.