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Review Article

5G Opportunities in the South Pacific: Leveraging Low-Band Spectrum for Socio-Economic Development

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Abstract

This paper explores the potential for deployment of 5G communication in the South Pacific, with a particular focus on leveraging the low-band spectrum for socio-economic development. The purpose of this study is to assess the feasibility of deploying 5G infrastructure in the South Pacific region, analyze the socio-economic benefits it may bring, and propose strategies to maximize these benefits. The research methodology includes a comprehensive review of existing literature on 5G deployment strategies, the socio-economic impacts of telecommunications infrastructure, and case studies of similar initiatives in other regions. The findings show that the deployment of 5G technology using low-band spectrum has the potential to significantly improve connectivity, healthcare, education, and economic opportunities in the South Pacific. Additionally, the paper proposes innovative approaches to address challenges such as infrastructure development in remote areas and affordability for marginalized communities. This study contributes to existing literature by providing tailored recommendations for leveraging 5G technology to address socio-economic inequalities in the South Pacific, thereby contributing to the development of telecommunications infrastructure in the region. Provides a new perspective on the possibilities of structure.

Keywords: Sustainability; Healthcare; Education; Financial Inclusion; Wellbeing; Employment; Environment; Climate Change.

1. Introduction

Based on their economics, nations are categorized into three groups by the United Nations World Economic Situation and Prospect (WESP): established economies, economies in transition, and developing economies [1]. Africa, Asia, and South America are developing countries, whereas most of Europe, North America, and Australia are either developed or in transition. The countries in the global south have a lower human development index of less than 0.8, while the countries in the global north have greater living standards and more developed technologies. They have inadequate infrastructure and restricted access to necessities of life, and their gross national income per capita is USD 4100 or less. Minimizing the disparity between the global north and south is one of the main objectives of the Sustainable Development Goals (SDG) [2].

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According to recent data, technology can be extremely important for accomplishing the Sustainable Development Goals (SDGs). When used properly, it can aid in bridging the divide between the global north and south. To combat world hunger, for instance, food productivity can be increased by the use of smart agricultural techniques [3]. Furthermore, remote patient monitoring is possible with the use of wireless body sensors and the Internet of Things (IoT) [4, 5]. Technology-based solutions such as sensor networks, cloud collaboration, and online and remote learning can all help to improve infrastructure, economic growth [6], education, and water quality [7]. All of these solutions depend on a strong communication network that can link billions of consumers to the internet and connect millions of access networks globally. As a result, two essential components of sustainable growth are the internet and next-generation mobile networks.

It is now essential to reorganize the current generation of cellular mobile communication and transition to the fifth generation (5G) of cellular technology due to the increasing use of mobile devices and the ensuing spike in multimedia data traffic. Three features set the 5G of cellular technology apart: ultra-low latency, ultra-high-speed data transfer, and ubiquitous connectivity [8]. With the introduction of 5G mobile networks, users are promised limitless bandwidth, reduced latency, and virtualization possibilities. With the help of this technology, network operators will be able to accommodate the anticipated demand for capacity from a wide range of new, real-time, bandwidth-hungry applications. Furthermore, 5G technology will allow many industry sectors to align with various Sustainable Development Goals (SDGs) in an emerging Information and Communication Technology (ICT) sector that aims to achieve significant increases in bandwidth, reduce latency, and drastically reduce emissions to mitigate the impact of climate change.

According to society's needs and desires, academics once imagined a digital communication network that might digitally link private affairs to continents. With the introduction of 5G technology, wireless connectivity to everything and everywhere is finally becoming a reality. Advanced features, including cell-less designs, massive three-dimensional processing, tangible response times, massive data processing, virtualization, and more, are also provided by 5G technology [8]. It is thought that the enormous bandwidth and low latency of the 5G network will offer an integrated platform for real-time connections between various devices. In the context of Industry 4.0, the idea of "smart manufacturing" or “factory of the future (FoF)” has important ramifications for supply chain management (SCM). 5G, which links a huge number of smart devices with any other anywhere and at any time, solidifies the route to FoF [9]. In today's wireless communication era, devices such as smartphones, hotspots, and Wi-Fi zones play a crucial role in the rapid growth of data usage. The Internet of Things (IoT) is a new technology that aims to improve people's lives by providing a wide range of applications and services. This IoT ecosystem is connected through 5G wireless networks. Network slicing is an important technology that enables the realization of IoT in 5G, making it a significant enabler for this technology [10]. It is anticipated that the introduction of 5G and other technologies will not only facilitate hyperdigitalization but also create new avenues for industrial and economic growth [11].

One of the biggest issues in the world is poverty, which results from a lack of resources needed to meet people's fundamental necessities for survival [12]. According to the United Nations, poverty has evolved into a human rights concern and is now more than just a problem of resources or income [13]. One of the main objectives of significant international organizations, including the UN, which has established 17 Sustainable Development Goals (SDGs), is to eradicate global poverty [14].

There is a lot of potential for people and businesses all over the world to eliminate poverty and improve access to resources, thanks to the arrival of 5G technology. Data transmission with 5G technology is groundbreaking and gives users faster and more reliable service. It has already had a big influence in many nations, giving people and businesses access to things like financial services, health services, and educational opportunities that they couldn't before. By enabling access to vital information and resources, 5G technology is assisting in the reduction of poverty in many regions of the world. For instance, 5G technology has made it possible for individuals to access education, health services, and financial services, which are crucial for assisting them in improving their quality of life, in rural areas of India where access to the internet and other technologies is limited.

The first of the 17 objectives on the list, designated as SDG1, is the target “End Poverty”. As a result, throughout time, the objectives set by international organizations to eradicate poverty have been gradually met. According to the World Bank in 2018, poverty levels have been steadily declining, though at a slower rate than before the epidemic, when it was estimated that the number of people living in poverty had decreased by as much as 10% [15].

Poverty levels have been steadily decreasing in the region over the past few years [16]. However, the COVID-19 pandemic's arrival sparked a global economic crisis, which has done great irreparable harm to the entire population [17]. It has even halted and damaged the progress made by the SDGs, with SDG1 being one of the most affected because the world economy experienced the worst recession in the last 90 years, with people in the most vulnerable sectors being the worst affected. Over the past 20 years, poverty levels have risen disproportionately, according to the World Bank [18].

According to research, developing countries in areas such as the Pacific Island Countries, the Caribbean, and Latin America, which have a poverty rate of 13.6% of the region's total population, are among the most affected countries in the world by the pandemic [19].

The Food and Agriculture Organization of the United Nations (FAO) and the Economic Commission for Latin America and the Caribbean (ECLAC) have been searching for solutions that can mitigate this damage and prevent a food crisis, as the United Nations has predicted that millions of people in Latin America and the Caribbean will fall into extreme poverty in 2020 due to the pandemic [20].

To combat and repair the damage caused by the pandemic, the United Nations Development Program (UNDP) has opted to deploy intelligent robots in Kenya [21]. However, the existing digital divide had a greater impact during the pandemic, resulting in high unemployment, lost employment opportunities, and limited access to public services such as education due to a lack of technological resources and the Internet, which increased poverty rates [22].

UNDP started implementing technology-driven programs as a result [23], supporting online learning, developing virtual learning environments, establishing work-from-home positions, etc. The attainment of the 17 SDGs has been made possible by the adoption of mobile technologies, which has brought about a range of economic, social, and environmental benefits [24]. Because of this, putting new solutions into action will help us get closer to realizing the SDGs [25]. Smart connectivity [26], which is seen as the most effective technology to assist in accomplishing the SDGs [27], is the culmination of several technical enablers (AI, 5G, IoT, and blockchain). Due to their ability to aid in humanitarian efforts, foster sustainable economic growth, and promote corporate expansion and employment creation, mobile technologies significantly contribute to SDG1 [28]. The 5G network, which is one of these technologies and is crucial to global sustainability, is among them [29].

The fifth generation of wireless mobile networks, often known as 5G technology, represents a considerable improvement over the preceding generations (2G, 3G, and 4G). It is distinguished by providing significantly faster connection rates, greater capacity, lower latency, and the capacity to connect numerous devices at once [30].

Eleven SDGs will be able to generate social benefits thanks to 5G technology [31]. The article claims that the 5G network will significantly aid in the accomplishment of SDG1 by 2035 as it will increase Internet connection, produce an economic output of USD 3.6 trillion, and create 22.3 million jobs [32].

The development of the Internet of Things (IoT) depends on the ability to connect many devices at once, thanks to 5G's increased capacity [33]. The planned connectivity of 5G will allow for industry automation [34] and networking in numerous industries, including healthcare, agriculture, and the Smart City [35].

To advance equity and create long-lasting jobs, our research focuses on examining the effects of using 5G network-based technologies and their contribution to poverty alleviation. The goal of this analysis is to emphasize the significance of utilizing 5G network-based technologies to fight poverty by enhancing access to essential services, spurring economic growth [36], encouraging digital inclusion, and increasing productivity in important industries. 5G network-based technologies can change lives and aid in the eradication of poverty by giving underprivileged populations the necessary resources and opportunities.

2. Literature Review

Among the most important developments in wireless communication is the 5G network. Compared to other generations of mobile networks, it offers substantially quicker data transfer speeds, lower latency, and a larger connectivity capacity [37, 38]. Goal 8 of the UN 2030 Agenda for Sustainable Development, which places a high priority on decent work and sustainable economic growth, may be achieved with the help of this technology [38]. The 5G network may significantly affect these factors by boosting operational effectiveness, fostering innovation, and opening up new commercial prospects. Here are some salient features regarding these places' potential impact of the 5G network.

A new technology that provides more connectivity capacity and better data transmission speeds is the 5G network. This implies that it can aid in the creation and uptake of fresh digital services and technology across a range of industries, including manufacturing, transportation, healthcare, and agriculture [39, 40]. It consequently boosts productivity and generates new business prospects. Infrastructure and technological development investments are necessary for the 5G network's deployment, which promotes economic growth [41].

The fusion of 5G with other cutting-edge technologies like IoT, big data analytics, AI, and ML has the potential to completely transform the healthcare sector, which is finding it difficult to keep up with the fast-expanding population and modern diseases. In the future, machine learning algorithms may help determine the proper micro dosages of pharmaceuticals, such as insulin delivered via an implanted pump, and identify any abnormalities that would require medical professionals' attention [39].

The healthcare, agricultural, and smart city sectors are just a few of the industries that the 5G network is changing [42]. The 5G network's low latency and connectivity allow telemedicine and remote healthcare to take advantage of its capabilities, enabling the provision of high-quality healthcare even in isolated and rural places. The 5G network also makes smart agriculture possible, enabling effective data analysis and sensor-based monitoring and management of animals, irrigation, and crops. In smart cities, the 5G network can also optimize urban services like trash management, transit, and lighting, fostering sustainability and efficiency in urban areas [43]. These are just a few instances of how 5G technology helps to create quality jobs and economic progress. There is potential for new opportunities and higher-quality work across a variety of sectors as it becomes more widely used and adopted.

3. Material and Methods

In academic writings and studies by international organizations, there has been discussion and controversy about the connection between 5G technology and poverty alleviation. The following provides some essential background information and earlier definitions. The potential of 5G technology to increase digital inclusion and close the digital divide between nations and regions is highlighted in the United Nations Economic Commission for Africa (UNECA) study on the digital revolution in Africa [44]. Additionally, it highlights how 5G technology may significantly affect industries like agriculture, health care, and education, which may help Africa's poor and unequal society.

By bridging the divide between urban and rural areas and providing accessible connectivity, low-band spectrum is a key factor in advancing digital equality. The digital gap will undoubtedly widen, and people living in rural regions will no longer have access to the newest digital technology if there is not enough low-band spectrum available. There will be 252 commercial 5G networks operating in 86 nations by the end of 2022, supporting more than 1 billion 5G connections. More than 5 billion 5G connections are anticipated globally by 2030, driving a nearly $1 trillion increase in GDP. Although 5G is anticipated to mature in North America, Europe, China, and the GCC countries by 2030, it will continue to develop in numerous low- and middle-income countries. Most nations currently use 600 MHz and 700 MHz as the primary low bands for 5G, whereas earlier versions used 800 MHz and 900 MHz. By the end of 2022, operators were using the 600 or 700 MHz bands for 5G in almost half of the nations where 5G had been introduced. These nations have surpassed those that do not use 600/700 MHz in terms of coverage levels, 5G availability, and indoor quality of service. In 2030, low-band 5G is anticipated to generate an estimated $130 billion in economic value. Massive IoT, or mIoT, will have a 50% impact. In addition to population coverage, many current and future IoT use cases need large area coverage, which the low-band spectrum is best suited to deliver. Applications for the Internet of Things (IoT) are expected to be crucial in driving digital transformation in several industries, including manufacturing, transportation, smart cities, and agriculture. The remaining economic effects will be driven by fixed wireless access (FWA) and enhanced mobile broadband (eMBB), as low bands will be crucial in providing high-speed broadband connectivity in locations that are underserved by fixed networks. Figure 1 illustrates how demand for international bandwidth utilization per Internet user in kbit/s will continue to grow because of the relentless worldwide Internet data consumption.

Low-band 5G applications will increase the social and environmental advantages brought about by mobile technology in addition to the macroeconomic effects. This involves lowering poverty, enhancing wellbeing, gaining access to health, financial, and educational resources, and facilitating the decrease of greenhouse gas emissions. This is crucial for rural inhabitants, who suffer the most from these issues yet are also 33% less likely than urban residents to receive mobile internet and have poorer network performance overall in low- and middle-income nations. In many rural locations, boosting capacity to supply 5G-based use cases won't be feasible without sufficient low-band spectrum.

As the repercussions of poverty continue to plague the world, the advent of 5G technology may open new avenues for addressing the problem. A whole new world of chances will become available thanks to 5G connectivity, including better healthcare, more educational prospects, and more.

With speeds up to 100 times faster than current 4G networks, 5G networks will provide more effective and efficient internet access, particularly in rural and distant locations. More individuals will have access to educational opportunities and job training thanks to this expanded internet connection, which will aid in the fight against poverty. Additionally, with the faster 5G networks, medical experts will be able to offer more effective telehealth services to those in underdeveloped regions, hence enhancing access to healthcare.

5G networks can assist in creating new job opportunities in addition to increasing access to healthcare and educational services. For instance, businesses will be able to create new goods and services that were previously impractical owing to the restrictions of 4G networks thanks to 5G networks. Because companies will need to hire people to develop, maintain, and run these new products and services, this will result in new job opportunities.

Finally, by enhancing access to financial services, 5G networks can also contribute to the reduction of poverty. For instance, 5G networks will give people access to speaker recognition banking services and other financial products and services, allowing them to save money and make investments that will increase their financial stability [45].

In conclusion, the rollout of 5G networks has the potential to open fresh avenues for addressing poverty. 5G networks can contribute to the eradication of poverty and the creation of a more just society by enhancing access to financial services, healthcare, employment prospects, and education.

3.1. Investigating 5G's Potential to Improve Education in Developing Nations

The potential for 5G technology to raise educational standards in underdeveloped nations is enormous. The world is transitioning to a digital future, and 5G is expected to completely change how individuals' access and use information. The introduction of 5G networks will increase access to dependable, high-speed connections in emerging nations. This will give students in these nations additional chances to access educational resources, participate in interactive learning, and take part in online classes.

Due to their high bandwidth and low latency connections, 5G networks have the potential to enhance education. This would make it possible for students to get real-time, minimally buffered access to online lectures, instructional films, and other interactive materials. Through virtual classrooms and video conferencing, 5G networks may potentially enable remote learning, giving students access to instructors and other students all over the world.

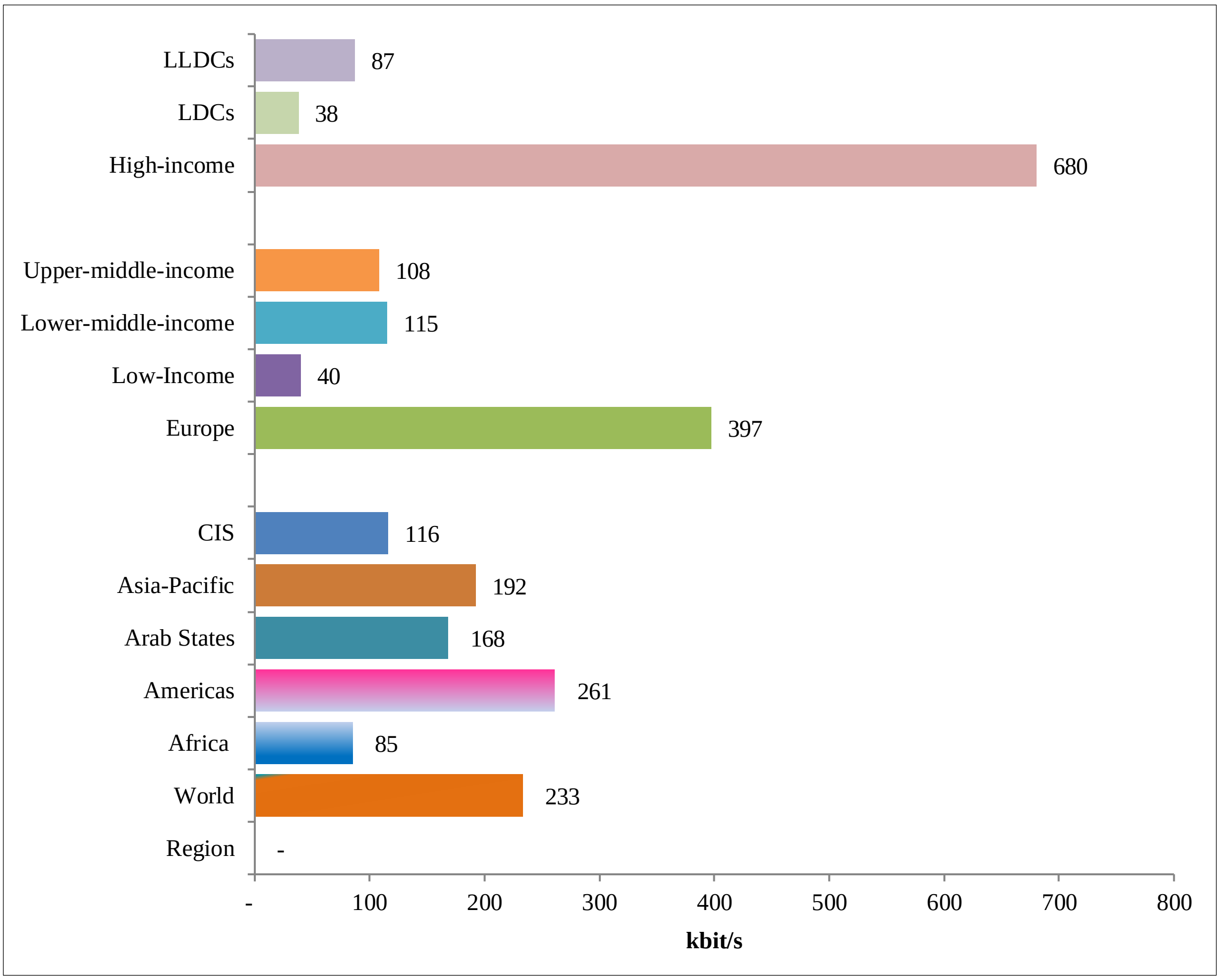

Figure 1. International bandwidth per Internet user, kbit/s, 2022

Additionally, 5G technology may help schools, universities, and students save money. Students might be able to access educational content stored on distant servers via fast 5G networks, which would eliminate the need for pricey hardware and software. Through resource sharing and international collaboration, 5G networks may also make it possible for educational institutions to gain access to a plethora of knowledge and resources without having to pay exorbitant trip expenses.

In underdeveloped nations, 5G technology has enormous potential to raise educational access and standards. However, it is crucial to remember that the availability of dependable, affordable infrastructure and dependable, affordable access to technology will be necessary for the effective deployment of 5G networks in these nations. The benefits of 5G for education in the underdeveloped world are apparent, though.

3.2. The Effects of 5G on Economic Growth and Poverty Alleviation

5G wireless communication technology is expected to alter all aspects of our lives, including how we work and play. 5G could improve economic growth and decrease poverty in addition to offering faster connections, more dependable data transmission, and more bandwidth. The development of 5G technology holds the potential of enhancing communication networks and enabling the quick transfer of massive volumes of data. This might make it easier to create systems that let people access information, conduct online business, and take part in the global economy. This can then result in more chances for economic expansion and job creation.

At the same time, isolated and underdeveloped people who were previously inaccessible could now have access using 5G technology. 5G may help to reduce poverty by linking those in need to the global economy [46]. In underdeveloped nations with limited access to information, communication, and digital services, this might be very advantageous.

Additionally, 5G technology may make it easier to create new programs that give poor people access to essential services like healthcare and education. For instance, 5G might make it possible to deliver healthcare services to isolated locations, enabling those in need to get the treatment they need. Similarly, 5G might make it possible to distribute educational materials and content to places where there is presently restricted access.

The potential for 5G to change how we communicate, work, and play might spur economic growth, lessen poverty, and enhance the quality of life for people all around the world. The impact of technology on economic growth and the eradication of poverty will be more and more clear as it develops.

The global rollout of 5G technology presents a special chance to link residents of impoverished areas to the global economy. High-speed internet access, dependable connectivity, and improved mobile broadband are all possible with 5G technology, and together they can help close the digital divide between people who live in poverty and those who live in more affluent places.

People in impoverished communities can access educational resources, employment possibilities, and job training through high-speed internet connectivity. They can interact with people around the world and create professional networks with dependable connectivity. Additionally, individuals may access services like e-commerce that can help them make money and better their quality of life thanks to enhanced mobile broadband.

3.3. The Effects of 5G on Health Care

Given the dispersed and rural character of much of the developing countries' population, especially Pacific Island countries, mobile technologies such as 5G play a significant role in enhancing healthcare services in the Pacific Islands by making them more efficient and equitable. Access to emergency services, diagnosis via online consultation, and interprofessional communication have all been enhanced thanks to the connectivity provided by the 4G network, which will further improve by the end of 2030 as by than in 11 Pacific Island nations, 5G connections will make up more than 20% of all connections [47]. Patients will obtain care more quickly and have more access to specialists who would not otherwise be available when the technology is fully utilized. Without their physical presence, professionals may be better able to reach these underserved patients thanks to 5G connections. It is advised to use sensor node infrastructure based on 5G for convenient patient health monitoring [48, 49].

3.4. The Mobile Network Coverage Gap is Still 5%

Mobile broadband (3G or above) is frequently the only option for connecting to the Internet in most developing nations. 95% of people on the planet have access to this kind of information. Since passing the 90% mark in 2018, global 3G coverage has only expanded by four percentage points, making it impossible to connect the final 5% of people who are still off the grid. This "coverage gap" must be closed. The population of central and western Africa is primarily impacted by the gap, which accounts for 18% of all of Africa.

The coverage gap almost equalizes between LDCs and LLDCs, falling short of Sustainable Development Goal 9's target to "significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020." 4G network coverage doubled to reach 88% of the global population between 2015 and 2022, but as with earlier technologies, growth is decreasing.

More than 90% of people in the Americas, Asia-Pacific, CIS, and Europe currently have access to 4G technology. In the Arab States, 25% of the population still does not have access to a 4G network, whereas in Africa, 50% of the population does (Table 1).

Many nations are replacing their aging networks with newer ones that are more efficient and enable the growth of a 5 G-compatible digital ecosystem. This is especially true for 3G, which is frequently turned down to make room for 5G while keeping 2G available for older legacy devices. Most European operators and those in the Asia-Pacific intend to turn off their 3G networks by December 2025, respectively. The road is less apparent in other parts of the world, largely because 2G and 3G networks continue to be widely used. This is particularly true in developing nations where both technologies are crucial for communication. The key constraints to 5G rollout in such nations include prohibitive infrastructure expenditures, prohibitively expensive devices, and adoption and regulatory hurdles. According to preliminary estimates, a 5G network will have coverage for 19% of the world's population in 2021. Europe had the highest roll-out rate at 52%, followed by the Americas (38%) and the Asia-Pacific area (16%).

Table 1. Coverage of the population by mobile network type and region, 2022 [50]

Coverage Area	Region	2G Coverage in %	3G Coverage in %	4G Coverage in %
World	Rural		13	76
	Urban			97
Africa	Rural	14	47	25
	Urban			84
Americas	Rural	5	8	65
	Urban			98
Arab States	Rural		37	55
	Urban			91
Asia-Pacific	Rural			92
	Urban			99
CIS	Rural		14	76
	Urban			100
Europe	Rural			95
	Urban			100
Low-Income	Rural	17	53	13
	Urban		20	72
Lower-middle-income	Rural		9	82
	Urban			97
Upper-middle-income	Rural			91
	Urban			100
High-income	Rural			97
	Urban			100
LDCs	Rural	13	42	32
	Urban		20	97
LLDCs	Rural	19	46	27
	Urban			88
SIDS	Rural	19	17	42
	Urban			88

Note: The values for 2G and 3G networks show the incremental percentage of population that is not covered by a more advanced technology network (e.g. 95% of the world population is covered by a 3G network, that is 7% + 88%).

The need for international data and, consequently, bandwidth utilization continues to be driven by the Internet's insatiable appetite for data. Despite this, the 25% increase in bandwidth demand in 2022 is less than in recent years, which were characterized by COVID-19's effects. The increase in bandwidth utilization per Internet user in 2022 was also less than it was in 2021, at 17%. The utilization of international bandwidth has increased by 33% over the last five years, while usage per Internet user has increased by 22%. The fastest-growing region in terms of bandwidth utilization per Internet user is the Americas (26%) followed by Africa (37%) for international bandwidth usage.

3.5. Asymmetries in Telecommunication Technological Advancement

One-third of the world's population, or 2.7 billion people, do not have access to the internet. In most low-income nations, the average consumer must spend 9% of their whole income on a basic mobile data plan. The cost as a percentage of global income in high-income countries is many times lower than this. This shows a growth rate of 6.1% over 2021, up from 5.1% for 2020–2021. However, it is still much below the 11% for 2019–2020 observed at the start of the COVID–19 pandemic. That still leaves 2.7 billion people without access, illustrating how much work needs to be done to meet the 2030 global goal of meaningful connection for all. Between 80 and 90 percent of people use the Internet in the nations of Europe, the Commonwealth of Independent States (CIS), and the Americas, which is close to universal use (defined for practical purposes as an Internet penetration rate of at least 95 percent). According to the global average, the Internet is used by almost two-thirds of people in the Arab States and Asia-Pacific countries (70 and 64%, respectively), but just 40% of people in Africa.

In the least developed nations (LDCs) and landlocked developing nations (LLDCs), where just 36% of the population is already online, universal connectivity also remains a distant possibility. The analysis demonstrates that universal and meaningful connection, which would allow everyone to have access to a secure, enjoyable, stimulating, productive, and inexpensive online experience, is still a long way off for LDCs. For instance, just 36% of people worldwide and 66% of people in LDCs used the Internet in 2022. The so-called access gap in LDCs was as high as 17% of the population not even having access to a fixed or mobile broadband network. 2.7 billion people are offline, even though two-thirds of the world's population access the Internet is shown in Figure 2.

3.6. Dimension and Trends

The World Bank estimates that in 2020, 9.2% of people worldwide will live in extreme poverty, defined as having a daily income of less than $1.90 [51]. In 2020, 41% of people in Sub-Saharan Africa and 13.6% of people in South Asia were estimated to be living in extreme poverty. On the other hand, the Economic Commission for Latin America and the Caribbean (ECLAC) estimates that 32.1% of people in Latin America [52] were living in poverty in 2021. Remember that many variables affect how poverty is measured and analyzed, and that these numbers are simply a sampling of poverty rates in various parts of the world [53].

In 2021, the GSM Association (GSMA) predicted that 5G technology would be adopted more quickly than any other mobile technology [54]. By 2025, it is anticipated that there will be more than 1.8 billion 5G connections globally. By the end of 2020, China will have deployed more than 1 million 5G base stations worldwide, ahead of South Korea, the United States, and Japan [55]. For the remainder of this decade, the 4G connection will continue to play a significant role in the Pacific region's coverage and adoption. Up to 2027, 4G usage is anticipated to increase steadily in the region. The global economy and society are anticipated to be significantly impacted by 5G technology [56]. In a 2020 analysis from the research firm IDC, 5G technology is predicted to have an $8 trillion worldwide economic impact by 2030. In conclusion, 5G technology is widely being adopted and deployed quickly, and it is anticipated to have a large impact on the world economy and support various industries to lessen poverty.

3.7. Questions and the Goals of the Research

Based on the literature analysis, this study will examine how the use of 5G technologies affects eradicating poverty as well as how these technologies are incorporated into various industries to make a direct or indirect contribution. The following are the research questions:

Research Question 1: Which industries are using 5G technology most effectively to reduce poverty?

Research Question 2: Which innovations based on 5G networks help to fight poverty?

Research Question 3: What 5G network-based applications technologies have the bi gest impact on eradicating poverty?

3.8. Methodology to Address the Socioeconomic Advantages of 5G

This section goes into great depth about how we looked for papers to use in our systematic literature review, a study that examines how the 5G network affects poverty. To perform a better analysis of the data, we can compare the findings using the PRISMA methodology [57] to choose the pertinent publications using various inclusion and exclusion criteria. The articles gathered and targeted at the suggested literature review topic have been reviewed using complementary sources. Figure 3 shows the articles classification source for this literature review.

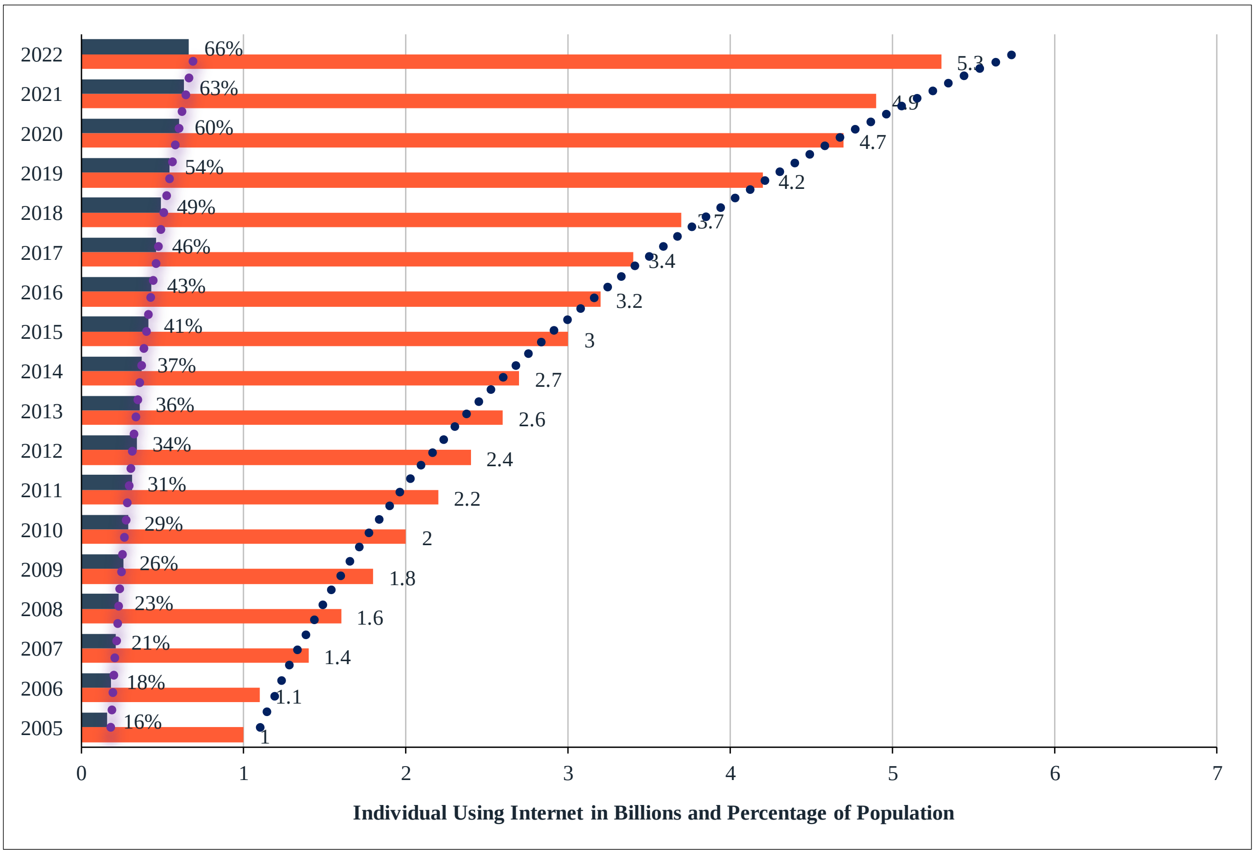

Figure 2. 2.7 billion people are offline, even though two-thirds of the world's population accesses the Internet [50]

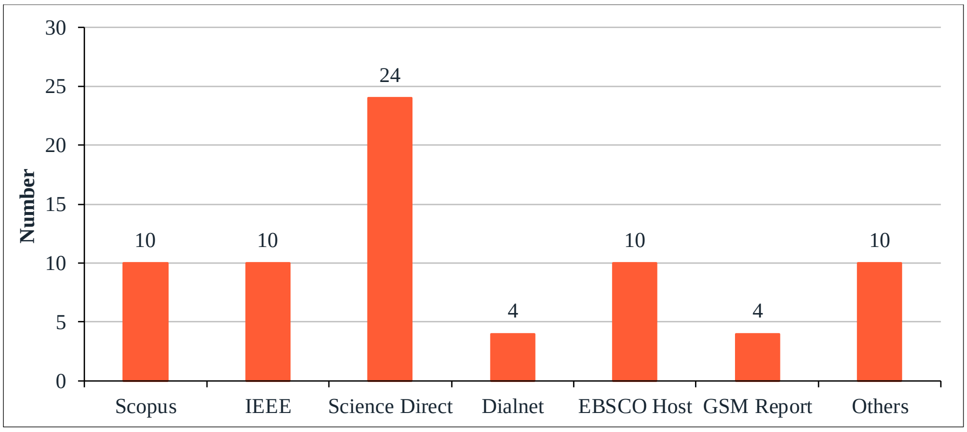

Figure 3. Articles classification source for this literature review

A total of 55 of the research papers were ultimately used for analysis and systematization of the selection process, depending on the various inclusion and exclusion criteria. Figure 4 displays the results, analysis, and synthesis of the data gathered from the selected publications.

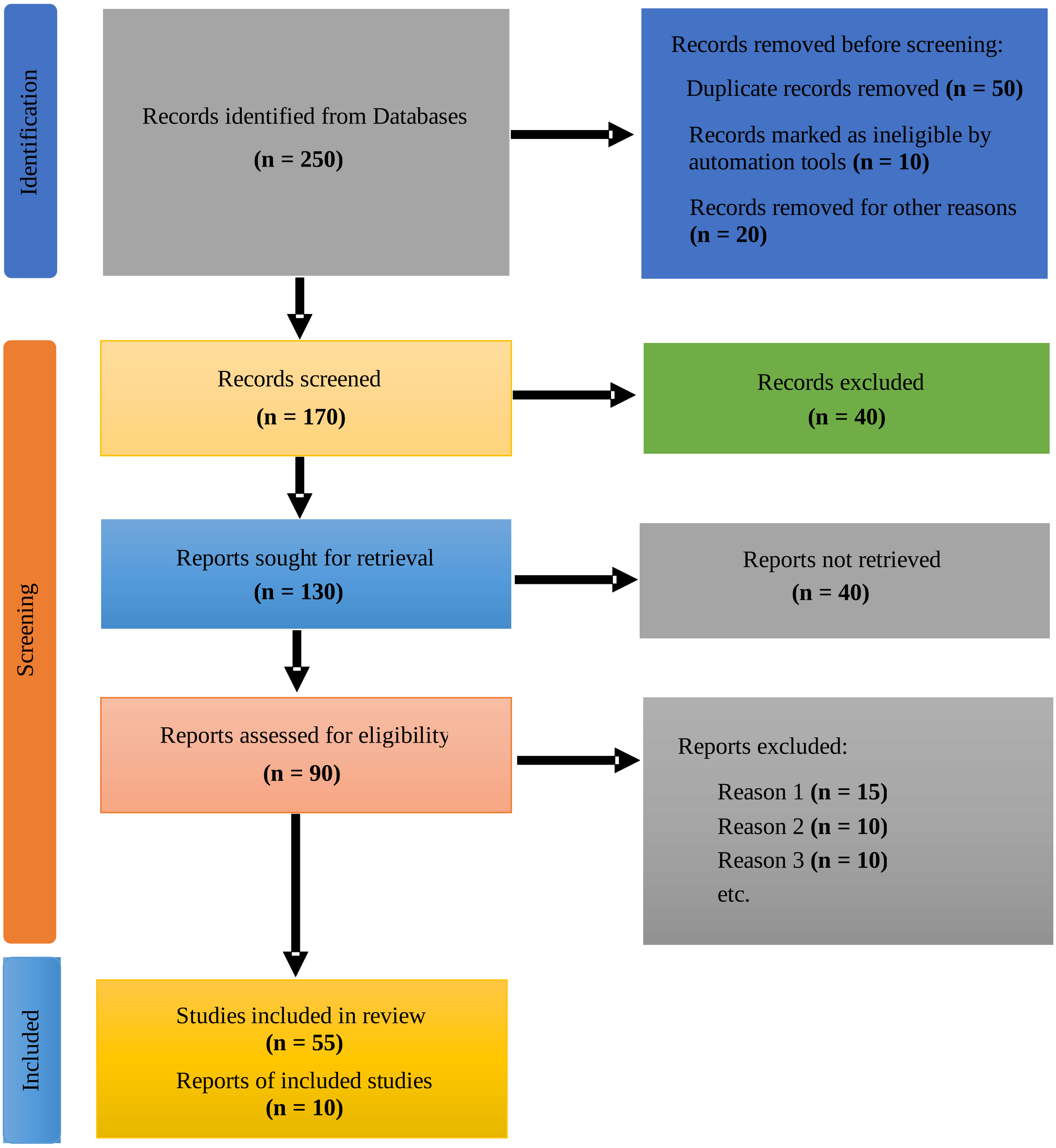

Figure 4. PRISMA methodology-based analysis, and synthesis of the data gathered from the selected publications

4. Next-Generation LTE 5G Spectrum Allocations

The term “5th generation wireless systems,” or simply “5G,” refers to upgraded networks that will be deployed in 2018 and later. They may employ current 4G or newly designated 5G Frequency Bands to function. The main technologies are as follows: Massive MIMO (Multiple Input Multiple Output - 64-256 antennas) delivers performance “up to ten times current 4G networks,” whereas millimeter wave bands (26, 28, 38, and 60 GHz) are 5G and offer speeds of up to 20 gigabits per second [58]. The “Low-band 5G” and “Mid-band 5G” bands operate between 600 MHz and 6 GHz, primarily between 3.5 and 4.2 GHz. The most widely used definition is that found in 3GPP Release 15 from December 2017. Some others favor the stricter ITU IMT-2020 definition, which excludes everything but the high-frequency bands for extremely fast speeds.

5G towers and devices exchange wireless radio signals. These radio waves have been tailored to frequencies in the 5G radio range. A variety of frequencies make up the 5G frequency bands. For the construction of their 5G network, cellular providers possess portions of various bands. Depending on where the 5G frequencies are located within the spectrum, the speed and range of 5G cellular transmissions will change.

Low-Band 5G uses frequencies that are less than 1 GHz. Currently, Low range 5G in Canada uses the 600 MHz range, which includes the frequencies 614-698 MHz. More low-band spectrums will become available in the coming years. The 800 MHz and 900 MHz bands should be examined for 5G deployment, according to the ISED's recommendation in the Outlook Consultation. Because they are at the lower end of the spectrum, these frequencies can go farther and are less susceptible to interference from objects. Therefore, they'll be crucial in providing distant suburban and rural areas with next-generation wireless access. However, the speed will be rather comparable to 4G. Figure 5 illustrates how commercial mobile spectrum in the 90 MHz, 600 MHz, and 800 MHz bands would give mobile operators the chance to expand their capacity and coverage across vast areas.

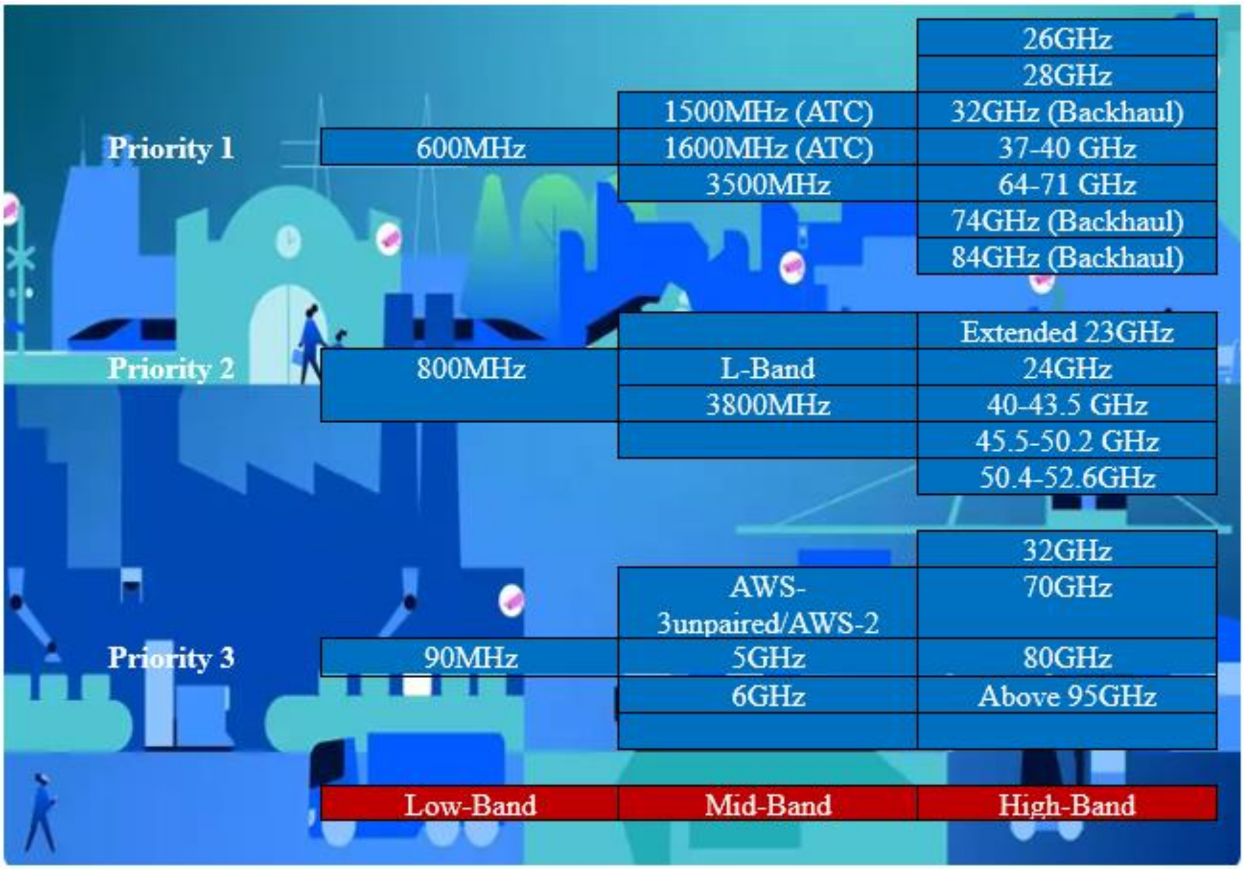

Figure 5. Spectrum Outlook priorities in the range of 90 MHz, 600 MHz, and 800 MHz bands [59]

The “just right” band for 5G is mid-band. It provides the ideal balance of speed, coverage, and capacity while operating between 1 GHz and 10 GHz. The ISED views the 3.5 GHz and 3.8 GHz bands, which will go into operation in 2022 and 2023 respectively, as crucial spectrums for 5G technology. For suburban and urban settings with consistently strong demand, the mid-band is suitable. For their 5G service, most Canadian carriers are utilizing the 1.7/2.1 GHz and 3.5 GHz bands. The only cellular service provider currently using the 2.5 GHz frequency is Rogers. Within the next few years, the ISED intends to provide more mid-band spectrum.

The spectrum over 10 GHz is referred known as the high-band spectrum. High-Band 5G, also known as mmWave 5G, will function above 20 GHz but is not yet accessible in Canada. Here, consumers will enjoy the lightning-quick speeds and extremely low latency that 5G offers. Range, though, is the compromise. Buildings cannot be penetrated by mmWaves, which can only travel short distances. The waves can be readily broken. There will be a need for 5G antennas and devices to transmit these signals inside of buildings [60].

For crowded venues and densely populated urban locations, this spectrum works well. The network will be able to support more devices at once thanks to its increased capacity. With High-Band 5G, connectivity issues caused by heavy traffic would be considerably reduced. South Korea is the nation that launched the first 5G network and is anticipated to maintain its lead in terms of the technology's uptake. Nearly 60% of mobile subscriptions in South Korea are anticipated to be for 5G networks by 2025. An auction for 5G bandwidth frequencies began this week, and a launch in India is anticipated for the following year.

4.1. Society Will Benefit More from Using the UHF Spectrum for Mobile than from Keeping it for Broadcasting

To ensure that 5G technology does not have a negative impact on the global economy, it is important to make enough sub-1 GHz spectrum available to meet the high demand for indoor urban coverage and ensure that rural populations are not left behind [61]. Studies show that nations using the 600 and 700 MHz frequencies are better equipped to provide 5G services to consumers than those using mid-band and mmWave channels alone. However, many countries require a more low-band spectrum to fully realize the socio-economic benefits of 5G. To allocate more capacity to 5G at both current and new sites, mobile operators need access to more sub-1 GHz airwaves. Without adequate low-band spectrum, operators may not be able to meet 5G performance standards in areas with existing coverage. In rural areas, adding base stations to enhance capacity is often not financially feasible. Therefore, utilizing the lower band spectrum at current base stations is the only viable method to boost capacity and provide the required speeds [62].

The cost-benefit analysis (CBA) findings demonstrate the potential cost savings of providing operators with more UHF spectrum for 5G network deployment in Europe, the Middle East, or Africa [63]. Without this spectrum, operators would incur higher expenses, which could impact the affordability and adoption of 5G and, in turn, limit its wider socio-economic benefits. If deployments prove financially unfeasible, operators may opt not to pay the extra expenses, leading to slower speeds, higher latencies, and less availability for consumers to enjoy the full benefits of 5G [64, 65].

The outcomes of a CBA will depend on various market-specific factors, such as expected 5G adoption rates, population distribution, and the level of reliance on Digital Terrestrial Television (DTT) for TV viewing [63]. It is clear from this analysis that no country should use the UHF spectrum in the same way. Governments should implement policies that benefit their citizens both economically and socially [66]. The CBA findings demonstrate the potential cost savings of providing operators with more UHF spectrum for 5G network deployment in Europe, the Middle East, or Africa. Without this spectrum, operators would incur higher expenses, which could impact the affordability and adoption of 5G and, in turn, limit its wider socio-economic benefits. If deployments prove financially unfeasible, operators may opt not to pay the extra expenses, leading to slower speeds, higher latencies, and less availability for consumers to enjoy the full benefits of 5G.

According to the report, allocating additional UHF spectrum for mobile purposes is more beneficial for society than keeping it available for broadcasting [67]. This is due to the increasing demand for 5G bandwidth and the decline of DTT, which is largely due to the growth of Internet Protocol television (IPTV) and on-demand streaming [68]. The cost savings of this allocation outweigh the expenses required to ensure that customers can still access their desired broadcasting services in all settings considered in the report.

Many countries may need to use frequencies below the 700 MHz band for broadcasting in the future [67]. This will ensure that operators have enough access to the low-band spectrum. The paper presents a cost-benefit analysis of using portions of the UHF band in ITU Region 1 (470–694 MHz) for mobile use. Allocating 80 MHz of UHF spectrum to mobile would be 6–24 times more beneficial for a typical nation in Europe, the Middle East, and Africa than the expenses required by the broadcasting industry to maintain the current amount of DTT programs. If the entire 470–694 MHz spectrum is dedicated to mobile phones, the benefits are 4–9 times greater for a typical country in Europe and the Middle East [63].

With 5G broadcasting, live video content can be accessed by multiple users. Early tests suggest that 5G Broadcasting can achieve similar capacity as DTT, given adequate reception conditions. This makes it a promising alternative to DTT. However, there is uncertainty around the economic structures necessary for 5G broadcasting, including financing and network management. Currently, there is limited 5G broadcasting hardware available, especially for consumer handsets. Manufacturers are conducting trials to incorporate support for this standard into their products, but no timeline has been provided for when this may occur [68].

Obtaining access to large amounts of spectrum can be challenging in certain areas because the sub-700 MHz band is shared with DTT transmissions [69]. If the amount of sub-700 MHz spectrum available is further reduced, securing sufficient spectrum will become even more difficult. However, there are ongoing efforts to enhance the spectral efficiency of Programme Making and Special Events (PMSE) or utilize new frequency bands or technologies. Wireless Multi-Channel Audio Systems (WMAS) have demonstrated promising innovation by utilizing wideband systems and digital encoding schemes, but this may not be suitable for all use cases, and commercially available equipment is not yet widely available. Additionally, the use of alternative frequency bands may not be suitable for all use cases due to their sub-optimal propagation characteristics. Developing and acquiring new equipment for alternative frequency bands requires investment and time.

4.2. Approach to the Cost Benefit Analysis (CBA) Using UHF Spectrum

In ITU Region 1, the evaluation of using the UHF frequency band for either mobile technologies or broadcasting services is conducted through a CBA in this section [70]. National regulators may take into account the economic implications of the following direct consequences that affect stakeholders:

- Producer surplus, which is the profit that producers make from selling at a market price higher than their minimum selling price.
- Consumer surplus, which is the difference between the price consumers pay and the price they are willing to pay for a good or service.

Spillover effects, also known as indirect impacts, have the ability to add value to society and the economy as a whole. Mobile technology is an example of a general-purpose technology that enhances productivity and efficiency, ultimately leading to economic growth. As consumers benefit from this technology, it generates social value. Similarly, DTT, a form of broadcasting, provides viewers with free access to all-encompassing TV content. This creates both social and economic value [71].

Entertainment, leisure, information, mobile, and broadcasting services have a significant impact on consumer surplus since many customers are willing to spend more on these services. However, for our analysis, we are focusing on producer surplus. Specifically, we are looking at the expenses that can be avoided by utilizing the UHF spectrum for either mobile or broadcasting. This is because data on producer costs is more readily available and comparable, as opposed to customer willingness to pay, which can vary depending on the consumer type. Unfortunately, there is not much recent research available that allows us to compare the indirect economic and social benefits of mobile phones and broadcasting. To determine the costs and benefits of each spectrum policy between 2021 and 2040, use net present value (NPV) estimates.

- Benefits are predicated on reductions in mobile network capex and opex brought about by increased access to the low-band spectrum in urban and rural areas.
- The costs are determined by reusing DTT and PMSE services, which run on the 470–694 MHz UHF spectrum now. They are predicated on the assumption that DTT providers will continue to broadcast TV programs on a national, regional, and local level at the same level [72, 73].

4.3. Low-Band Spectrum's Importance in the Rollout of 5G Networks in Developing Nations

Due to its exceptional propagation properties, it is especially well suited for providing coverage in outlying and rural locations. This is crucial because network deployments in low- and middle-income nations with significant rural and sparsely inhabited populations are much less likely to be financially viable. Rural residents may not have access to the newest digital technology if there is insufficient low-band spectrum as shown in Figure 6.

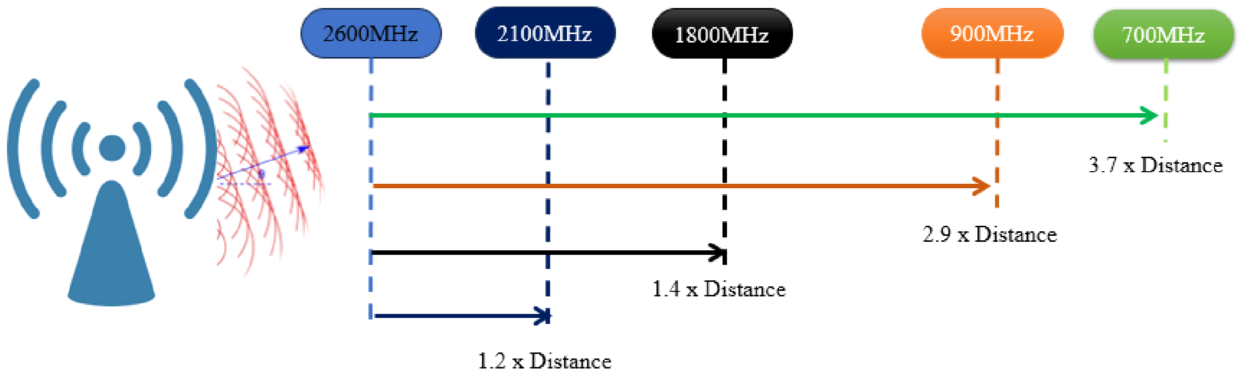

Figure 6. Comparison of coverage by 5G spectrum band [63]

It has improved building penetration and serves built-up regions with greater capacity, offering "deep" indoor coverage that extends into places where people live and work. Indoor traffic can make up between 30 and 70 percent of all mobile traffic, depending on the area and kind of house. As a result, low bands frequently carry more traffic than they can handle. To meet future 5G demand in both urban and rural areas, it is essential to allot enough low-band spectrum.

4.4. Faster 5G Rollout Has Been Achieved in Countries Using the 600 and/or 700 MHz Band

Many countries have utilized the 700 MHz frequency range as their primary low band for 5G, with North America being the exception as it uses the 600 MHz band. While most countries have used 800, 850, and 900 MHz for 2G, 3G, and/or 4G, it is expected that these frequencies will also be used for 5G. Mobile operators are predicted to use either the 600 MHz or 700 MHz bands for 5G in almost half of the countries that have already adopted the technology by the end of 2022, according to Figure 7. Figure 7 emphasizes the importance of preserving these low bands for 5G use. Countries that have implemented 5G using the 600 or 700 MHz bands have achieved greater population coverage compared to those that haven't.

4.5. Regional Commonwealth in the Communications Sector (RCC)

In the RCC region, low band 5G is expected to bring about $3 billion of benefits to the economy by 2030, which is more than 0.1% of the total GDP. A variety of local industries, such as retail, oil and gas, manufacturing, and transportation, will adopt low band 5G. 5G applications are expected to improve the efficiency of operations and offer quick repairs to prevent equipment failure, which will improve the safety and productivity of oil and gas plants. The use of 5G applications will include remote device control, smart monitoring, and AI that is 5G-enabled. Figure 8 illustrates the GDP contribution of low band 5G spectrum, by industry, in the communication sector of the Commonwealth region from 2020 to 2030.

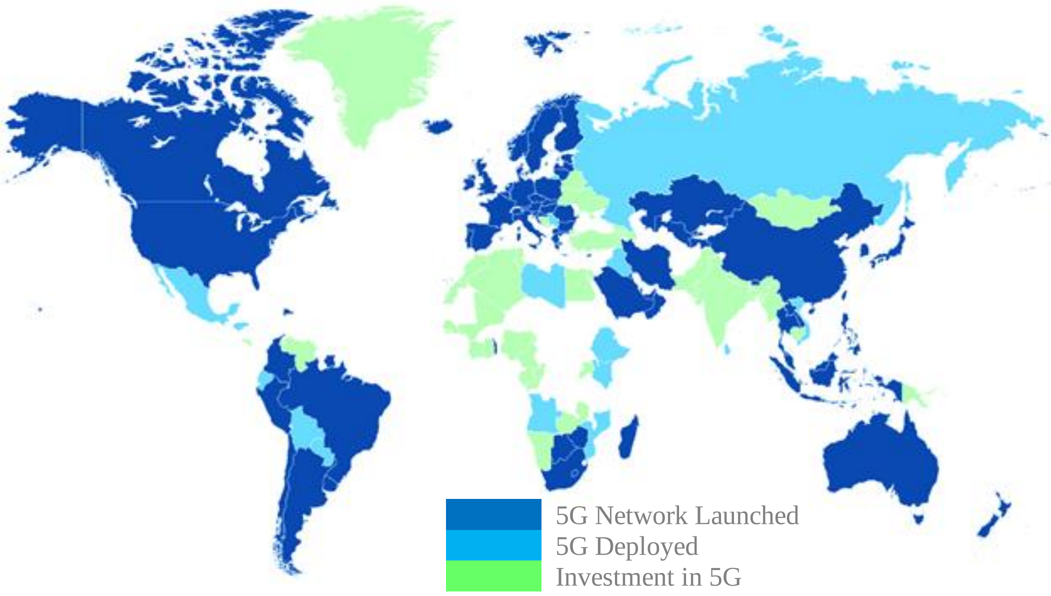

Figure 7. Countries that have implemented 5G networks and technology and have invested in 5G

5. In 2030, Low Band 5G is Projected to Increase GDP by $130 Billion

By 2030, low band 5G is expected to have an economic impact of $130 billion. The impact of massive IoT, also known as mIoT, will account for 50% of this impact. Many current and future IoT use cases require broad area coverage along with population coverage [74]. Low-band spectrum is best suited to provide this coverage. The Internet of Things (IoT) applications are predicted to play a significant role in accelerating digital transformation across various industries, such as manufacturing, transportation, smart cities, and agriculture. Fixed wireless access (FWA) and enhanced mobile broadband (eMBB) will be responsible for the remaining economic impact. This is since low bands are essential for providing high-speed broadband connectivity in areas that are underserved by fixed networks.

Low band 5G technology will enhance mobile technology's social and environmental benefits, as well as macroeconomic impacts. This involves lowering poverty, enhancing well-being, gaining access to health, financial, and educational resources, and facilitating the decrease of greenhouse gas emissions. This is crucial for rural inhabitants, who suffer the most from these issues yet are also 33% less likely than urban residents to receive mobile internet and have poorer network performance overall in low- and middle-income nations. In many rural locations, boosting capacity to supply 5G-based use cases won't be feasible without sufficient low-band spectrum. Figure 9 illustrates how much each sector will contribute to global GDP using low band 5G spectrum projections in 2030.

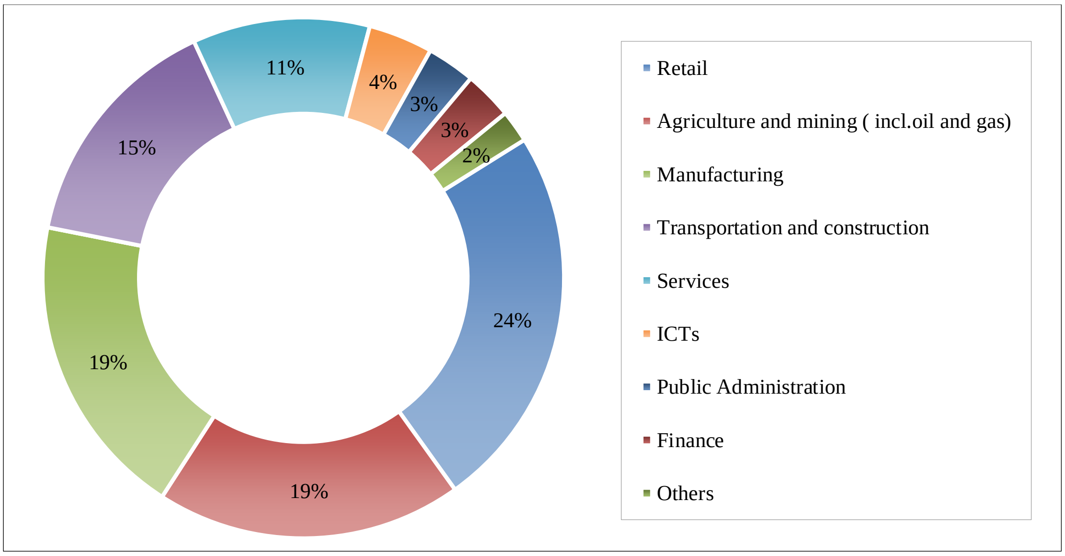

Figure 8. RCC GDP contribution from low-band 5G spectrum, broken down per industry, 2020–2030

Because of the Internet of Things, the global market for precision farming is quickly growing. It is anticipated to reach $26 billion by 2030, growing by 14% annually from about $8 billion in 2021.

The looming food problem and growing interest in ways to increase agricultural output can both be addressed with precision farming technologies. The adoption of precision agriculture raised farmers' output by 4%, decreased their use of fertilizer and herbicides by 7% and 9%, and decreased their use of fossil fuels by 6%, according to research by the Association of Equipment Manufacturers (AEM). Precision agriculture provides farmers with a wide range of tools and methods to monitor their fields more efficiently by observing multiple indicators.

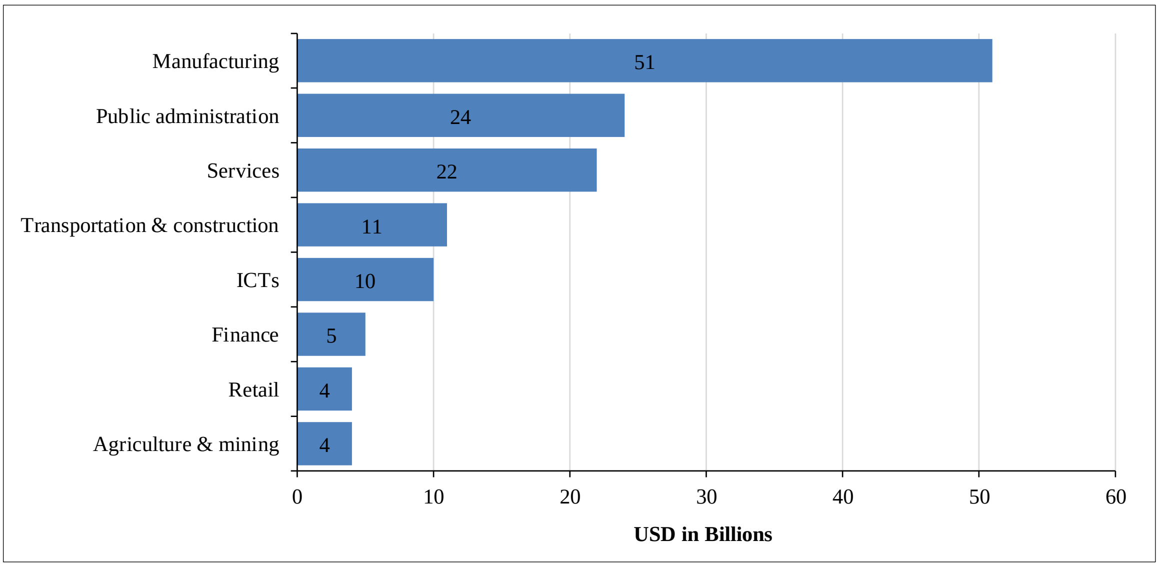

Figure 9. Global low-band 5G spectrum GDP contribution, by industry, projected for 2030

For example, farmers can monitor rainfall, analyze soil samples, predict fertilizer use, or determine crop nutrient requirements. All this helps us understand the circumstances that favor the highest agricultural production [75]. In Table 2, the regional breakdown of low band 5G's GDP contribution in 2030 is presented.

Table 2. Impacts of low band 5G on regional GDP contributions, 2030

Region	GDP Contribution USD Billions	Percentage of GDP
North America	26	0.07%
Latin America and the Caribbean	9	0.11%
Asia Pacific	62	0.11%
Europe	26	0.08%
RCC	3	0.11%
Middle East and North Africa	4	0.08%
Sub-Saharan Africa	3	0.08%

Countries that have adopted 5G technology utilizing the 600 or 700 MHz bands have achieved greater population coverage than those that have not. Figure 10 demonstrates that 5G offers broader social and environmental advantages compared to low-band technology, resulting in greater accessibility for more people, as well as significant macroeconomic impacts.

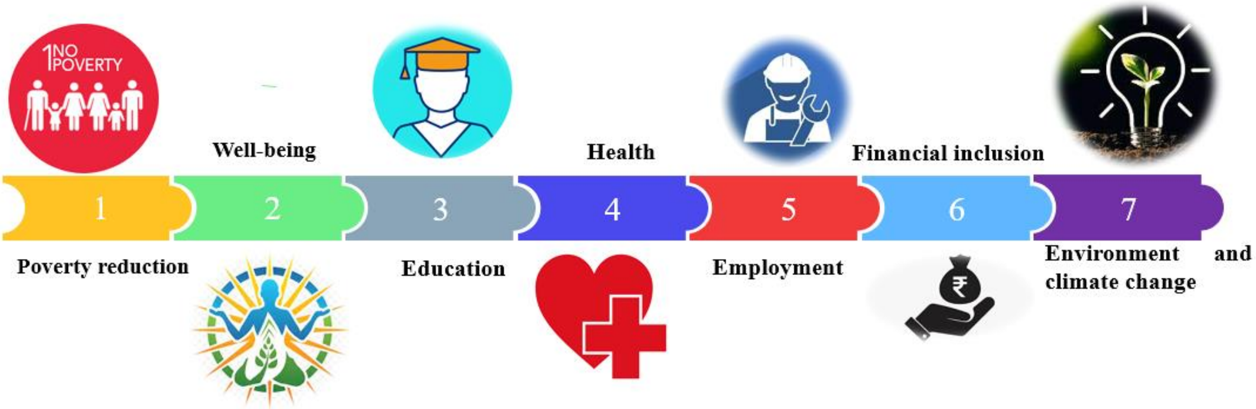

Figure 10. Low bands can help offer 5G's macroeconomic benefits which include broader social and environmental advantages to more people [54, 70, 76, 77, 78]

5.1. By 2030, the Pacific Islands will have 1.5 Million 5G Connections

Some Pacific Island nations will soon adopt 5G technology, while others will continue to rely on older networks such as 2G and 3G for the foreseeable future. By 2030, the Pacific Islands are expected to have 17% of all connections on 5G, compared to the global average of 54%. The introduction of 5G will help improve connectivity and digital transformation, which will enhance living conditions in the region. Additionally, access to emerging digital services like the metaverse will become more accessible. Certain nations in the area have already planned to take advantage of the opportunities that the metaverse presents.

It is projected that by 2030, the number of smartphone connections in the Pacific Islands will reach 8 million. Across the region, there will be an average increase of 10 percentage points in smartphone adoption from now until 2030. By 2030, smartphones are expected to make up 90% or more of mobile connections in the area, which is a trend that has been steadily increasing. The growing affordability of smartphones and the need for connectivity are the main contributors to this positive adoption trend. Figure 11 depicts a comparison of smartphone connections in the South Pacific in 2022 and 2030.

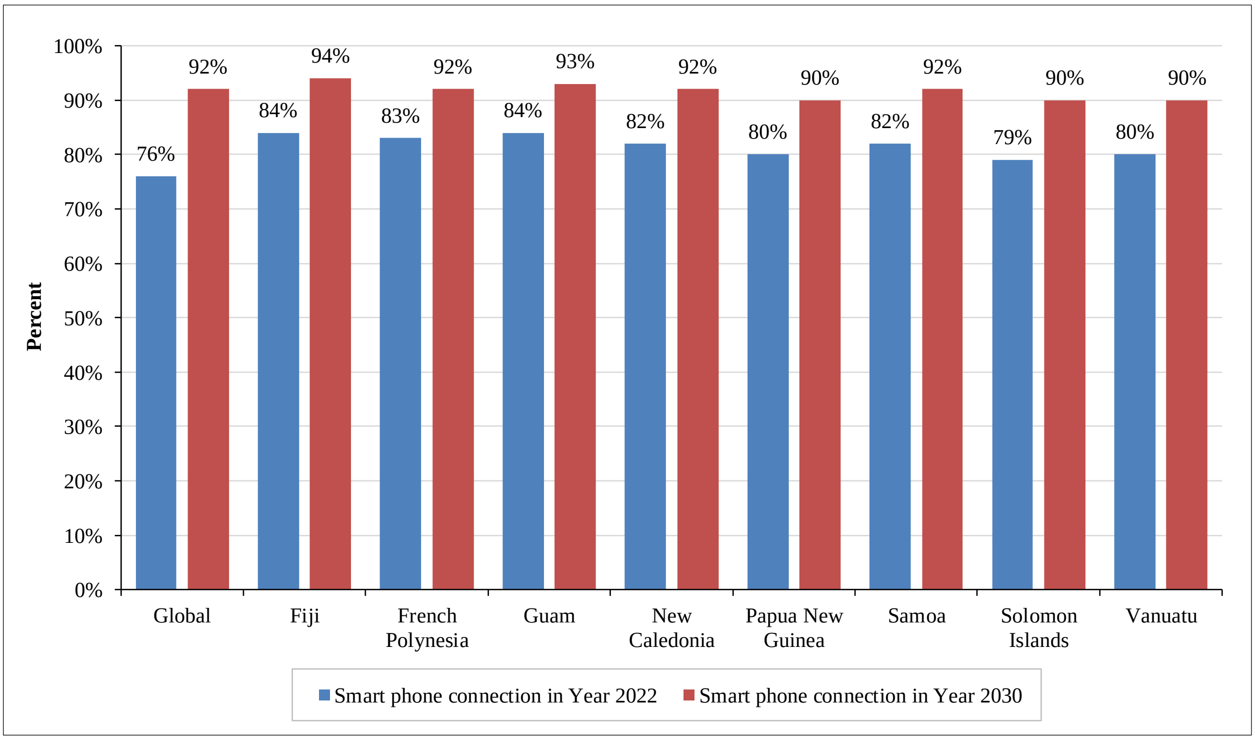

Figure 11. Smartphone connection comparison in the South Pacific by the year 2030 concerning 2022

5.2. Fiji Will be the Region's Leader in Authorized Cellular IoT Connections

Fiji leads the Pacific Islands in cellular IoT connections due to its efforts in digital innovation and transformation. In contrast, other markets such as Papua New Guinea, the second-largest cellular IoT market in the region, are still in the early stages of the market. The Cook Islands have implemented cellular IoT systems for smart metering and energy management in the utility sector. Furthermore, industries such as aggrotech and climate tech also utilize cellular IoT solutions [79].

The pandemic had a negative impact on the growth of operator revenue, but it picked up once restrictions were eased. However, competition is expected to slow down the rate of revenue growth in the coming years. Despite this, demand for data services is on the rise, ensuring that revenue growth will remain positive. As mobile markets in the region mature, operators will have to expand their service portfolios to create new sources of revenue, as revenue growth from core telecom services starts to slow down.

Access to formal financial services in the Pacific Islands remains challenging, but recent initiatives at both national and regional levels have made significant progress. Thanks to the Pacific Financial Inclusion Programme (PFIP), over 2 million Pacific Islanders now have access to financial services. Since its establishment in 2008, PFIP has supported 44 initiatives with financial service providers that have utilized innovative technology and products [72, 80].

In many underdeveloped regions, mobile technology can greatly assist in the uptake of financial services. Currently, there are nine live mobile payment services available to those without access to traditional banking in six different Pacific Island nations. These include two services in Fiji, three in Papua New Guinea, and one each in Samoa, the Solomon Islands, Tonga, and Vanuatu. On some islands, registration rates are particularly high, with 51% of adults in Fiji, Samoa, the Solomon Islands, and Tonga collectively having a mobile money account. However, despite these high registration rates, fewer than 10% of these accounts are currently active, indicating low levels of activity [71, 73, 80].

Within the region, subscriber penetration rates vary greatly, with Fiji having the highest rate at 84% and the Marshall Islands having the lowest at only 11%. Despite Papua New Guinea being the most populous nation in the area, with a significant number of unconnected residents, its subscriber penetration rate is only 30%. This presents a significant challenge for operators, governments, regulators, and other industry stakeholders in the region, who must work towards connecting the largely disconnected masses [71].

As of the end of 2018, over 50% of the connection base was made up of mobile broadband connections (devices capable of 3G and 4G). These connections are becoming increasingly popular in the region. It is projected that by 2023, 4G connections will account for more than half of all connections, which is more than triple the amount at the end of 2018.

The area now has operational networks from 34 LTE. Tuvalu Telecom, located on the island of Tuvalu, began operations in 2018. Operators are investing in improving the speed and coverage of their networks. For example, Vodafone Fiji announced in 2018 that it would invest FJD207 million ($98.6 million) in upgrading its mobile networks to expand "4G+" coverage to over 90% of the population. They plan to build 244 new sites to expand 4G coverage and speed and upgrade about 100 current 3G cell sites to LTE-A technology. Digicel also revealed a $50 million initiative to enhance LTE-A coverage in Fiji's most populous areas [80].

The use of mobile broadband is increasing, as seen in the growing popularity of smartphones. It is expected that by 2025, 65% of connections will involve smartphones, up from just 30% in 2018. The average selling price of cell phones dropped below $120 in many low-income markets around the world in 2018. Gionee and Tecno, among other Asian producers, are offering sub-$100 smartphones. MINTT, an Australian company, is also offering cheap devices to low-income consumers [80]. They introduced their first products in Papua New Guinea in 2017 at lower prices than many feature phones, providing a 4G-capable smartphone with a full metal body, fingerprint scanner, and glass screen. Figure 12 shows the key mobile industry milestones in the Pacific Islands through 2030, with an expected increase of over 1 million mobile customers in the region over the next seven years. However, even with this increase in subscribers, penetration will still be lower than the global average of 73%, as indicated in Table 3.

5.3. Impact on the South Pacific's 5G Networks and the Associated Higher Rollout Costs

To begin, we must estimate the demand for 5G traffic in urban areas. Technical assumptions are made to calculate the downlink and uplink capacity per site, which helps us determine the number of sites required to meet the traffic demand in both the baseline and the scenario. We assume that operators will meet the portion of 5G traffic demand that is not offloaded to Wi-Fi. Using cost hypotheses for capex and opex, we can determine the total cost of ownership (TCO) for the two simulated 5G networks. These two TCOs are then compared in the CBA template. If the costs of the scenario are more or less than the baseline, some of the cost increase or decrease is passed on. We assume a certain level of demand elasticity to calculate the decrease or increase in 5G penetration in the scenario compared to the baseline. The model then adjusts the traffic demand estimation to account for the fall in 5G penetration until it reaches numerical equilibrium. The reduction in adoption in the scenario helps us determine the GDP benefits that would be lost or gained compared to the baseline. Our assumptions for estimating traffic demand in urban areas include:

- The proportion of urban residents to the overall population, as well as its growth through time.
- Examine the adoption of 5G connectivity and how they have changed over time.
- The minimal DL and UL performance standards per connection that 5G networks will provide.
- The proportion of users who are using the network actively at its busiest point, as well as their growth rate over time.
- The proportion of traffic that is sent over Wi-Fi.
- The incumbent operators' market share over the period.

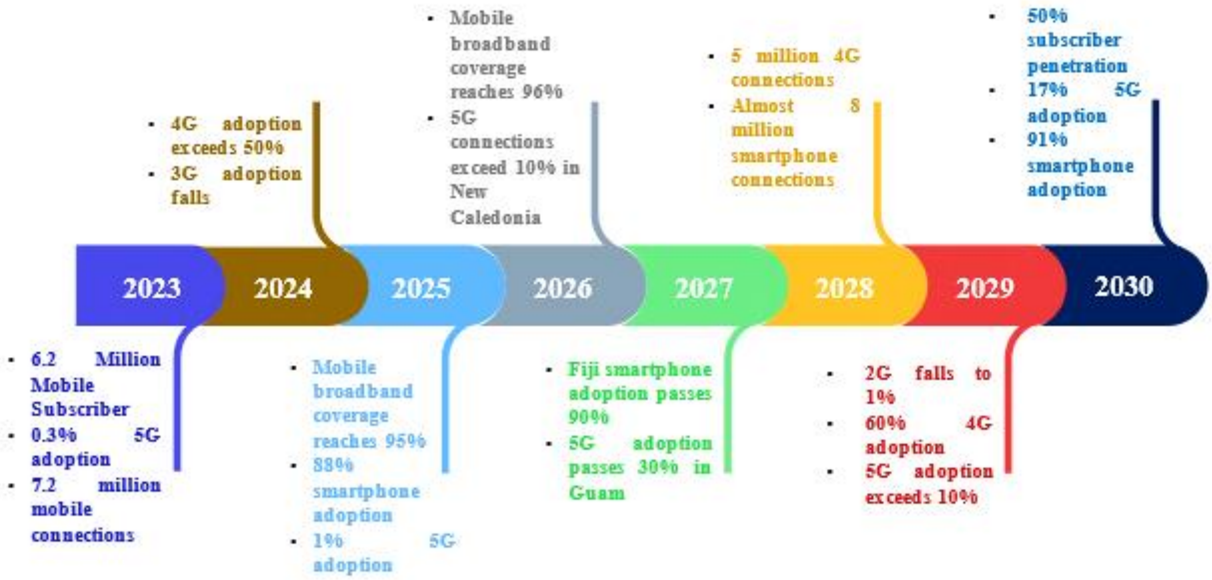

Figure 12. Key mobile industry milestones in the Pacific Islands to 2030

Table 3. The Pacific Islands' Mobile Economy

Categories	Number of Subscribers in 2022 in Millions	Number of Subscribers in 2030 in Millions	Percentage of the population have mobile phones in 2022	Percentage of the population have mobile phones in 2030	Compound annual growth rate 2022-2030
Unique mobile subscribers	6.0	7.3	47%	50%	2.5%
Mobile internet users	3.5	4.5	27%	30%	3.1%
SIM connections (excluding licensed cellular IoT)	7.0	8.8	54%	60%	2.8%
4G percentage of connections (excluding licensed cellular IoT)	48%	59%			
5G percentage of connections (excluding licensed cellular IoT)			0.2%	17%	
Smartphones Percentage of connections (excluding licensed cellular IoT)			80%	91%	
Licensed cellular IoT connections for Fiji and Papua New Guinea	64400	102500			
Operator revenues and investment	USD1.3 billion	USD 1.6 billion			
Public funding	USD 296 million				
Mobile industry contribution to GDP	USD 2.1 billion	USD 2.7 billion			
Employment	23,000 jobs				

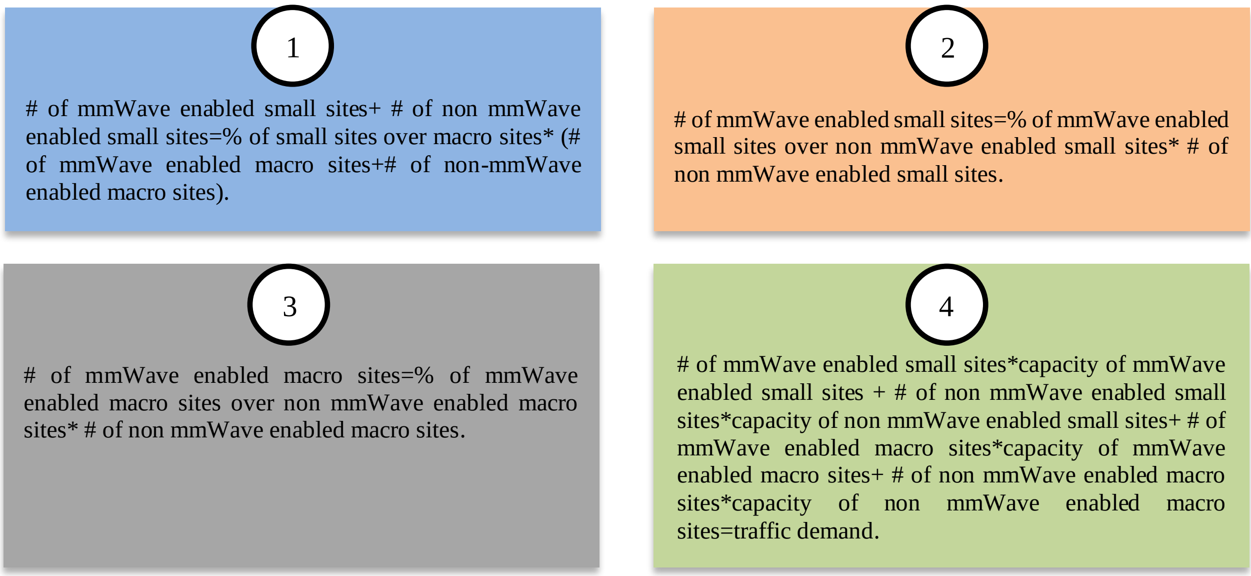

Figure 13. The number of sites required to meet traffic demand each year

It is expected that the 5G networks will have to meet the ITU's minimum performance standards of at least 100 Mbps DL and 50 Mbps UL everywhere [81]. Based on predictions, the connected user shares for all nations will be 20% at the start of the period and will decrease to 10% after the period [82, 83]. At the beginning of the term, connected user shares are expected to be 40% and 20%, respectively. Additionally, it is assumed that 71% of traffic demand will be offloaded to Wi-Fi [84]. To calculate traffic demand in both the uplink and the downlink, we utilize the equation shown below:

$$\begin{aligned} 5G\ Traffic\ Demand \\ &= urban\ population\ \times\ performance\ requirement\ \times\ share\ of\ connected\ users \\ &\times\ share\ of\ connected\ users\ that\ are\ active\ \times 5G\ penetration\ \times (1 - offload\ to\ WiFi) \\ &\times Market\ share\ of\ incumbent\ operators \end{aligned}$$

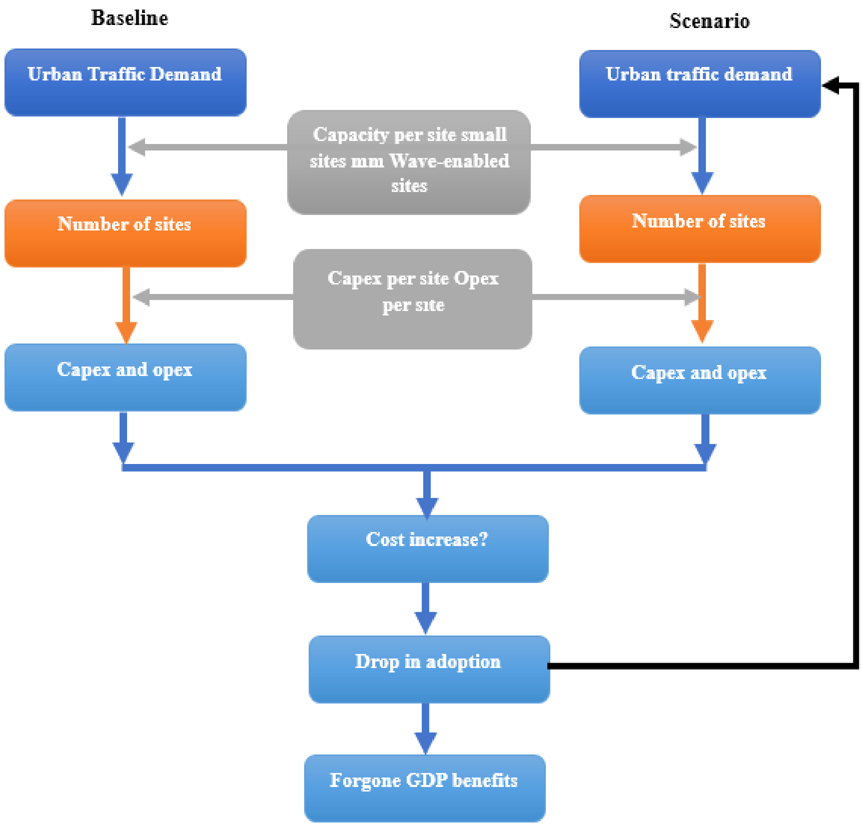

Figure 14. Impact on 5G networks: higher rollout costs approach

By resolving the system of four steps as shown in Figure 13 with the four unknowns below, both for DL and UL traffic demand, one can compute the number of sites required to meet traffic demand each year:

Site planning central assumptions are made as follows [85]:

- The share of small sites over macro sites is 10%, 20%, and 50% in the low, mid, and high-income countries respectively.
- The tiny sites that support mmWave account for 30%, 30%, and 20% of all tiny sites, respectively.
- The mmWave-enabled macro sites make up 30%, 30%, and 20% of all macro sites, respectively, compared to non-mmWave-enabled macro sites.
- Sites that support mmWave will be ready in 2023 and 2025 accordingly.

The total number of sites is then calculated as the sum of the maximum number of sites needed to satisfy DL and UL traffic demands. A schematic of the 5G networks in the South Pacific is shown in Figure 14, along with an estimation method for their greater rollout costs.

6. Obstacles in the Deployment of the 5G Network

5G has entered a new age, and telecom companies are speeding up the deployment of these networks. In the twenty-first century, a wide range of technologies have been adopted by a number of industries, including healthcare, transportation, manufacturing, and the automotive industry. Numerous business cases have also been implemented, bringing innovation to the ecosystem as a whole and improving our quality of life [86]. In this sense, every other industry's success in the modern business world is being facilitated by the development of wireless network technologies like 5G. The 5G technology is an advancement above 4G LTE technology. 5G has much more to offer than just low latency and fast speeds. It has the potential to bring about revolutionary changes, and every industry is keen to adopt this cutting-edge technology in order to reap major rewards and gain a competitive edge. Mobile carriers are moving to expedite the rollout of 5G and increase its accessibility for an increasing number of users. Nevertheless, several challenges are impeding the rollout of 5G and causing a delay in the entire process.

- Spectrum availability and frequency band issues: As 4G gives way to 5G technology, new use cases will arise that require high-frequency bands. Nonetheless, because of its affordability and accessibility, spectrum is regarded as a vital resource, requiring operators to create a solid economic case. The kind and quantity of spectrum that network operators currently possess or can acquire through upcoming spectrum auctions will dictate the viability of 5G networks, as well as the novel features and obstacles that accompany the chosen radio bands [87].
- Deployment of several tiny base stations and antennas: Higher frequency radio waves are used in 5G and can be targeted. Despite the fact that 5G antennas can beam data over shorter distances and can handle more users and data, their restricted range poses the largest implementation problem for 5G [88]. Even though they are smaller, the antennas and base stations utilized in these scenarios would probably need to be put on houses or other structures. To propagate waves over longer distances and maintain consistent speeds in densely populated areas, more repeaters will need to be installed in cities. Until the 5G network reaches maturity, providers will continue to cover larger areas utilizing low-frequency spectrum bands.
- It is more crucial in complex 5G architecture: With a single network infrastructure to handle both core networks and Radio Access Networks (RAN), 5G promises to satisfy a variety of service requirements. In order to create various radio networks and connections, slice the network, create intelligence networks at the edge, and accomplish many other things [89], 5G networks are making extensive use of the Network Functions Virtualization (NFV) concept. However, these new methods call for a new operating model that differs and is more sophisticated than its earlier iterations. Additionally, building an architecture that can meet network requirements requires the right understanding.
- Methodology for the rollout of 5G networks: Operators must first develop a plan for the rollout of 5G networks. Second, the strategy chosen determines how the deployment process will go depending on how this strategy is implemented. Operators design their deployment model and strategy based on the spectrum networks they have, as well as the densification and coverage requirements, which are eventually necessary for addressing particular 5G use cases [90]. A new approach to 5G network deployment and its regulatory requirements will be necessary due to the issues posed by the massive volume of 5G tiny cells and the use of mmWave frequencies.
- 5G Expertise manpower is required: Telecommunication service providers must ensure that their power distribution networks and fiber solutions with cell towers are in place to easily support 100–400 Gbps devices made practicable by the new telecoms policy before they can begin deployment chores. Telecom companies require qualified experts to deploy the cutting-edge technology since they want to roll out 5G as soon as feasible. The majority of businesses currently employ workers who lack the necessary skills to do their jobs, and this problem is exacerbated by the lack of available talent finding such talent is like trying to find a pearl in a sea of

talent [41, 91]. Because of this, operators face a significant challenge when implementing 5G networks. However, this challenge can be met by providing their 5G workforce with reskilling programs, such as online and offline courses and certifications pertaining to 5G technologies, to upgrade their skill sets and make them more capable of managing network deployment workloads.

- Overseeing the costs associated with the rollout of 5G networks: The 5G rollout is trickier than it first appears. Everything from spectrum bands to cell sites, equipment such as cell towers, fiber cables, and skilled labor, in addition to the commercialization fees required by regulators prior to making it accessible to users. The majority of operators find it difficult to deal with the costs associated with each and every step of the 5G implementation process. Prior to making an investment, planning and strategy are required. A methodical approach to cost investment can prevent them from squandering money and instead allocate it towards meeting essential requirements [92].
- Regulations impede the rollout of 5G networks: 5G will be developed differently in each country, with few common and many unique features. This indicates that while certain technological specifications are universal, rules and regulations differ from nation to nation and represent a significant obstacle to the widespread deployment of 5G networks. In the region where they are going to provide 5G mobile network services to users, mobile network operators must adhere to the standards created for 5G network technology [93].
- Deployment of 5G networks presents security and privacy issues: Although 5G appears to be leading the way and bringing new advancements to the ecosystem, the cutting-edge technology comes with certain security and privacy concerns. From the perspective of the consumer, identity, location monitoring, and personal data are the main privacy concerns. In contrast to earlier technologies, the 4G network is located in an area with extensive coverage, and signals are transmitted from a single cell tower. However, 5G networks are different from 4G technology in that they have a smaller coverage area and less effective signal penetration [94].

Because of this, 5G wireless networks function effectively with smaller indoor and outdoor base stations and antennas. As a mobile user talks with the antenna repeatedly, the information on this 5G cell tower / antenna can reveal a user's position and even the building in which they are present. Threats such as semantic information assaults may arise as a result of this data. Location data leaks can potentially occur in 5G mobile networks due to access point algorithms [95]. As a result, additional 5G antennae enable accurate user position monitoring both indoors and outside. Moreover, mobile users' identities may be revealed using International Mobile Subscriber Identity (IMSI).

6.1. 5G Future Directions and Recommendation in Day-to-Day Business

Leaders in business and consumers alike have a natural interest in 5G networks and the devices and apps that operate on them. Almost 120 million 5G devices were shipped by the end of 2023, up 9.3% from the previous year, according to recent data conducted in the US alone. A compound annual growth rate (CAGR) of 7.4% is predicted for the 155 million units that are anticipated to ship by 2027, the last year the study covers [96, 97]. 5G is already helping the healthcare sector operate more efficiently, gain deeper insights from data, and enhance patient outcomes. Doctors will be able to access patient information on the go, do vital surgeries remotely via robotics, and discover new treatments because to its low latency, fast speed, and expanded bandwidth [97]. To be more precise, 5G will keep doing the following:

- Increase the quantity of IoT devices being utilized to track the health of patients remotely.
- Provide personnel with consistent connectivity and real-time data so they can decide on patient care more quickly and intelligently.
- Send high-definition images and videos, including X-rays and mammograms, quickly and safely so that the results may be viewed from a distance.

Worldwide supply chains will profit from 5G's blazing-fast speeds and enhanced dependability as it becomes more widespread. Global commerce networks are more dependent than ever on 5G speeds and high-speed data transfer capabilities since they are becoming more and more digitalized. The more a supply chain is automated and digitalized, the more 5G may be used to boost productivity, cut expenses, and improve security. Although its potential has not yet been fully realized, 5G service is currently being deployed in train stations, airports, ports, and other logistical hubs that are essential to supply chain infrastructure [96]. You may anticipate that 5G connectivity will soon have a greater impact on improving the consumer and staff experience. IoT gadgets, such as shelf sensors that detect when an item is out of stock and promptly reorder it, cashier-less checkouts, and HD cameras and drones to replace security guards are just a few of the trial programs that are now underway.

More individuals and locations can have access to the internet at a lower cost thanks to the idea of “fixed” wireless connections, which are internet connections that use radio waves rather than cable or fiber to provide a seamless wireless experience in a house or place of business. An antenna that links to the closest 5G transmitter is connected to a home or place of business in a fixed 5G environment [9, 98]. For significantly less money, 5G fixed wireless networks may provide the same connectivity, speeds, and dependability as fiber or cable connections.

The introduction of 5G connectivity is anticipated to bring about a dramatic alteration in urban areas. These neighborhoods are in dire need of transformation because of their congested streets, heavy traffic, pollution, and noise levels. The application of Internet of Things (IoT)-connected sensors has already assisted cities in improving air quality and traffic flow [99]. But as 5G technology advances, we should anticipate even more innovation in this field. Smart cities stand to gain a great deal from 5G's AI capabilities. A number of applications that leverage AI provided by 5G technology are presently being evaluated to help with tasks like emergency call routing and energy management.

A computing system known as "edge computing" uses a 5G network to execute operations closer to data sources [100]. Businesses can obtain more control over their data and derive insights more quickly with the use of this technology. Cloud computing is one area where edge computing has a lot of potential because AI needs a lot of processing power to manage the data it's studying [101]. In this case, achieving value for the company depends heavily on 5G connectivity and dependability. For example, moving data from one location to another in a chat or personal financial application uses more power and resources than necessary if the data is being examined at the source [102].

7. Conclusion

The South Pacific region becomes a key player when it comes to favoring socio-economic development through the spread of 5G technology. One of the abilities of 5G is that it can use a low-band spectrum and making use it can ultimately improve connectivity and close the digital divide. Besides, new opportunities for innovation will be introduced in education, healthcare, tourism, agriculture, and so on. Government, businesses, and other communities can engage in the 5G network in the South Pacific for better results and have a great deal of advanced telecommunication that can empower people, promote common development, and create robust and sustainable economies. The 5G technology, has the potential to reduce inequality by providing high-speed internet connectivity to both rural and urban areas that are currently underserved. By increasing productivity and efficiency in crucial sectors, 5G can help fight poverty. The most important sectors in this regard are government and society, agriculture, business and employment, and health, as they are responsible for enabling automation and access to real-time information. Among the many technologies available, the Internet of Things and artificial intelligence stand out particularly. 5G connectivity can improve the quality of life and economic opportunities in disadvantaged areas by facilitating access to essential services such as healthcare and education. Applications enabled by 5G network-based technology include smart cities, digital and online banking, and precision agriculture.

It is important to note that the impact of 5G on reducing poverty may vary depending on different circumstances and strategies. The digital divide remains a major obstacle to poverty reduction. However, the implementation of the 5G network can help narrow this gap by providing high-speed connections and internet access in areas with limited communication infrastructure. This will enable underserved populations to access resources such as online banking, remote employment, and educational opportunities. The successful rollout of the 5G network is expected to have a positive impact on poverty reduction by improving access to vital services, promoting economic growth, and bridging the digital divide in disadvantaged regions. However, this beneficial outcome will only be possible once the 5G network is fully established.

Although the 5G network has the potential to eradicate poverty, there are some limitations that must be considered, such as the need for a significant and costly infrastructure, including base stations, antennas, and fiber optics. Unfortunately, the availability and deployment of this necessary infrastructure in rural and low-resource areas are limited, which can make it challenging for less affluent populations to take advantage of the benefits of the 5G network.

8. Declarations

8.1. Author Contributions

Conceptualization, S.S. and P.S.; methodology, S.S. and P.S.; validation, S.S.; formal analysis, S.S., P.S, J.S., and L.V.; investigation, P.S. and L.V.; data curation, S.S.; writing—original draft preparation, S.S. and P.S.; writing—review and editing, J.S. and L.V.; visualization, S.S., P.S., J.S., and L.V. All authors have read and agreed to the published version of the manuscript.

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The data presented in this study are available on request from the corresponding author.

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8.5. Informed Consent Statement

Not applicable.

8.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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