The WRC series

# Regional Spotlights: Impact of mmWave 5G

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# Executive Summary

Over the past 30 years, mobile technology has fundamentally transformed our lives – improving human connections and access to vital services on a global scale. Today, more than two-thirds of the world's people are connected to a mobile network. Mobile connectivity impacts how we work, play, live, learn, and conduct business.

This is especially true for emerging economies, where mobile technologies currently connect 3.7 billion people and counting. Particularly for people in these economies, mobile technologies are the great connector, empowering societies, providing financial access to previously unbanked communities, and facilitating access to communications and information for those living in remote areas. The mobile industry fuels development – providing the tools to fight malaria, empower women, document birth registrations, generate new businesses, assist with refugee crises, and respond to natural disasters.

We are on the verge of another critical leap forward for mobile services, as countries increasingly shift to the deployment of 5G technologies. 5G has the potential to impact societies even more broadly than other mobile technologies, driving innovation and transforming the digital landscape across different industries and sectors of the society. We will soon see the mass availability of phones with faster broadband, cars that communicate with other vehicles and smart transport infrastructure. Add to that intelligent factories, and innovative tools for remote access to education and medical care, among many other new 5G-powered developments.

The benefits of 5G are truly global, with impacts and new capabilities cutting across industries (e.g. energy production, transportation, professional services, mining, healthcare). They also combine multiple use cases (e.g. remote object manipulation, high-speed broadband to the home and office, industrial automation, next-generation broadband for transport). However, realising the benefits of 5G networks requires the allocation of new spectrum, especially in high-frequency bands above 24 GHz, also known as mmWave.

5G enabled by mmWave spectrum will bring far-reaching benefits to individuals, businesses, and governments around the world. The economic impact of mmWave 5G will vary between countries and evolve over time, taking into account national priorities and challenges as well as the development and deployment of 5G applications. Beyond the significant economic impact, the societal benefits of mmWave 5G are substantial, as the following regional examples demonstrate.

# Regional Spotlights

To provide a deeper analysis of mmWave 5G's potential to address specific challenges, this report looks at two specific use cases in each of the following regions:

- Sub-Saharan Africa;
- South and South East Asia and the Pacific Islands;
- Latin America and the Caribbean (LAC); and
- The Regional Commonwealth in the field of Communications (RCC).

While mmWave 5G will transform economies and societies in a multitude of ways beyond those described below, the examples highlighted in this report reflect both the scale and breadth of the potential impact of mmWave 5G across the globe.

## REGIONAL SPOTLIGHTS: EXAMPLES OF PROJECTED IMPACTS AND BENEFITS

| Region | Impact examples | Description of impact | Project benefits |
|---|---|---|---|
| **Sub-Saharan Africa**<br>mmWave 5G is predicted to increase GDP by $5.2 billion by 2034 | **Port Infrastructure** | By enabling improvements to vital links in the economy such as port logistics infrastructure, 5G will drive growth in the trade industry. mmWave 5G will enable coordinated movement of goods and remote control of essential machinery, leading to more efficient port operations and lower costs, allowing for increased trade. | **Improved port efficiency**<br>**Lower logistics costs** |
| | **Mining and Oil Extraction** | Sub-Saharan Africa's important extractive industries will be able to leverage high-capacity wireless networks enabled by mmWave 5G to reduce costs and improve worker safety. Remotely controlled machinery, video surveillance, and remote diagnostics will bring the potential for lower operational and exploration costs, improved monitoring systems and reduced risk to personnel. | **Reduced extraction costs**<br>**Increased safety** |
| **South & South East Asia and the Pacific Islands**<br>mmWave 5G is expected to increase GDP by $45 billion | **Connectivity** | mmWave 5G can provide "wireless fibre" connectivity, enabling use cases that provide economy-wide benefits, such as smart transportation, industrial automation, and improved healthcare. These and other use cases enabled by mmWave 5G will provide additional tools to policymakers designing integrated urban policies that improve quality of life for all citizens. | **Expanded broadband access** |
| | **Disaster management** | High-capacity, low-latency networks can be used to deliver mission-critical communications and enable connected ambulances, unmanned ground and/or aerial vehicles, remote control of drones, and augmented reality applications. In addition, mmWave 5G will help operators address the fluctuating network demands characteristic of emergency situations. | **Faster, more efficient emergency response** |
| **Latin America and the Caribbean**<br>mmWave 5G is expected to contribute to an economy-wide GDP increase of $20.8 billion | **Education** | mmWave 5G will provide high-speed broadband to support virtual and augmented reality educational applications, allowing distance learning and richer educational experiences. This will expand opportunities and support improved educational outcomes, a benefit that will ripple through entire communities and societies. | **Improved access**<br>**Richer education** |
| | **Transportation** | mmWave 5G applications can assist with the impact of rapid urbanisation by providing solutions to traffic congestion, long commute times, and poor air quality. It will enable connected transport environments, including V2X communication, connected cars and public transport systems, and intelligent transportation systems (ITS). | **Optimised transport routes/improved commute times**<br>**Reduced pollution**<br>**Decreased fatalities** |
| **Regional Commonwealth in the field of Communications**<br>mmWave 5G applications are predicted to lend $6.7 billion in GDP growth | **Workforce productivity** | mmWave 5G-enabled automation, connected transportation infrastructure and the introduction of remote object manipulation will benefit key industries in the region. They include transport, logistics, mining and oil extraction, and manufacturing. These increases in productivity will be key to continued long term economic growth in countries with declining population growth. | **Automation and digitalisation of productive activities** |
| | **High-quality healthcare** | mmWave 5G will provide high-speed broadband that enables virtual training to healthcare staff, remote participation of experts during difficult procedures, and remote diagnostic services. In this manner, mmWave 5G will lead to improved healthcare, especially through access to medical services in rural areas and higher-quality medical services overall. | **Improved healthcare quality and access** |

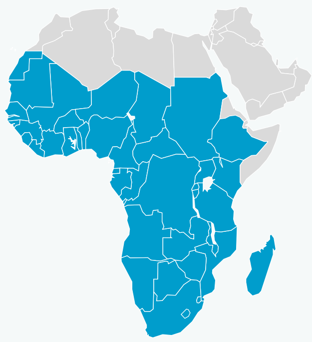
# Unlocking the benefits of mmWave 5G

The mobile industry has a track record of using spectrum to spur innovation and improve global communities. However, access to a sufficient amount of spectrum is an essential precursor to the development of the mobile ecosystem and the realisation of the full societal benefits of mmWave 5G. As noted by the regional examples highlighted on the previous page, mmWave spectrum can provide numerous high-capacity, low-latency 5G applications that will fuel economic growth and societal benefits around the world. However, the full potential of these benefits is dependent on administrations supporting the identification of new mmWave spectrum for mobile services at the 2019 World Radiocommunication Conference (WRC-19). Without adequate support, the deployment of 5G services may be delayed by up to a decade.

# 1. Introduction

## This report considers how mmWave 5G may play a role in the following four regions:

### SUB-SAHARAN AFRICA



### SOUTH AND SOUTH EAST ASIA AND THE PACIFIC ISLANDS

### LATIN AMERICA AND THE CARIBBEAN (LAC)

### REGIONAL COMMONWEALTH IN THE FIELD OF COMMUNICATIONS (RCC)[1]

For each region two use cases are analysed. They all use mmWaves to enable new or improved tools and processes to increase economic growth and quality of life. The case studies consider key industries such as healthcare, education, trade, and extractive industries, as well as overarching applications like connectivity, industrial workforce productivity, and disaster communications.

This report highlights key potential socioeconomic impacts of mmWave 5G across each of the included regions. Ultimately, the mix of tools and services enabled by mmWave 5G in each region (and the resulting socioeconomic impacts) will depend on numerous factors and will not be limited to the selected examples presented here. Similarly, these examples are relevant to varying degrees across all regions of the world. As such, the conclusions also offer a broader context of the expected overall impact of mmWave 5G.

Access to a sufficient amount of spectrum is fundamental to continue the positive benefits provided by mobile services, including those highlighted in this report for 5G networks. Furthermore, mmWave 5G requires new spectrum identification and in-country assignment, and this must be a top priority for administrations—including emerging economies. As such, the upcoming 2019 ITU World Radiocommunication Conference (WRC-19) presents a critical moment for administrations to secure mmWave spectrum for future use and delivery of 5G-enabled services and applications in their countries.

1. The Regional Commonwealth in the field of Communications includes 12 countries from the former Soviet Union.

# 2. Sub-Saharan Africa

In Sub-Saharan Africa, the roll-out of mobile networks and services has allowed communities to leapfrog wired infrastructure and embrace the Information Age much quicker and more cost effectively than in many developed countries. Building on earlier generations, 5G brings new capabilities for mobile networks to contribute to and enable economic growth. 5G, coupled with mmWave spectrum, opens up the potential for low-latency, data-intensive applications that can provide unique solutions to challenges facing countries in the region. This section focuses on two particular cases where mmWave 5G applications can significantly impact the region in the medium-term. The first case considers applications in transport logistics infrastructure, and the second examines the mining and hydrocarbon industries.

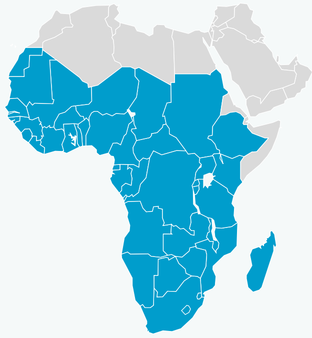
FIGURE 1: EXPECTED CONTRIBUTION FROM mmWAVE 5G TO GDP AND TAX, 2034

**SUB-SAHARAN AFRICA**

**$5.2 billion** boost to GDP

**0.7%** of total GDP growth

**$970 million** taxes generated



Source: GSMA and TMG (2018), "Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands," https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf

This is not to say that transport infrastructure and extractive industries are the only cases where mmWave 5G applications will be deployed or be impactful in the region. Quite the contrary, across industries, mmWave 5G is expected to contribute $5.2 billion in GDP and $970 million in tax revenue (Figure 1).[2] This contribution is forecasted to impact a wide variety of industries and use cases. In a practical sense, mmWave 5G applications will be deployed and used in various ways, which in turn will impact multiple industry verticals as shown in the illustrative case studies considered below.

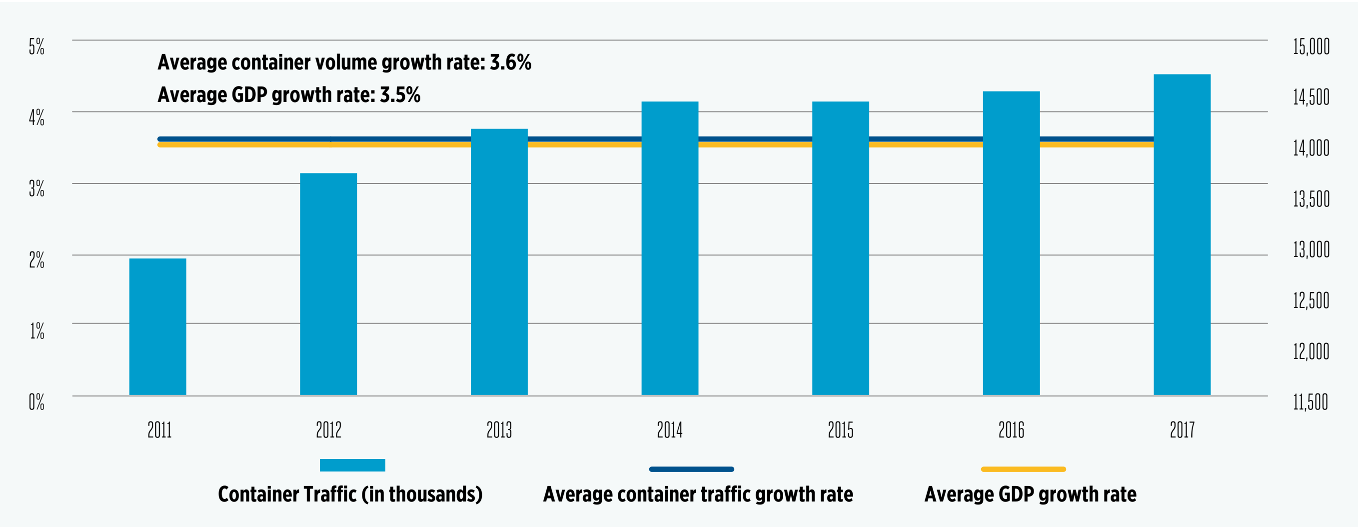
2. These figures were based on the 2018 GSMA report, Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands, which studied the socio-economic impact of mmWave spectrum over a 15-year period (2020-2034). For more information, we invite you to read the full report at https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf.

# 2.1. Sub-Saharan Africa, Case Study #1: Smart transportation logistics hubs

**This case study examines how mmWave 5G will impact transport logistics infrastructure, such as in-land transport hubs and seaports. The application of several mmWave 5G uses cases will be considered in the context of smart infrastructure, including next-generation broadband for transport, remote object manipulation, and high-speed broadband to the office. Certain industries may be particularly impacted by these mmWave 5G applications, beyond the direct benefits to trade. For instance, manufacturing, mining, agriculture, and other sectors will see lower transport costs.**

Africa has 38 countries with a coastline and over 50 ports handling container and other types of cargo. More than 90% of trade to and from Africa is by sea. The volume of container traffic in and out of Sub-Saharan Africa has been increasing at an average annual rate of 3.6% from 2011-2017, demonstrating the growing trade volumes handled in the country. This growth rate is at a similar pace to average GDP annual growth rate, which was 3.5% over the same period (Figure 2).[3] In addition, the remaining landlocked African countries are served indirectly by these coastal seaports and have various forms of inland transportation hubs. These inland logistics hubs are also referred to as "dry ports" and link various modes of transport to seaports in order to deliver cargo from overseas destinations to inland destinations, and vice versa.

FIGURE 2. ESTIMATED VOLUME OF CARGO TRAFFIC IN SUB-SAHARAN AFRICA, MILLIONS OF CONTAINER UNITS (20-FOOT EQUIVALENT UNITS (TEUS)) SHIPPED AND GROWTH RATES, 2010-2017




Source: TMG based on World Bank data.

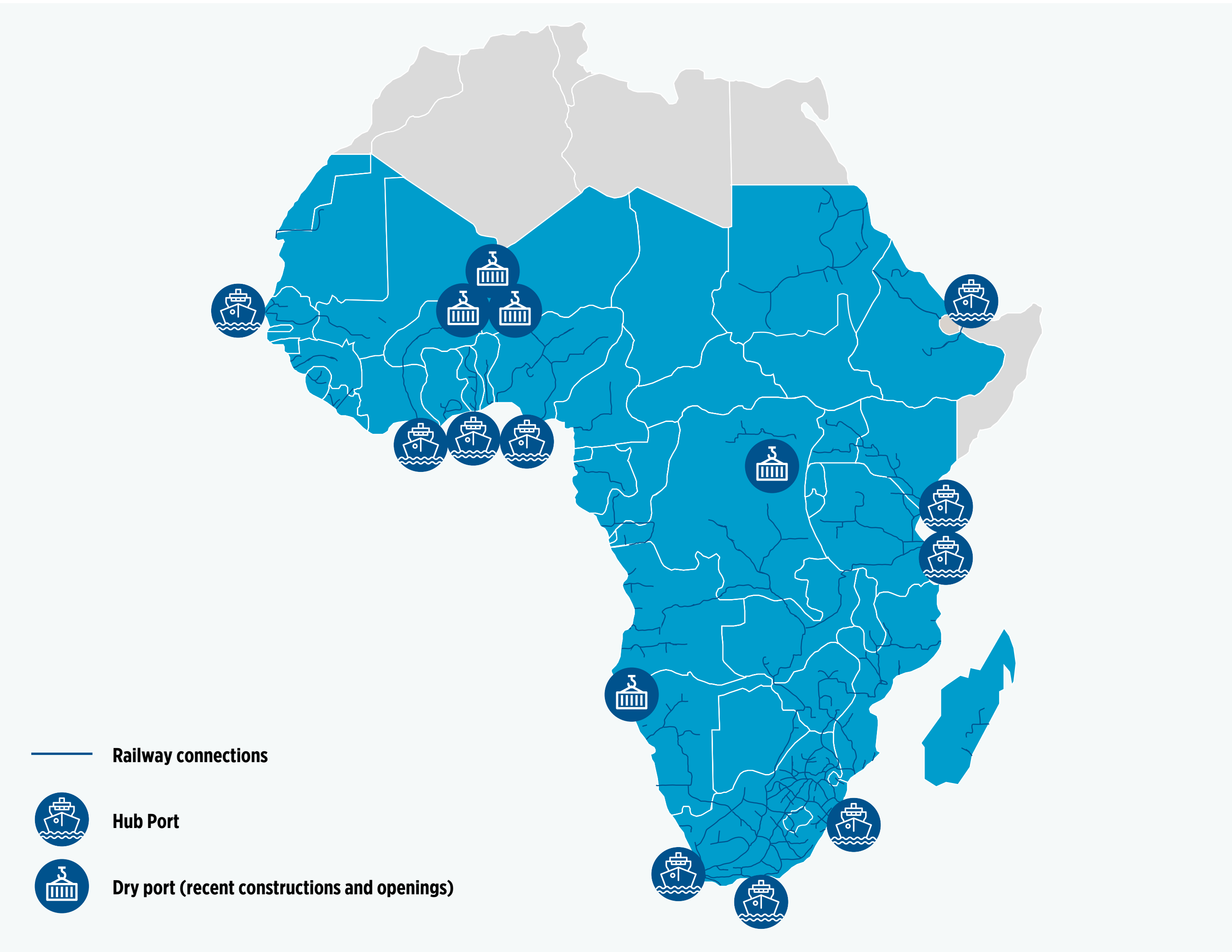
3. World Bank (2019), "GDP Growth (annual %)" and "Container port traffic", https://data.worldbank.org.

Throughput at sea and dry ports is a significant component of incremental growth in Sub-Saharan Africa. According to a recent study by PwC, improving seaport performance by 25% could reduce the price of imported goods in the region by $3.2 billion annually and add $2.6 billion to the value of exports. This would add at least $510 million per annum to GDP growth in Sub-Saharan Africa, a 2% increase in GDP.[4]

For landlocked countries in the region transport logistics present different challenges than for coastal countries and the need to increase speed and reduce costs in the supply chain is arguably even more important. For these countries, dry ports demonstrably reduce transport costs, mitigate traffic jams, accelerate customs clearance, and create virtuous circles of transport infrastructure development. Recent dry port construction and openings include those in Dosso and Niamey in Niger, Bobo-Dioulasso in Burkina Faso, and Kigali in Rwanda. In addition, recent improvements to the Walvis Bay port in Namibia have provided additional logistical support so that Botswana, Zambia, and Zimbabwe authorities can process and ship goods directly at the facility. Figure 3 shows a snapshot of the main transportation and logistics infrastructure in the region, including railway connections, together with 10 key hub ports, and recent dry port constructions.

Expanding overall infrastructure is key to improving port performance. For seaports, this means increasing draught and crane sizes. For both seaports and dry ports, road construction, and expanded warehousing facilities are essential. However, beyond the expansion of capacity, lowering costs in the supply chain is also important. Figure 4 illustrates how mmWave 5G applications can lower costs and improve performance of future sea or dry port environments.

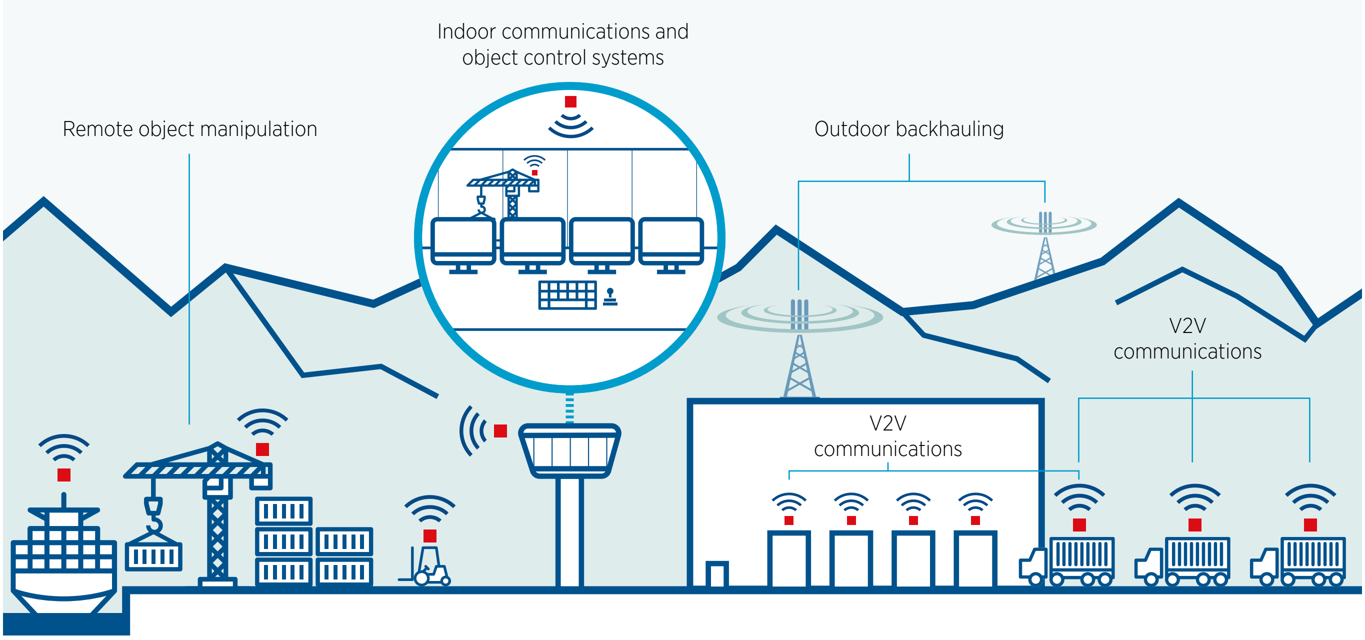
FIGURE 3. MAP OF MAJOR PORT-RELATED INFRASTRUCTURE IN SUB-SAHARAN AFRICA




Source: TMG based on PwC (2018), "Strengthening Africa's gateways to trade," https://www.pwc.co.za/en/assets/pdf/strengthening-africas-gateways-to-trade.pdf

4. "Strengthening Africa's gateways to trade: An analysis of port development in Sub-Saharan Africa," PwC, April 2018.

FIGURE 4: ILLUSTRATIVE EXAMPLE OF mmWAVE 5G COMMUNICATIONS AT SMART PORT




Source: TMG.

Rapid loading and offloading cargo to and from ships, trucks, and railway cars is a critical driver of port performance. Remote object manipulation enabled by mmWave 5G connections to a control centre will allow coordination of the increasingly complex smart cranes that lift containers. This interaction requires a high level of precision, involving demanding network requirements in terms of low latency, reliability, and user experience data rate. These mmWave 5G-based innovations will increase efficiency and lower the hazards related to cargo loading and unloading.

Coordinating the activity of multiple types of transport—shipping, road, and rail—is an increasing challenge for multi-modal logistical hubs. Connecting these varied transport vehicles to internal distribution fleets and infrastructure within the port would lower the costs of processing and moving goods and increase port throughput. Vehicle-to-Vehicle (V2V) communications systems will allow connected vehicles to exchange high-definition dynamic map information between transport vehicles, roadside units, and logistics managers. Thus, vehicles will effectively navigate themselves through the complex and changing port environment to ensure containers are brought to the correct location for loading and shipping.

Similarly, Vehicle-to-Everything (V2X) communications will improve back-of-port operations by enabling coordinated warehousing and transport within the port facility. Connected vehicles will depend heavily on reliable transport communications due to the high volume of data to be exchanged, such as in search of cargo databases, label interpretation, traffic management, and in communication with infrastructure for loading and storing conditions. mmWave 5G will also improve safety conditions in this connected environment by enabling ultra-low latency for control and warning signals.

**Remote object manipulation enabled by mmWave 5G connections to a control centre will allow coordination of the increasingly complex smart cranes that lift containers. This interaction requires a high level of precision, involving demanding network requirements in terms of low latency, reliability, and user experience data rate. These mmWave 5G-based innovations will increase efficiency and lower the hazards related to cargo loading and unloading.**

mmWave 5G will further allow high-throughput indoor data speeds without expensive cabling. It will also support high-capacity, short-distance backhaul to link port facilities to the public network in the absence of fibre links. Through these applications, mmWave 5G will be instrumental in the rapid, inexpensive roll-out of super-fast connectivity solutions that forms a communications base for the port facilities.

Together, these mmWave 5G applications represent multiple use cases within the smart sea and dry port ecosystem, benefiting multiple verticals by delivering the integrated high-speed, low-latency communications necessary for automating numerous logistics activities. Further, this creates pass-through benefits to all verticals importing and exporting goods, and consequently, to the rest of the economy.

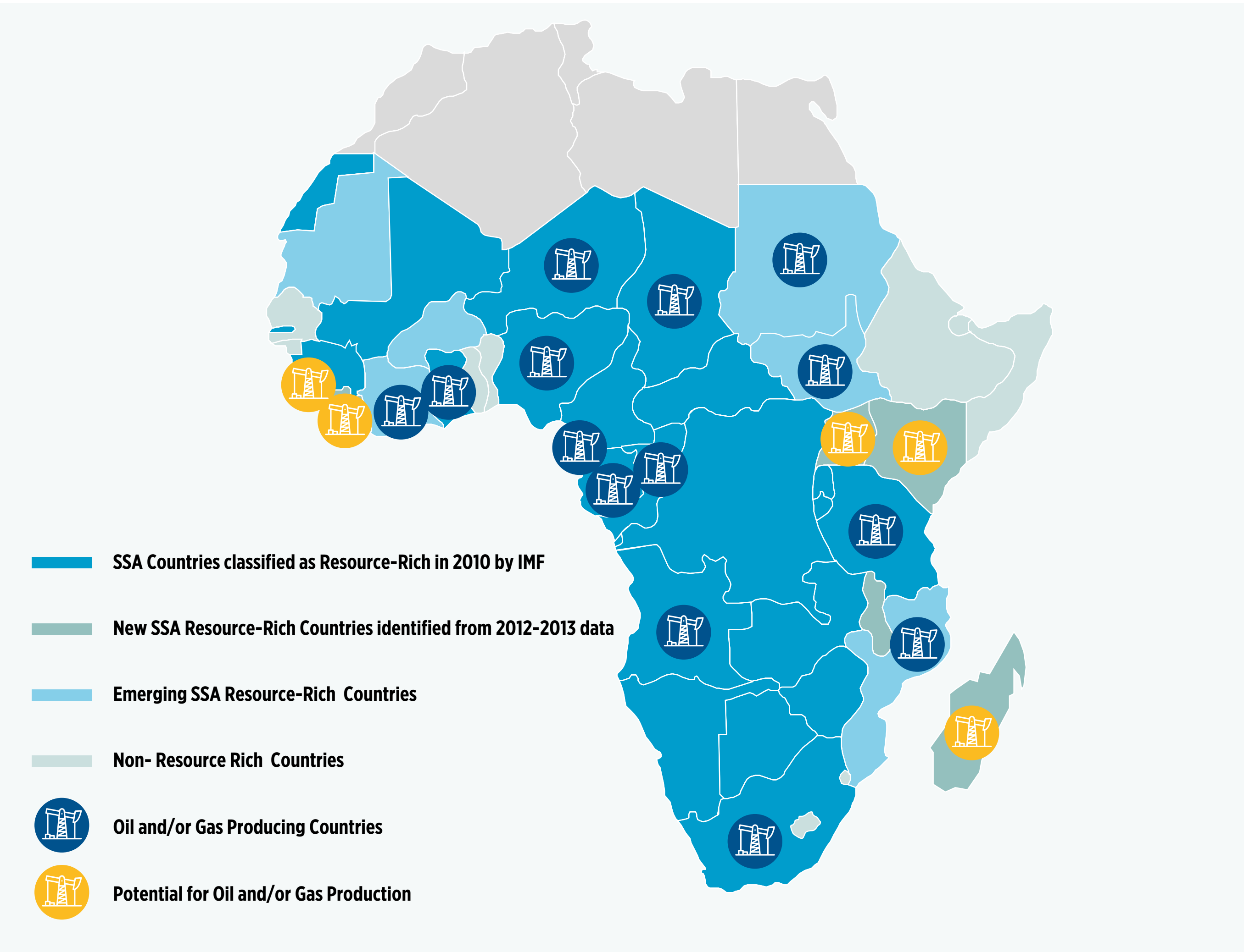
# 2.2. Sub-Saharan Africa Case Study #2: Extractive industries

**This case study shows how mmWave 5G applications can impact the extractive industry (i.e. mining and hydrocarbon production), which are among the highest contributors to GDP in the Sub-Saharan Africa region.[5] Several mmWave 5G use cases apply to the mining and hydrocarbon industries, namely industrial automation, next-generation broadband to transport, and remote object manipulation, as well as broadband to the office.**

The overwhelming majority of countries in Sub-Saharan Africa are classified as resource-rich in terms of hydrocarbons (e.g. oil and natural gas) and minerals (e.g. gold, copper, and iron ore) (see Figure 5).

The nature of commodity markets—subject to highly fluctuating prices—and the reliance on one or two commodities make these countries particularly susceptible to boom-and-bust economic cycles.

FIGURE 5. RESOURCE-RICH AND OIL AND GAS PRODUCING COUNTRIES IN SUB-SAHARAN AFRICA



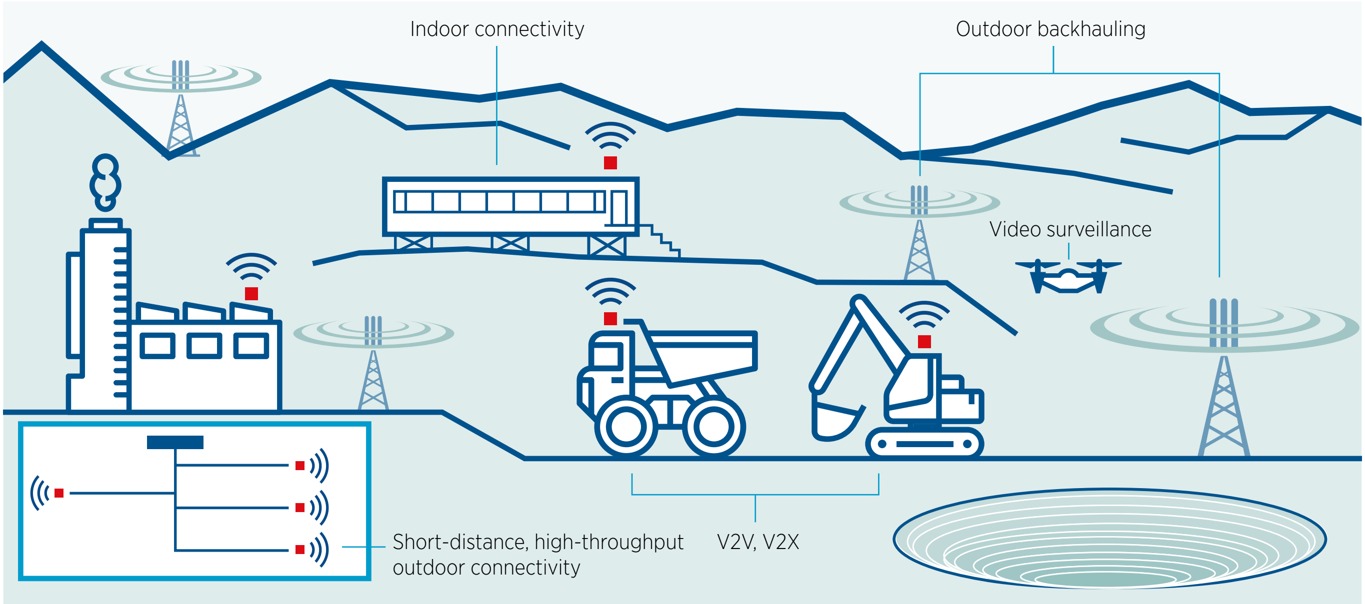

Source: TMG adapted from IBIS, 2014.

5. The manufacturing industry includes hydrocarbon production.

Historically, these industries have been at the forefront of industrial automation for a few reasons. First, the nature of the extraction of non-renewable resources forces technological innovation, as easily accessible sources are quickly exhausted and increasingly costly and dangerous locations are targeted. Second, mining and hydrocarbon producing companies face increasingly stringent environmental and labour regulations to keep workers safe in remote and challenging conditions. Finally, the production of these commodities tends to involve high fixed costs and lengthy start-up times for developing new operations. Cost efficiency becomes critical to increasing production flexibility to protect profitability.

Beyond these considerations, more advanced industrial coordination and mechanisation may be a critical factor in the long-sought objective of moving local extraction companies down the value chain—expanding their role from simple extraction to more complex processing of the commodity into an end product. Figure 6 depicts an extractive industry site, enabled with mmWave 5G applications, to achieve the objectives of lowering costs and improving safety.

FIGURE 6. mmWAVE 5G APPLICATIONS IN THE EXTRACTIVE INDUSTRY




Source: TMG.

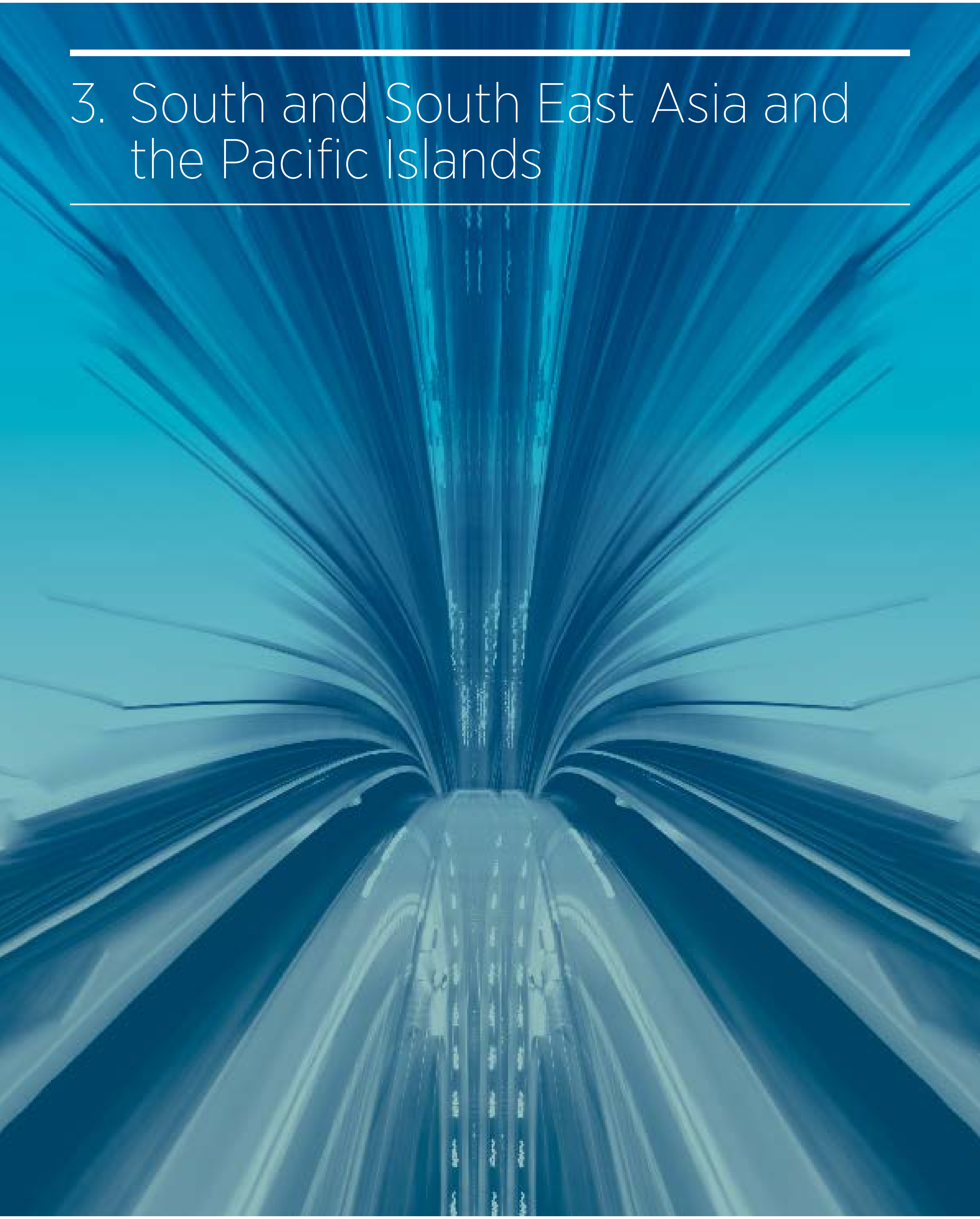
Here, as in a port facility, mmWave 5G could provide short-distance, high-throughput transmission links without the cost of deploying fibre or another cabling in indoor (operational control centres) or outdoor environments (fixed-wireless access to the public network or moving hotspots). However, the most impactful applications would be more industry-specific. For example, on-site processing facilities could be run and monitored remotely, lowering operational costs. Extensive and sophisticated underground monitoring systems could be supported with surface connectivity to transmit information back to control centres for analysis and assessment.

New sites can be more cheaply and safely explored through smart and remotely controlled exploration vehicles. Similarly, dangerous extraction activities involving blasting, digging or crushing could be carried out through remote operation of machinery, given the level of precision made possible by the reliable low latency and data rate speeds available with mmWave 5G.

V2X communications will enable coordinated interaction between extraction vehicles, loading/off-loading equipment and transport vehicles. In contrast to remote monitoring and manipulation, this interaction will entail huge amounts of wireless data exchange for coordinated positioning traffic management and ultra-low latency for control and warning signals.

mmWave 5G applications can potentially make extraction activities in the mining and manufacturing verticals more cost effective and safer by leveraging the use cases of connectivity, remote object manipulation for machinery and next-generation transport connectivity, among others.

# 3. South and South East Asia and the Pacific Islands



In the South and South East Asia and the Pacific Islands region, Indonesia, Thailand, and Vietnam are drivers of growth in the mobile industry, with the region serving as a key source of new subscribers globally.  Given the projected continued growth of the region's mobile industry, 5G is expected to play an important role in the future. Enabled by the capacity of mmWave spectrum, even more possibilities will open for 5G through various data-intensive and latency-critical applications.

This section explores two specific cases to examine how mmWave 5G applications may address pressing challenges in the region. Certain geoclimatic and geographic characteristics of this region pose challenges to deploying and maintaining high-quality ICT networks, notably its rapid urbanisation and its susceptibility to natural disasters. The two case studies explore the mmWave 5G applications that present possible solutions to address these specific challenges.

These two cases are only an example of where mmWave 5G applications could make an impact in the region. Beyond these cases, there are numerous mmWave 5G applications that will more broadly impact the region. Recent estimates predict that, by 2034, mmWave 5G will deliver the region $45 billion in GDP and $8.7 billion in tax revenue across a range of industries (Figure 7).[7]

FIGURE 7. EXPECTED CONTRIBUTION FROM mmWAVE 5G TO GDP AND TAX, 2034

**SOUTH AND SOUTH EAST ASIA AND THE PACIFIC ISLANDS**

**$45 billion** boost to GDP

**0.6%** of total GDP growth

**$8.7 billion** taxes generated

Source: GSMA and TMG (2018), "Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands," https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf.

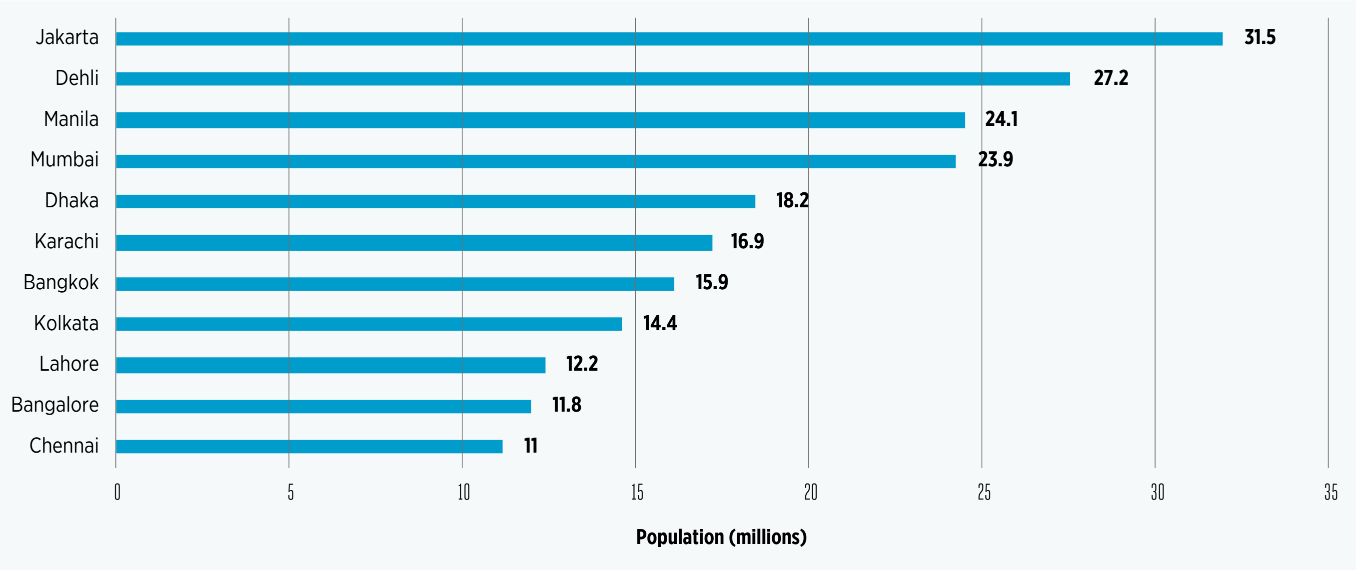
7. These figures were based on the 2018 GSMA report, Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands, which studied the socio-economic impact of mmWave spectrum over a 15-year period (2020-2034). For more information, we invite you to read the full report at https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf.

# 3.1. Case Study #1: Connectivity

**This case study examines how mmWave 5G can improve the region's connectivity, especially considering its rapid urbanisation. mmWave 5G can provide fibre-like speeds without the high deployment costs of fixed infrastructure, enabling urban populations from all backgrounds to connect to data-intensive 5G applications. High-speed connectivity will also benefit the regional economy by enabling the full spectrum of mmWave 5G use cases across all industries in the economy.**

Urbanisation is a long-term, global phenomenon that poses perennial challenges for societies. The United Nations (UN) predicts that the global percentage of city dwellers will increase from 55% today to 68% by 2050 with most of this increase attributable to Asia and Africa.[8] For the developing Asia-Pacific region, urbanisation is a particularly significant issue. Including China, 26 of the world's 47 megacities—cities with more than 10 million people—are located in this region. Excluding China, 11 megacities are located in South and South East Asia (see Figure 8).

FIGURE 8: POPULATION OF MEGACITIES IN SOUTH AND SOUTHEAST ASIA, 2016, MILLIONS OF INHABITANTS

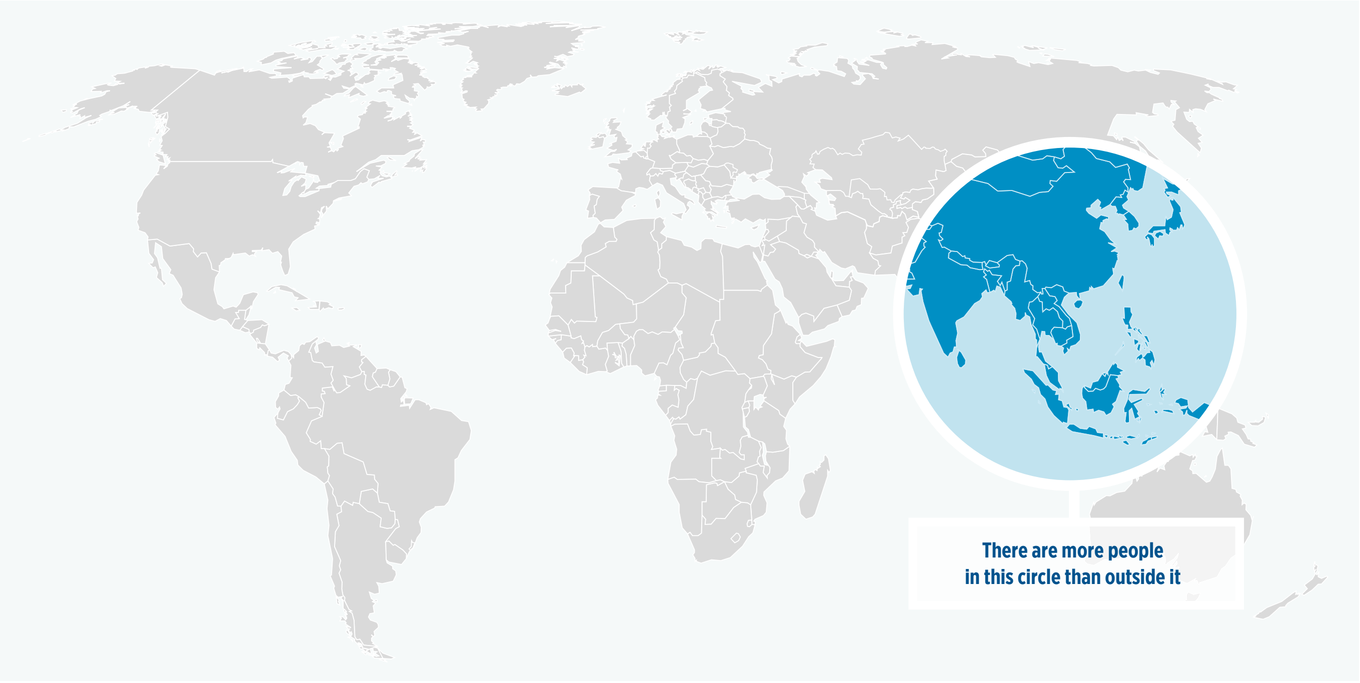



Source: UN, "2018 Revision of World Urbanisation Prospects;" https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html.

However, there is an even more important trend taking place in small- to medium-sized cities. Contrary to what may be assumed from the above figure, the majority of the region's urban residents live in small- and medium-sized cities, and these cities are rapidly growing. Over 50% of urban residents live in smaller cities with populations under 500,000 inhabitants.[9] Together, the populations living both in megacities and small- and medium-sized cities make the Asia-Pacific region the densest on Earth (see Figure 9).

8. 2018 Revision of World Urbanization Prospects at https://population.un.org/wup/. Indeed, these figures may be underestimated.
See https://www.reuters.com/article/us-global-cities/everything-weve-heard-about-global-urbanization-turns-out-to-be-wrong-researchers-idUSKBN1K21UU, which suggests that already 84 percent of the world's population, or almost 6.4 billion people, live in urban areas.
9. The World's Cities 2016, United Nations, at https://www.un.org/en/development/desa/population/publications/pdf/urbanization/the_worlds_cities_in_2016_data_booklet.pdf.

FIGURE 9: ASIA-PACIFIC IS HOME TO THE DENSEST POPULATIONS



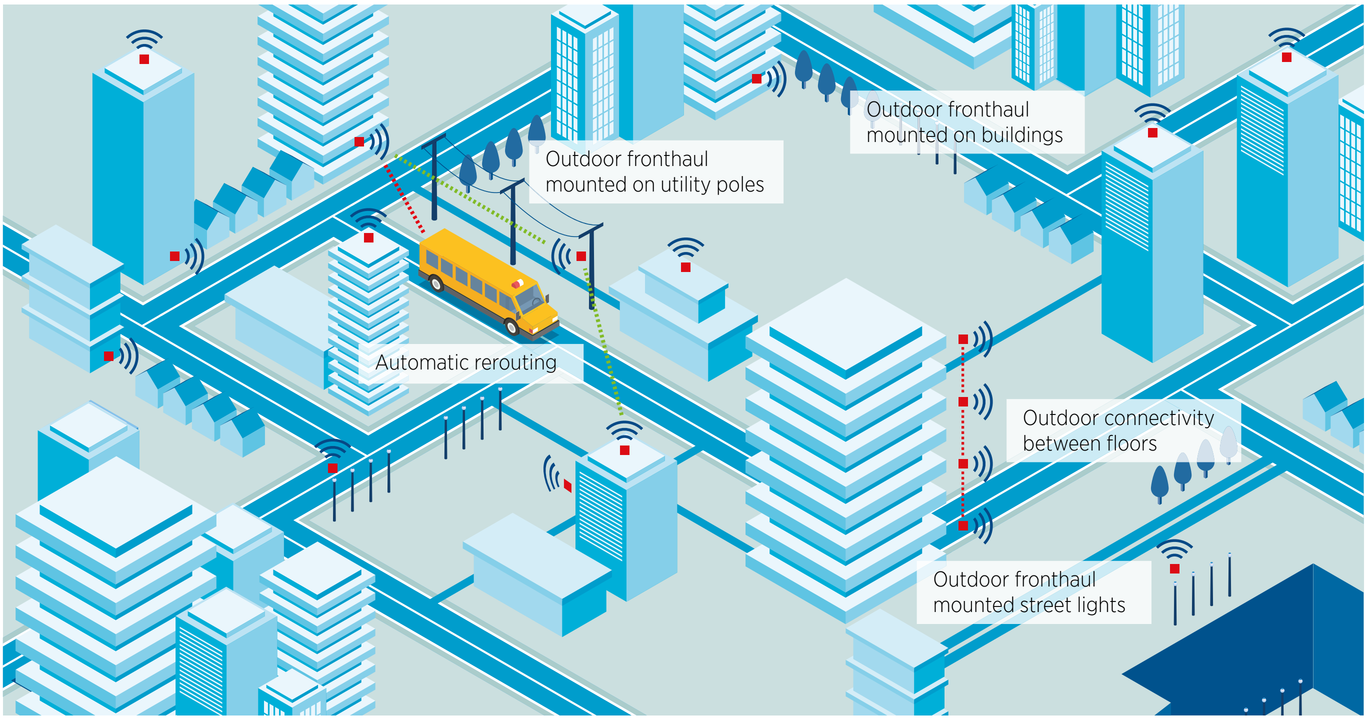

Source: Desjardins, J. (2019), "Mapped: the world divided into four regions with equal populations," https://www.visualcapitalist.com/mapped-the-world-divided-into-4-regions-with-equal-populations/

For these countries, the challenges of urbanisation are particularly pressing. Challenges include the need for adequate housing, transport, energy and communications infrastructure, as well as education and healthcare systems. High-speed broadband is becoming a more significant part of a well-functioning urban environment and a key part of an integrated urban policy. Yet, rolling out high-speed broadband can be especially problematic in these urban environments. Laying cable means acquiring rights-of-way (ROW), a costly and time-consuming process, particularly when traffic congestion is already a problem or permit processes are convoluted. Typically, these cities have few available ducts and for those that do, securing space may require extensive and costly negotiations and bureaucracy, as well as recurring fee obligations.

Low fixed broadband penetration numbers in the region reflect the high cost of rolling out high-speed broadband. For instance, while developing economies such as Cambodia, Thailand and Vietnam have among the highest mobile Internet penetration rates in the region, they lag in fixed broadband penetration. According to the UN Economic and Social Commission for Asia and the Pacific (ESCAP), the top performers in South and South East Asia in terms of fixed broadband subscriptions per 100 inhabitants are Thailand and Malaysia with only 9.2 and 9.0, respectively, followed by Vietnam (8.1) and Brunei (8.0).[10] By comparison, Myanmar (0.3), Laos and Cambodia (0.5), Indonesia (1.1), and the Philippines (3.4) have the lowest penetration rates in the region.[11]

This confluence of challenges makes the application of mmWave 5G connectivity promising for the region. mmWave 5G can deliver high-speed connectivity in dense environments at a very low cost when compared to fibre, as it avoids the need to dig up streets and co-ordinate with various levels of government. mmWave 5G enables "fibre in the air" connectivity in urban environments achieving multi-gigabit speeds by transmitting via antennae on the sides of buildings, rooftops and street fixtures (lamp posts, traffic lights). Small fixed wireless nodes can be attached to existing structures and eliminate the need for significant civil works (Figure 10).

## FIGURE 10: mmWAVE 5G URBAN CONNECTIVITY




Source: TMG

10. Figures reported in 2015. UN ESCAP (2016), "State of ICT in Asia and the Pacific 2016: Uncovering the widening broadband divide," pp. 18, https://www.unescap.org/resources/state-ict-asia-and-pacific-2016-uncovering-widening-broadband-divide.
11. Idem.

These mmWave 5G solutions would work together with existing technologies. For example, an anchor cell connected via fibre to an operator's core network would provide coverage to the neighbourhood or office area, then smaller cells would channel a signal around the neighbourhood to provide high-throughput distribution. Distribution cells would provide connectivity directly to end-user locations.

Until recently, mmWave 5G solutions were not considered a realistic option due to their short range and susceptibility to blockage. However, several notable industry innovations remove many of these obstacles. In particular, by deploying numerous antennas with multiple line-of-sight transmission paths, the network can re-route traffic by an indirect route when unforeseen, temporary blockages occur (e.g. passing traffic or building construction).

With time, there will be greater integration of mmWave with sub-6 GHz bands to ensure wide-area coverage and seamless connectivity, thus fostering the development of multimode devices. In turn, users will simultaneously connect to both sub-6 GHz bands for wide-area coverage and mmWave bands for additional bandwidth and capacity.

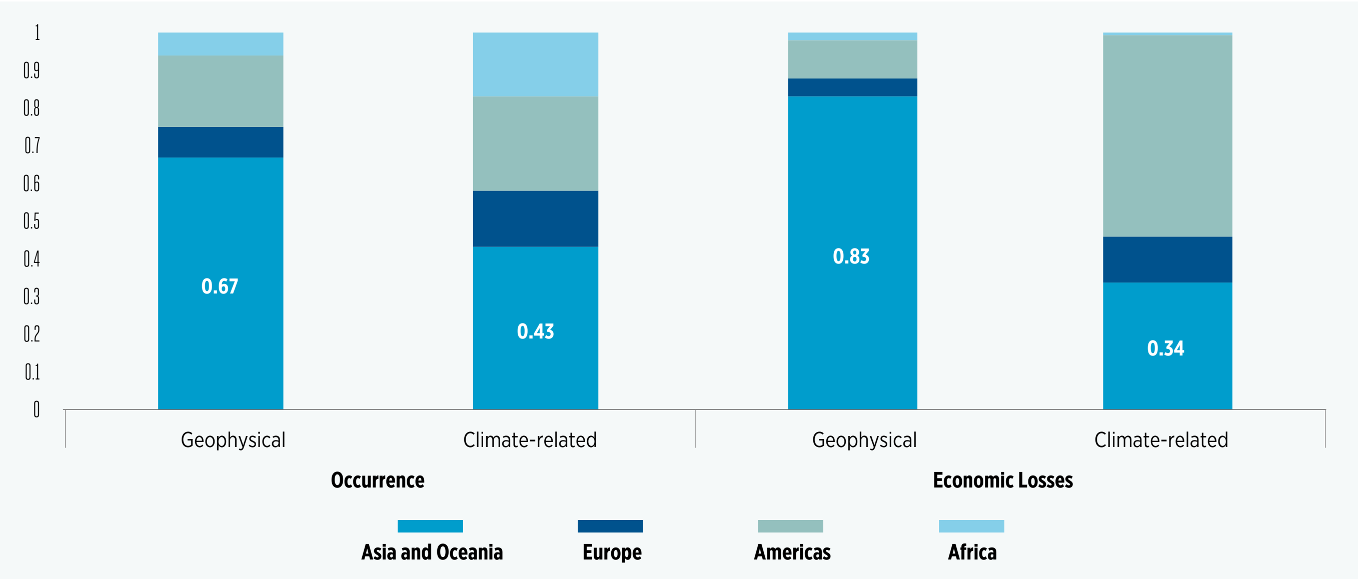
mmWave 5G can enable rapidly growing urban communities to avoid many of the problems associated with rolling out fixed broadband networks. In so doing, these communities can embrace more leading-edge technologies and deploy innovations available with high-speed connectivity in various ways, for instance in transportation, healthcare, and education, among others.

# 3.2. Case Study #2: Disaster Communications

**This case study considers the different ways in which mmWave 5G applications may impact the region's ability to handle natural disasters. Several mmWave use cases are relevant, such as connected vehicles and infrastructure, virtual reality applications, and quick deployment to maintain connectivity. Similar to the connectivity example, the benefits identified in this case study are expected to span all industries due to the wide-ranging impacts of natural disasters across a country's economy.**

South and South East Asia and the Pacific Islands are particularly vulnerable to natural disasters due to the geoclimatic characteristics of the region, including mountain ranges, coastlines, seas, and sea floors (e.g. tectonic plates). Between 1998 and 2017, the broader region of Asia and Oceania has reported the highest numbers of disaster events from geophysical and climate-related disasters and the second-highest in terms of economic losses (see Figure 11).[12, 13]

FIGURE 11. RELATIVE HUMAN AND ECONOMIC COSTS OF DISASTER




Source: TMG based on UNISDR and Centre for Research on the Epidemiology of Disasters (CRED) (2018), "Economic losses, poverty and disasters: 1998-2017," p. 17, https://www.cred.be/sites/default/files/CRED_Economic_Losses_10oct.pdf.

12. Geophysical disasters include earthquakes, mass movements of dry material, and volcanic activity, while climate-related disasters refer to floods, landslides, wave actions, storms, extreme temperatures, fog, droughts, glacial lake outbursts, and wildfires.
13. UNISDR and Centre for Research on the Epidemiology of Disasters (CRED) (2018), "Economic losses, poverty and disasters: 1998-2017," p. 17, https://www.cred.be/sites/default/files/CRED_Economic_Losses_10oct.pdf.

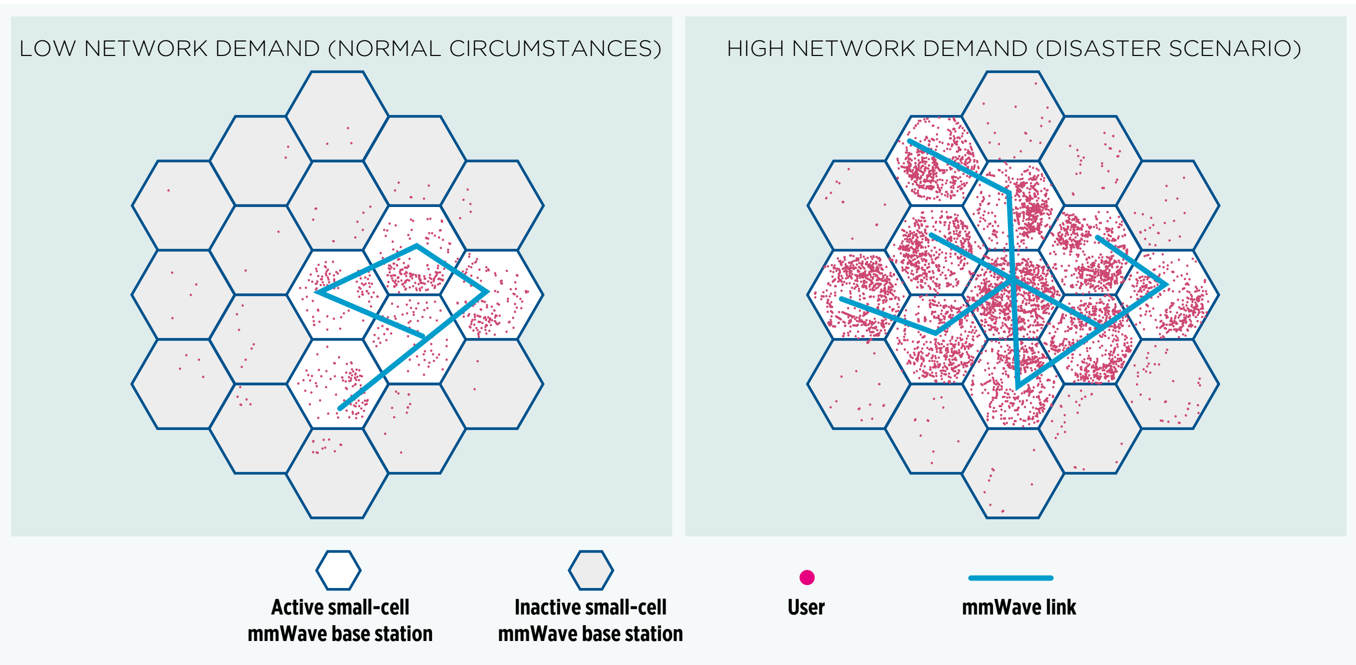
In addition to existing social and economic costs, climate change amplifies the risk of losses from natural disasters, increasing the intensity and frequency of catastrophic events and making the disasters themselves more intense and unpredictable.

While it is always difficult to predict and prepare for natural disasters, mobile communications play a vital role in rescue and relief activities, as shown in past natural emergencies. For instance, mobile communications came into play during the aftermath of Typhoon Haiyan in the Philippines in 2013 and two severe earthquakes in Nepal in 2015, when drones obtained information regarding the cartography of the emergency areas and helped rescuers deliver aid.[14] SMS messages have also been used for communications between aid relief organisations or governmental agencies and those in need.[15] 5G networks, including those enabled by mmWave 5G, are expected to play an even greater role in disaster risk management schemes in the future.

mmWave 5G networks are poised to provide and maintain high-capacity, low-latency communication infrastructure to deliver mission-critical communications. While mmWave 5G networks will face some of the same physical vulnerabilities affecting existing networks in natural disasters, research on mitigation tactics is increasing network dependability during weather events.[16] mmWave 5G networks may also extend coverage to out-of-coverage areas by leveraging device-to-device connectivity in cases of infrastructure failure. Building resilient and high-capacity networks will be especially important to restore mobile communication networks in urban areas hit by natural disasters and to handle the high-volume data demands of a highly concentrated population.

Since a disaster can hit anytime, network demand is dynamic. mmWave 5G can manage this dynamic demand by quickly deploying temporary connectivity to the affected areas.[17] mmWave 5G can act either as a last-mile connection or a backhaul network to effectively turn on or off nodes according to traffic on the network.[18] As shown by the left side of Figure 12, under low traffic conditions in normal circumstances, the mmWave 5G small-cell base stations are activated or deployed only when sufficient traffic exists to warrant the extra capacity. As many future mmWave 5G networks are expected to be implemented in conjunction with other lower-band frequencies, traffic may be handled by other frequencies in cases where the mmWave 5G small cells are not activated. However, when a disaster strikes, mobile data traffic abruptly increases, activating many more mmWave 5G nodes. This method of quick deployment of increased capacity with mmWave 5G small cells allows the network to meet unexpected demand in an efficient way that adjusts as needed, based on network demand.

FIGURE 12. EXAMPLE REPRESENTATION OF A DYNAMIC mmWAVE 5G NETWORK




Source: TMG based on Sakaguchi et.al., "Where, When and How mmWave is Used in 5G and Beyond," https://arxiv.org/ftp/arxiv/papers/1704/1704.08131.pdf.

14. United Nations University, "World Risk Report: 2016," pp. 23-26, http://collections.unu.edu/eserv/UNU:5763/WorldRiskReport2016_small_meta.pdf.
15. Idem.
16. See, for example, Jabbar, et. Al. (2011), "Survivable millimeter-wave mesh networks," https://www.sciencedirect.com/science/article/pii/S0140366411001733; Jabbar, et. Al. (2008), " Weather disruption-tolerant self-optimising millimeter wave mesh networks," https://www.semanticscholar.org/paper/Weather-Disruption-Tolerant-Self-Optimising-Mesh-Jabbar-Raman/3be1abdf796a58c232e6eafb048b20648aac13a7.
17. In the medium term, mmWave 5G networks are expected to focus on densely populated urban areas that are demanding the additional capacity that mmWave bands provide, above what can be covered through existing IMT bands.
18. Sakaguchi et.al., "Where, When and How mmWave is Used in 5G and Beyond," https://arxiv.org/ftp/arxiv/papers/1704/1704.08131.pdf

This additional capacity will allow for many other 5G applications to operate effectively in a disaster zone, as shown in Figure 13. These include:

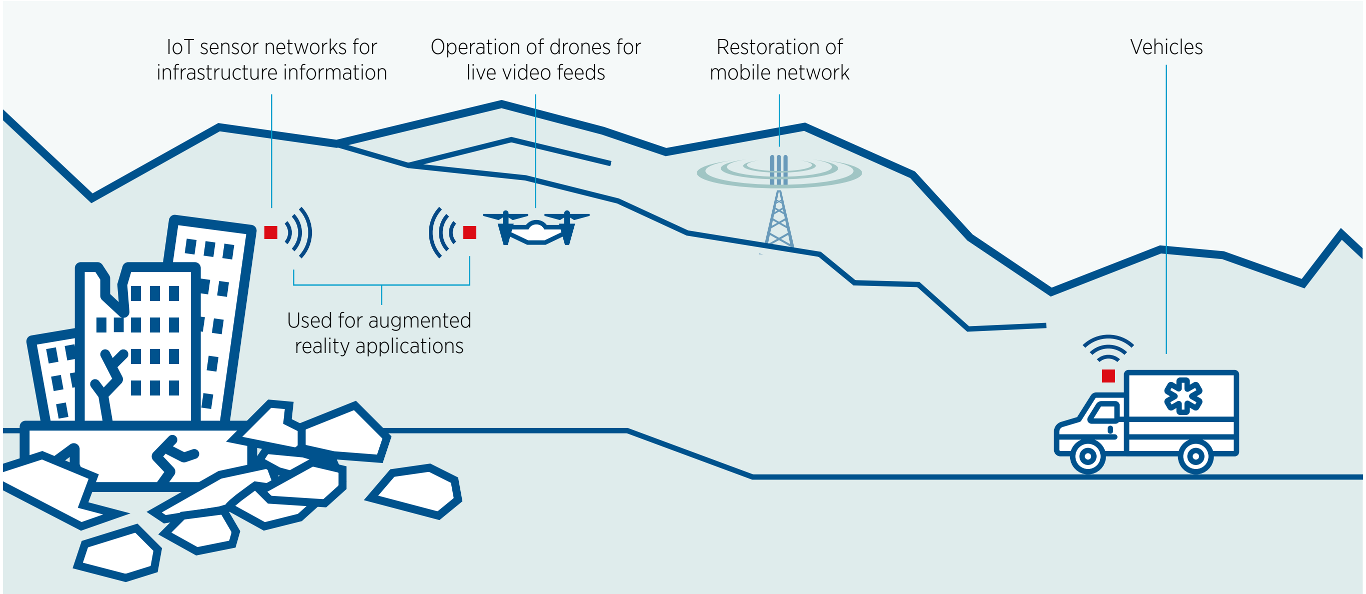
- Remote operation of drones for live video feeds and high-definition cartographic mapping, as well as aid delivery to inaccessible areas;
- Data transmission from Internet of Things (IoT) sensor networks and connected vehicles for information regarding terrain, environmental and infrastructure stability, and position of population;
- Unmanned ground (e.g. ambulances) or aerial vehicles for emergency rescue operations;
- Augmented reality applications that provide environmental and structural information to first responders or firefighters entering into dangerous buildings/terrain and assist in situations of poor visibility due to smoke or debris; and
- Live video feeds to transmit to experts in other locations to assist in rescue or relief operations, potentially including emergency health operations.

These applications can improve safety for first responders and relief workers by providing more tools to analyse critical disaster areas, receive feedback from remote experts, and assess risk, ultimately resulting in more informed decisions and actions. In addition, the use of remotely operated vehicles and devices can help reach inaccessible areas and people or provide needed resources.

The collection of high-quality and detailed data, enabled by mmWave 5G, also opens possibilities to use other new technologies, such as big data analysis. This may improve predictive meteorological models, resulting in more proactive disaster risk management plans.

The potential applications that mmWave 5G networks make viable create new possibilities to improve disaster response and rescue activities through the quick deployment of temporary connectivity, virtual and augmented reality applications, connected infrastructure, and automated vehicles. The disaster response management improvements enabled by mmWave 5G are likely to broadly impact the economy, lessening the overall socioeconomic impacts of the disaster.

FIGURE 13. mmWAVE 5G APPLICATIONS FOR DISASTER COMMUNICATIONS




Source: TMG

# 4. Latin America and the Caribbean

Countries in Latin America and the Caribbean have greatly expanded access to communication services in recent years, with mobile technologies and services becoming a larger part of daily life. As the region's mobile industry continues to grow, operators are expected to deploy 5G in the medium-to-long term, with some initial cases expected sooner. This section presents two case studies that examine how 5G applications, enabled by mmWave spectrum, may develop and impact the LAC region in the mid-term. In particular, mmWave 5G can support ongoing actions and initiatives that many countries in the region are undertaking. It can firstly improve the quality of and access to education. Secondly, it can provide connectivity that will upgrade transportation infrastructure.

Aside from education and transportation, mmWave 5G will more broadly impact development. By 2034, mmWave 5G is expected to deliver $20.8 billion in GDP and $6.8 billion in tax revenue to the LAC region (Figure 14).[19] This GDP contribution will impact the economy through a variety of industries and through a number of different mmWave 5G use cases. The case studies presented illustrate how mmWave 5G applications may be deployed and applied to impact the regional economy in the context of education and transport.

FIGURE 14. EXPECTED CONTRIBUTION FROM mmWAVE 5G TO GDP AND TAX, 2034

**LATIN AMERICA AND THE CARIBBEAN (LAC)**

**$20.8 billion** boost to GDP

**1.2%** of total GDP growth

**$6.8 billion** taxes generated

Source: GSMA and TMG (2018), "Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands," https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf.

19. These figures were based on the 2018 GSMA report, Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands, which studied the socio-economic impact of mmWave spectrum over a 15-year period (2020-2034). For more information, we invite you to read the full report at https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf.

# 4.1. Case Study #1: Education

**This case study examines how mmWave 5G will impact access to and quality of education in the region. By providing high-capacity mobile broadband to dense urban areas mmWave 5G networks can support applications such as virtual and augmented reality. As education is a critical enabler for development, improving educational quality and outcomes in the region is expected to impact all industries in the economy.**

Improving educational outcomes is a key driver for economic development and is especially important to avoid the so-called "middle-income trap" (MIT) affecting a number of countries in the region. Analysis from the Organisation for Economic Cooperation and Development (OECD) contends that LAC countries that have successfully avoided this trap have better-quality education and an adequate supply of skills in the workforce, among other factors.[20] Many governments acknowledge education's importance and have focused efforts to improve access to and quality of education. These efforts have substantially improved access to education. However, there is still work to be done to decrease inequality based on socio-economic status and increase the quality of education overall.[21] Across the region, socio-economic status remains a key factor in predicting a child's educational performance and attainment, more so than in other countries.[22]

Additionally, those who do stay in school tend to have lower levels of actual learning—indicating that the quality of education itself is another area for improvement—and report a high repetition and dropout rates.[23] These areas illustrate the skills gap present in many LAC countries and shed light on the region's high youth unemployment numbers: one in five youth aged 14-25 in LAC were actively looking for a job but unable to find one.[24] The lower levels of learning and enrolment rates in higher education may be compounded by an out-dated school curriculum that has not evolved to meet changing demands from the labour market.

Emerging mmWave 5G applications can further existing governmental efforts by improving access to and quality of education, for both young and adult learners. They can help to expand access by improving distance learning possibilities. By leveraging mmWave 5G networks, communities can use augmented reality (AR) and virtual reality (VR) applications over high-speed broadband to offer rich virtual classrooms, regardless of location. As tactile Internet applications become available, online learning can also teach manual skills that are currently difficult to teach in an online setting. These possibilities could be particularly useful for several groups, including:

- Young students who may not be able to attend class;
- Adult learners who must take classes around work and familial obligations; and
- Students in secondary, tertiary, or vocational training interested in subjects that may not be offered at locally accessible universities or schools.

20. OECD, CAF, ECLAC (2018), "Latin American Economic Outlook 2018: Rethinking Institutions for Development," p. 30, http://dx.doi.org/10.1787/leo-2018-en. Other factors include the quality of public institutions, trade openness, strong rule of law, strong democracy, solid tax revenues, sufficient levels of investment and developed capital markets.
21. Inter-American Dialogue (2018), "The future of education in Latin America and the Caribbean: Possibilities for United States Investment and Engagement," pp. 10-12, http://www.observatorioeducacion.org/sites/default/files/usaid-layout-6.12.2018-final_pdf.pdf.
22. Idem, 17-18. See also Inter-American Development Bank – Centro de Información para la Mejora de los Aprendizajes (CIMA)(2017), "Tasa de asistencia por grupo etario [database]," https://www.iadb.org/es/sectores/educacion/cima/inicio.
23. Idem, 13, 15-16.
24. ILO (2018), "Labour Overview 2018 (press release)," https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_655210/lang--en/index.htm.

Possibilities are also emerging for mmWave 5G to improve the quality of education. Many of the AR/VR and tactile Internet applications can improve quality by better engaging with students overall, whether in a virtual or physical classroom. Some emerging examples include:

- AR/VR applications bring subject matter to life through interactive games and help students understand difficult concepts (e.g. using VR to show the inside of an atom or a black hole);[25]
- Mixed reality applications geared towards assisting students with learning or social disabilities to improve learning outcomes or social skills (e.g. helping children with autism practice social skills within a game setting);[26]
- Interactive lessons that track students' progress, notes taken, and mark areas of difficulty to provide feedback for teachers to use to tailor lessons in real-time;[27]
- AR applications to help teachers use emerging technologies to transform lessons into more engaging lesson plans for students;
- Applications in conjunction with artificial intelligence (AI) that assist students with special needs (e.g. a highly-interactive AI assistant marking areas of difficulty and altering teaching method to meet the specific needs of the child); and
- Tactile internet to practice manual skills on a variety of scenarios online, without requiring physical set-up or tools.

In low-income urban areas, the provision of high-speed broadband to the home may also improve the quality of education. According to 2017 ITU estimates, fixed broadband penetration in Latin America per 100 inhabitants was 11.89 compared to 112.08 for mobile cellular telephone subscriptions.[28] As mobile broadband is more prevalent than fixed broadband penetration, the fibre-like speed and capacity offered by mmWave 5G can provide more reliable mobile broadband for students who already have Internet access via smartphones. This will allow students to more easily access classroom content or research materials and play back lessons to complete homework assignments.

Other complementary applications can help the school function more effectively, for instance by creating a "connected classroom" that reduces administrative burdens on teachers. This increases the potential for data collection and analysis of learners' problems, improving eventual outcomes under various teaching methods. There are also possibilities for big data analysis to identify teaching tactics that are more effective, further increasing the potential for improving the quality of education. In addition, the diversity of potential data points from online learning could be leveraged to "teach" AI systems and thereby avoid cultural, gender, or other socio-economic biases.[29]

mmWave 5G will improve broadband infrastructure and provide the necessary capacity and latency requirements needed to support AR/VR and tactile Internet applications which can greatly expand opportunities for access to high-quality and engaging education at distance, as well as improve the overall quality of education for virtual and physical learners, both youth and adult.

25. Verizon Foundation (2019), "The Verizon Foundation names 5G EdTech Challenge winners and awards a total of $1M to bring classroom solutions to life," https://www.verizon.com/about/news/verizon-foundation-names-5g-edtech-challenge-winners-and-awards-total-1m-bring-classroom.
26. Verizon Foundation (2019), "The Verizon Foundation names 5G EdTech Challenge winners and awards a total of $1M to bring classroom solutions to life," https://www.verizon.com/about/news/verizon-foundation-names-5g-edtech-challenge-winners-and-awards-total-1m-bring-classroom.
27. Avedisian, A. and Matsumoto, E. (2018), "Three emerging technologies that will reshape education in 2019," https://www.edsurge.com/news/2018-12-29-3-emerging-technologies-that-will-reshape-education-in-2019.
28. ITU (2019), "Statistics: Country ICT Data (until 2018)," https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.
29. Avedisian, A. and Matsumoto, E. (2018).

# 4.2. Case Study #2: Transport

**This case study examines ways that mmWave 5G applications can impact the region's transport infrastructure. The most important mmWave use case expected in this case study is applications of next-generation transport connectivity, including connected transport infrastructure, connected vehicles, and V2X communication ecosystem. These applications are expected to impact the economy in a broad sense across industries as a result of improved transport.**

Road traffic accidents are the eighth highest cause of fatalities, responsible for 1.35 million people each year and aside from the human tragedy, cost most countries approximately 3% of their GDP.[30] According to reports from the WHO, high-income countries in the Americas region record 11.8 road fatalities per 100,000 inhabitants, compared to 18.3 in low-income countries in the region.[31] Various reasons exist for these road deaths, including poor transportation infrastructure, unsafe vehicles, poorly enforced traffic rules, and insufficient post-crash care.[32]

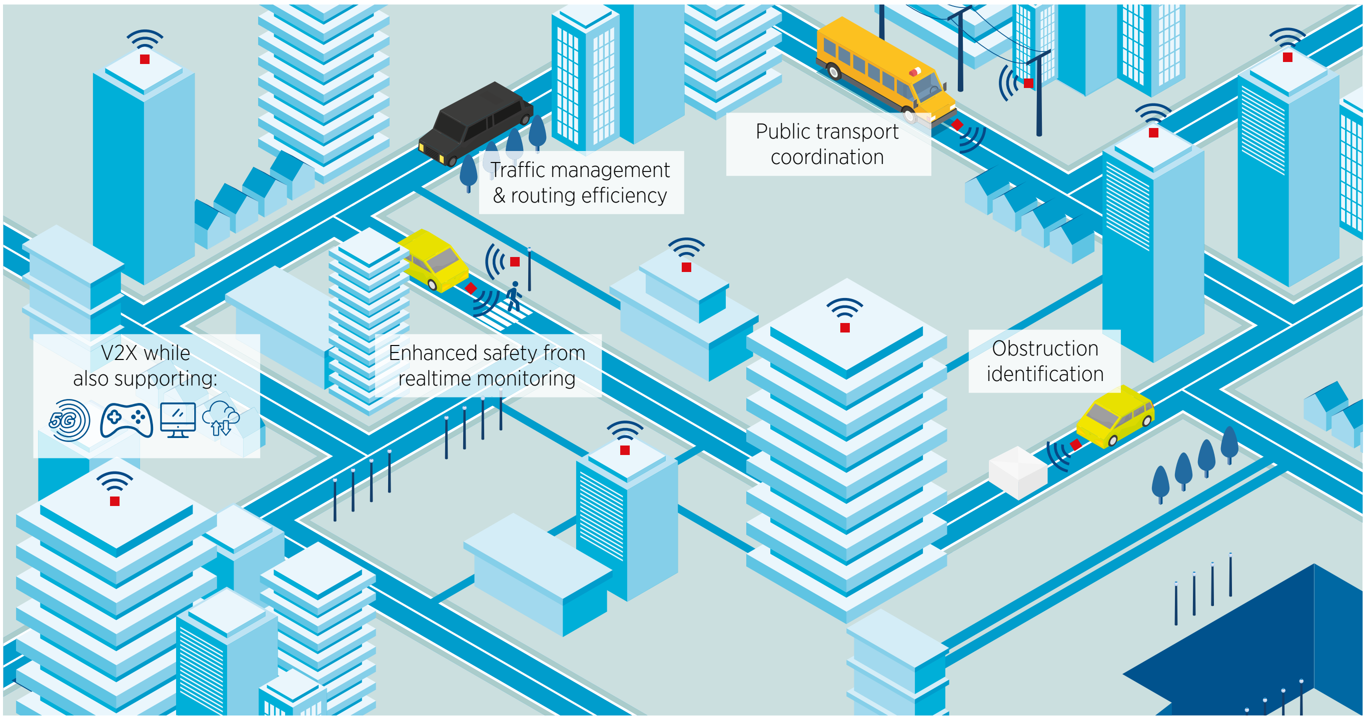
In addition to traffic fatalities, the LAC region has seen a rapid urbanisation rate, with 80% of its population now living in urban areas, which further contributes to traffic congestion and pollution.[33] This has put a great deal of stress on transportation infrastructure to handle the increasing amount of people and traffic, often resulting in inefficient and slow transportation options. In some Latin American cities, the average one-way commute time reached two hours, with riders of public transport links requiring 50-100% more travel time than automobile or motorcycle drivers or riders.[34] The high level of congestion also contributes to air pollution. Over 90% of cities in low- and medium-income countries in the Americas have air quality levels that exceed WHO guidelines, compared to less than 20% of cities in high-income countries in 2016.[35]

In this context, 5G enabled by mmWave offers several applications to address some of the current transport challenges facing governments in the region. First, the capacity and low-latency broadband of mmWave spectrum will allow for many applications to enable a connected transport environment, including V2V, Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), Vehicle-to-Network (V2N) communication, and eventually to a V2X ecosystem. V2X ecosystems can deliver a number of improvements, most notably to increase safety through vehicle platooning (V2V), advance collusion or obstruction alerts (V2V or V2I), alerts of pedestrian crossing (V2P), and better adherence to traffic rules and adaptive driving under cases of automated or assisted driving. In Latin America, 68% of urban passenger travel is on public transit or some form of shared system, most notably on bus systems.[36] As initial deployments of 5G are expected to be limited to major cities in the region, urban public transportation systems, especially buses, have the opportunity to be among the first to benefit from next-generation transport infrastructure. These applications can assist LAC government efforts to decrease road fatalities and increase the safety of vulnerable road users, especially pedestrians, cyclists, and 2- and 3-wheeled vehicles.

Governments can also take advantage of mmWave 5G applications enabling V2X ecosystems to implement intelligent transport systems (ITS) to reduce congestion in urban areas (Figure 15).

30. World Health Organization (WHO) (2018), "Road traffic injuries," https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries and WHO (2018), "Global status report on road safety 2018," p. 4, https://apps.who.int/iris/bitstream/handle/10665/276462/9789241565684-eng.pdf?ua=1 .
31. Idem, pp. 8-9.
32. WHO (2018), "Road traffic injuries."
33. Development Bank of Latin America (2019), "The impact of transportation infrastructure and Latin American development," https://www.caf.com/en/currently/news/2019/01/what-is-known-about-the-impact-of-transport-infrastructure-interventions/.
34. Institute of Labor Economics (2018), "Urban transport systems in Latin America and the Caribbean: Challenges and Lessons learned," p. 8, http://ftp.iza.org/dp11812.pdf.
35. WHO (2016), "WHO's urban ambient air pollution database – Update 2016," p. 4, https://www.who.int/phe/health_topics/outdoorair/databases/AAP_database_summary_results_2016_v02.pdf?ua=1. Note that the figure presented above refers to cities which had available data in the WHO's air quality database (13 cities in 7 countries in low- and medium-income Americas and 343 cities in 6 countries in high-income Americas).
36. Institute of Labor Economics (2018), p. 8.

FIGURE 15. mmWAVE 5G APPLICATIONS IN TRANSPORT




Source: TMG.

Connected sensors and cameras in infrastructure and vehicles can send high-quality, detailed, real-time information on traffic flows, accidents, and congestion to traffic management centres. In turn, these centres can analyse the data to reroute or re-signal traffic infrastructure, and instantly communicate with connected vehicles. Over time, such data can be used to make effective and impactful urban transport planning decisions to manage traffic patterns, as well as maintain detailed and up-to-date navigation maps for drivers. Immediate notifications of traffic accidents can allow ITS to deploy first responders quickly to the scene, leveraging traffic data to find the most time-effective paths both to reach the accident as well as to medical facilities.

Tests simulating a road accident in an environment with an intelligent transport system show that ambulances are able to reach an accident between 10 to 13 minutes faster, and traffic is able to recover an average of 15-20 minutes faster than in a normal traffic setting.[37] ITS can, therefore, help to improve immediate after-crash care for victims of traffic accidents, reduce congestion and associated commute times, and increase air quality as vehicles spend less time emitting pollutants.

mmWave 5G will also enable and support high-speed and high-capacity broadband in vehicles and public transportation options, allowing riders to consume high-capacity video entertainment or augmented or virtual reality applications. Transport can benefit from mmWave 5G applications to improve safety for road users, passengers, and drivers, reduce pollution and improve air quality, and decrease urban congestion, thereby improving the health and well-being of citizens.

37. Liu, J, Wan, J, Jia, DY et al. (4 more authors) (2017) High-efficiency Urban-traffic Management in Context-aware Computing and 5G Communication. IEEE Communications Magazine, 55 (1). 16598530. pp. 34-40, http://eprints.whiterose.ac.uk/104579/.

# 5. Regional Commonwealth in the field of Communications

The mobile industry has significantly impacted the countries of the Regional Commonwealth in the field of Communications (RCC).[38] As of 2018, 80% of the population had mobile phones, which makes it one of the most highly penetrated regions in the world. As the region's mobile industry continues to grow, 5G is expected to play an important role in the future, with deployment expected in the medium term. This section examines two case studies of how mmWave 5G applications may develop and impact the RCC region. In particular, 5G enabled by mmWave can address some of the labour shortage issues present in the region across multiple verticals, as well as the ubiquitous challenges faced by the healthcare industry.

These case studies are only two examples of ways that mmWave 5G applications may provide solutions to some of the challenges facing the region. More broadly, 5G enabled with the high-capacity of mmWave is expected to deliver $6.7 billion in GDP in 2034 and $1.4 billion in tax revenue in the region (Figure 16).[39]

This contribution to GDP will impact the region across industries through a number of different use cases. The two case studies below consider how a mix of mmWave 5G applications can be applied and benefit specific industries.

FIGURE 16. EXPECTED CONTRIBUTION FROM mmWAVE 5G TO GDP AND TAX, 2034

**RCC**

**$6.7 billion** boost to GDP

**1.0%** of total GDP growth

**$1.4 billion** taxes generated

Source: GSMA and TMG (2018), "Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands," https://www.gsma.com/spectrum/wp-content/uploads/2019/01/5G-mmWave-benefits.pdf.

38. RCC includes 12 nations of the former Soviet Union: Azerbaijan Republic, Republic of Armenia, Republic of Belarus, Republic of Georgia, Republic of Kazakhstan, Kyrgyz Republic, Republic of Moldova, Russian Federation, Republic of Tajikistan, Turkmenistan, Republic of Uzbekistan, Ukraine.

39. These figures were based on the 2018 GSMA report, Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands, which studied the socio-economic impact of mmWave spectrum over a 15-year period (2020-2034).

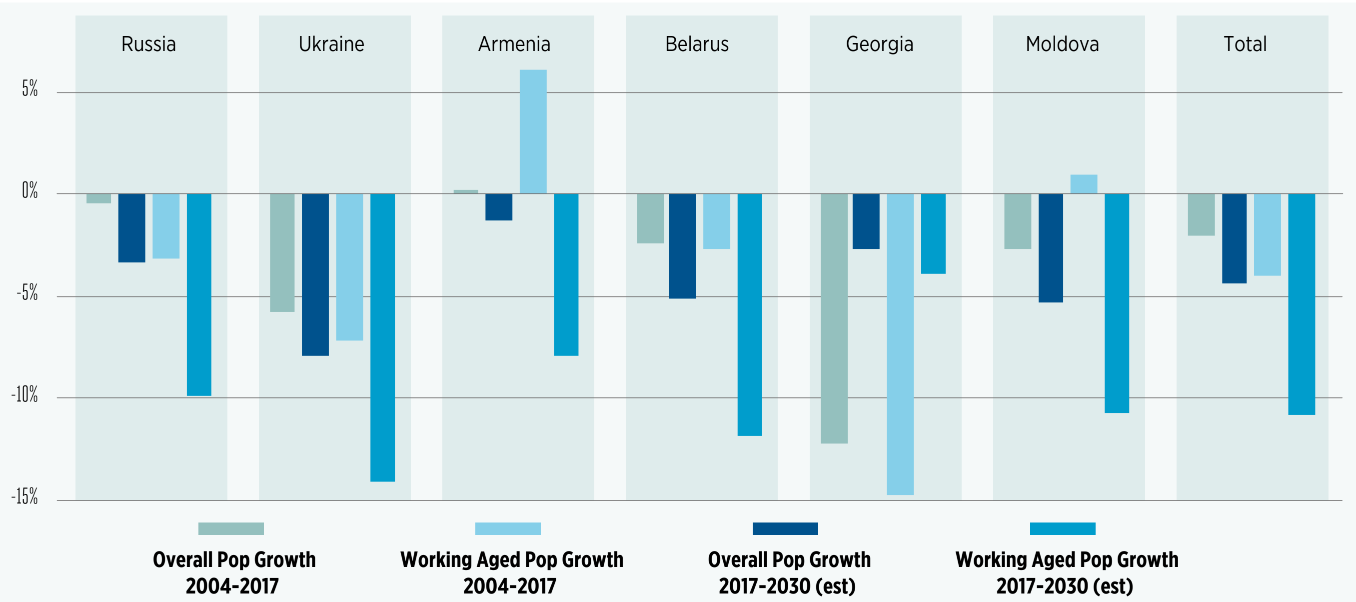
# 5.1. Case Study #1: Automation across industry

**This case study examines how mmWave 5G-enabled automation can assist with a long-term demographic challenge for many RCC countries. Many countries in the region have above-average concentrations of industry, skilled labour, and transport infrastructure, but this is coupled with an aging workforce. However, this combination allows for opportunities to exploit mmWave 5G automation on a greater scale than other emerging nations. Such mmWave 5G applications could be expected to impact a variety of industries in the economy, including manufacturing and utilities and trade.**

The countries of the RCC have a number of positive attributes that derive in part from their shared political legacy. These include well-educated populations, extensive transport infrastructure, and high industrial capacity. Many of these countries rank above-average—sometimes significantly so—in skills, transport infrastructure, and percentage of GDP produced by industry (as opposed to agriculture and services).[40]

Simultaneously, much of the RCC region faces the same demographic dilemma as their Western European neighbours. Indeed, while many European countries anticipate labour shortfalls between 2020 and 2030, labour supply is already decreasing in certain RCC countries.[41] Figure 17 shows that the trend is expected to worsen dramatically in the years to come with more negative growth rates of both total and working-age populations. Most significantly, the reduction in working age population between 2017 and 2030 is expected to be 10.8% on average, more than twice the level of the population overall (4.4%).

FIGURE 17. GROWTH RATES OF OVERALL AND WORKING-AGE POPULATIONS IN SELECTED RCC COUNTRIES, 2004-2030




Source: TMG based on data from PopulationPyramid.net

40. For further information, see The Global Competitiveness Report, 2018, World Economic Forum (transport infrastructure and percentage of GDP produced by industry) and the World Bank (skills).

41. Armenia and Moldova enjoyed an anomalous increase in working-age population between 2004-2017, but the growth was transitory.

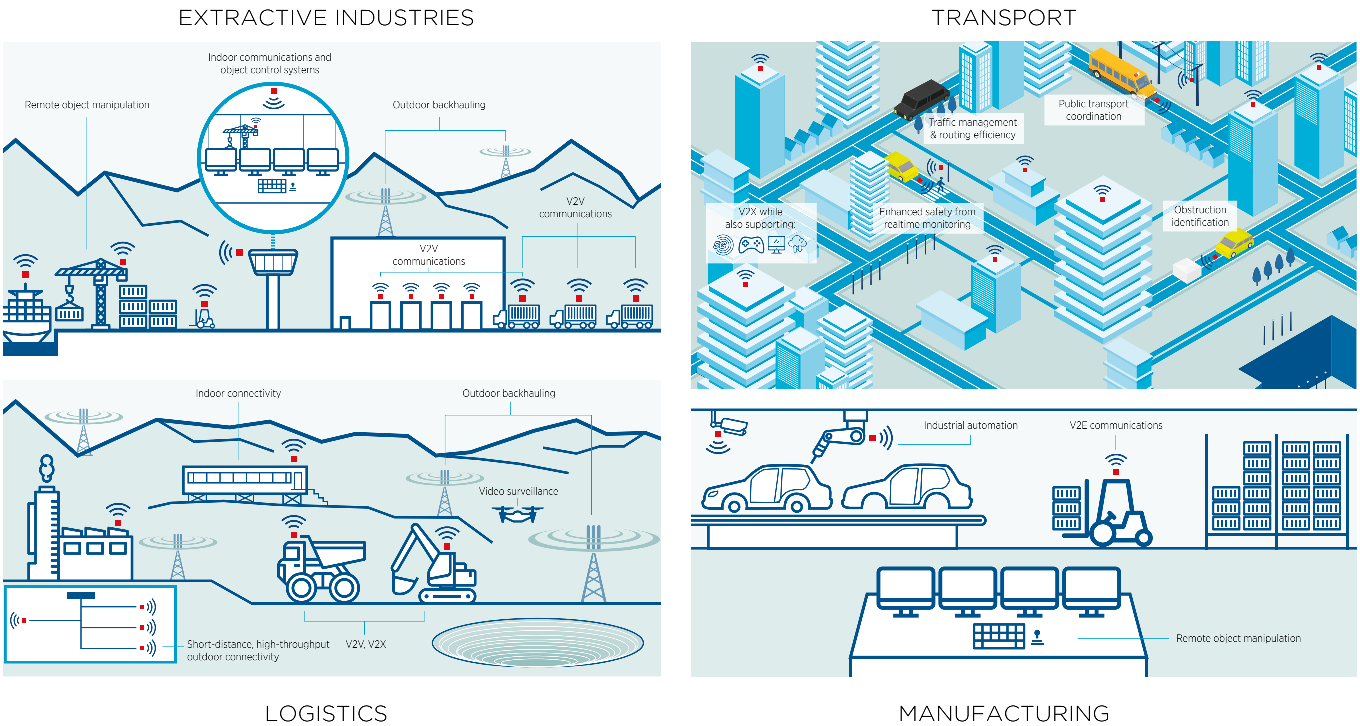
This labour shortfall can have consequences, including a significant reduction in productivity and profitability. The key to addressing this challenge will require a large number of initiatives to retain and grow the workforce, but also increase the utilisation of the workforce—a goal to which mmWave 5G can contribute solutions. Specifically, mmWave 5G can support innovation that automates productive activity, such as:

- Adding digital capabilities to manual processes;
- Allowing visualisation of manufacturing processes;
- Using simulation and analysis to enrich engineering capabilities;
- Implementing remote object manipulation;
- Facilitating vehicle automation through V2V and V2I; and
- Incorporating stationary robots into production processes.

This automation does not refer to humanoid robots, but rather automating technologies that are approaching commercialisation today.

Even for those RCC economies that are not facing significant demographic challenges, such as those in Central Asia, mmWave 5G can facilitate automation and offer significant benefits, including higher productivity in transport, logistics, and the extractive industries. Figure 18 illustrates the wide variety of use cases that would benefit RCC countries through the automation of industries in the medium term.

FIGURE 18. mmWAVE 5G ENABLED AUTOMATION ACROSS RELEVANT SECTORS OF RCC ECONOMIES




Source: TMG

In these contexts, mmWave 5G will provide the communications base for several applications, including the following.

- For collaborative robots using various levels of AI, human resources can focus on the management and maintenance of these systems. Key capabilities like peak data rate and user experience data rate are highly relevant for such industrial automation. New generations of stationary robots will produce large amounts of data and communicate with each other to improve manufacturing processes in real time.
- Remote object manipulation where AI is not of central relevance, but allows operators to accomplish tasks requiring a high level of precision, will rely on mmWave 5G. These cases will support situations where certain on-the-ground staff are unavailable and/or where the activity involves personal safety concerns. The required precision implies very high needs in terms of low-latency, reliability, and user experience data rate.
- Automated transport for direct vehicle communications (V2X), such as to vehicles (V2V), to pedestrians (V2P), V2I, or to the network (V2N). Autonomous vehicles, for example, will depend heavily on reliable transport connectivity due to the high volume of data expected to be exchanged, such as in the use of high-definition maps and in communication with infrastructure for road conditions, among others. Thus, this use case has a mix of requirements, from ultra-low-latency for control and warning signals, to higher data rates required to share video information between cars and infrastructure.
- The integration of high-speed imaging in machines can improve quality assurance and the data collected by automated machines can be used to proactively prevent faults and modify processes.

The RCC economies appear to be particularly well-placed to benefit from the automation of industrial processes that mmWave 5G will enable. This is particularly true for those economies in the region facing a relentless squeeze on the labour force, where such automation, facilitated by mmWave 5G, can provide the productivity boost needed to maintain current GDP per capita growth.

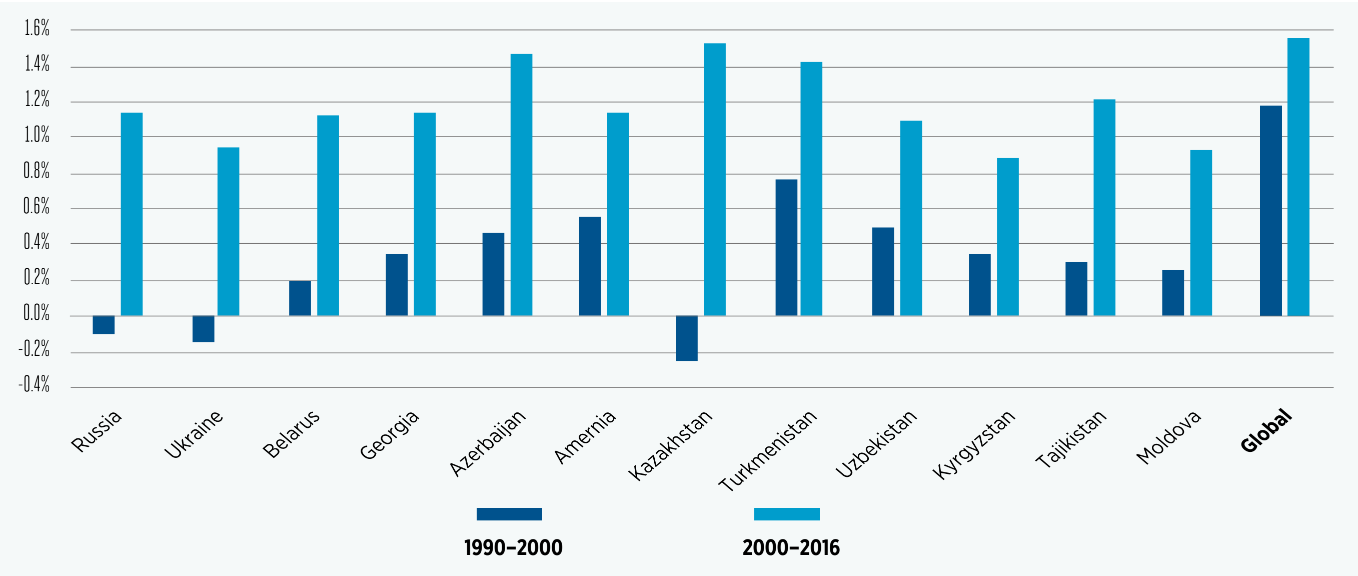
# 5.2. Case Study #2: Healthcare

**This case study explores how mmWave 5G applications may impact the region's healthcare system, which is key to resolving one of the most important challenges in the RCC region. mmWave 5G is expected to provide high-capacity, low-latency broadband able to support data-intensive applications in virtual and augmented reality and virtual meeting.**

Life expectancy in the region has shown significant improvement across all RCC countries over the past 20 years. Higher quality of healthcare is a leading reason for this improvement, which began to appreciably improve in terms of both access and quality in the 2000s (Figure 19).

Yet there is room for improvement in healthcare systems.[43] RCC countries share some areas of concern with other emerging markets, such as the need for comprehensive and continued training for doctors. Rural healthcare provision remains a particular problem as localities often cannot attract and keep quality staff. Where services cannot be provided at the locality, patients may have to travel long distances to receive care. Other problems relate to a political legacy in which decision-making and resources were highly centralised and primary care under-emphasised.[44]

FIGURE 19. AVERAGE ANNUAL CHANGE IN HAQ INDEX[42]

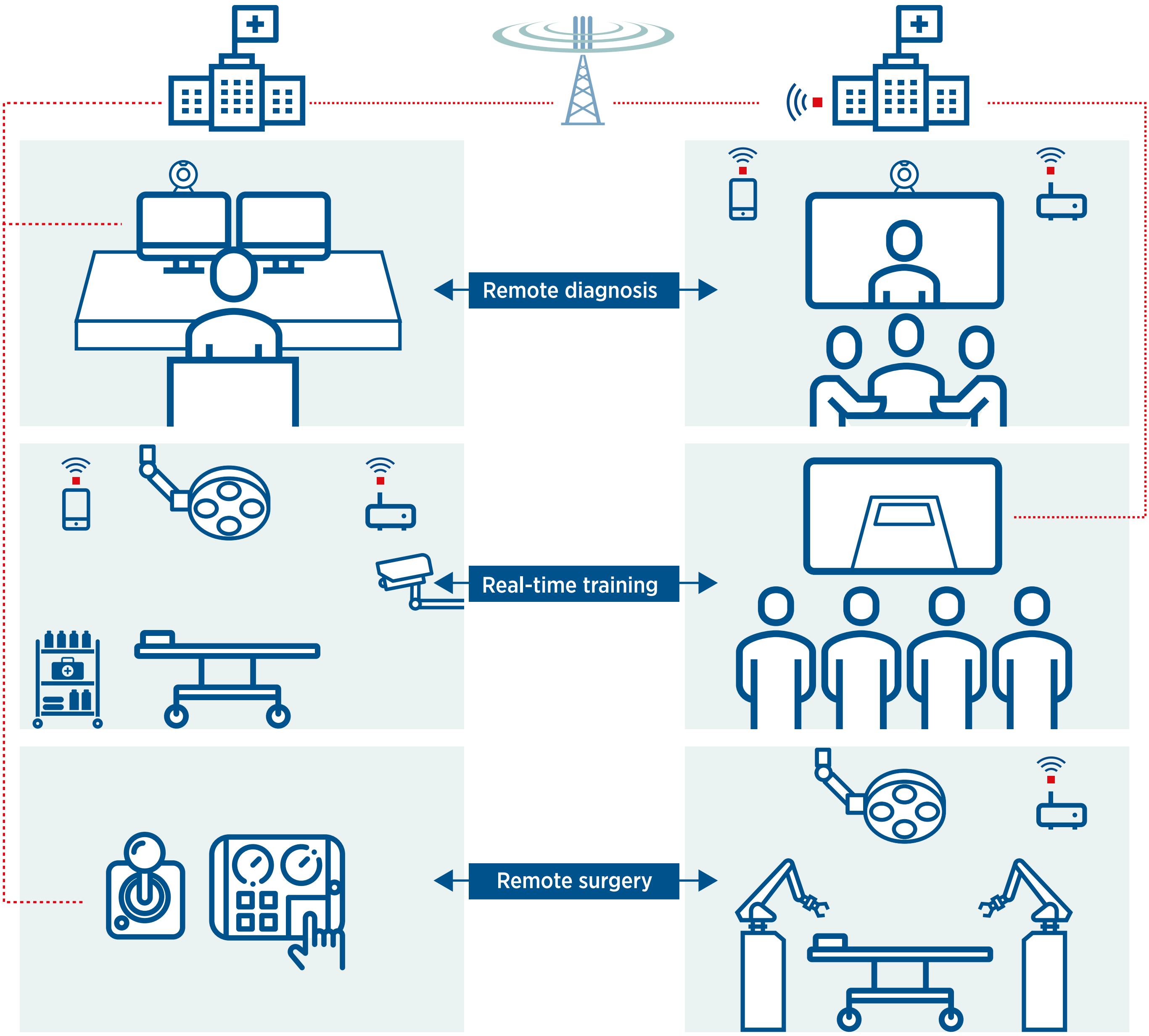



Source: "Measuring performance on the Healthcare Access and Quality Index for 195 countries and territories and selected subnational locations: a systematic analysis from the Global Burden of Disease Study 2016" https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)30994-2/fulltext.

42. The Healthcare Access and Quality (HAQ) Index measures healthcare performance in 195 countries.
43. See, for example, the World Bank's Universal Health Coverage Series (#27 Armenia, #28 Azerbaijan, #37 Russia), WHO Country Assessments (Belarus, Georgia, Kazakhstan, Kyrgyzstan and Tajikistan) and National Institutes of Health country reviews of Ukraine and Uzbekistan.
44. For an overview of these issues, see, for example, "Health system developments in former Soviet countries" in Quarterly of the European Observatory on Health Systems and Policies, volume 21, number 2, 2015, pp. 3-19.

In this context, 5G enabled with mmWave offers several applications to address these challenges in the region's healthcare systems, as depicted in Figure 20.

FIGURE 20. mmWAVE 5G APPLICATIONS IN HEALTHCARE




Source: TMG

First, as shown in the top diagram, mmWave 5G can address the circumstances in which qualified staff are not available on location. For example, medical specialists will be able to provide remote diagnoses in real-time. 5G-enabled cameras, robotics, and other devices can enable distant medical professionals to diagnose some conditions without an in-person visit. Additionally, virtual reality applications can support providers and patients within the context of remote diagnoses.

Second, as in the middle picture, mmWave 5G applications can improve the quality of local staff. Doctors, nurses, or other healthcare staff needing ad hoc or ongoing skills can obtain training by remote specialists or more experienced general practitioners. In this case, mmWave 5G networks can provide high-speed broadband access to the office to support rich virtual classrooms, regardless of location, with augmented and virtual reality applications. As training curricula incorporate tactile Internet applications, which can also teach manual skills that are currently difficult to teach in an online setting. The central application in the mid-term is virtual meetings, where next-generation video conferencing or telepresence allows individuals to be virtually present by sending and receiving high-resolution details between two or more remote environments

Additionally, in a similar setting to that depicted by distance training, mmWave 5G applications can improve quality assurance. They can also provide virtual meetings allowing one or more reviewers to observe and give advice during procedures, thereby assure the quality of healthcare services delivered.

Finally, the bottom graphic depicts remote surgery, which is envisioned in the longer-term. For example, remote object manipulation can allow an operator who is physically located far away from the device to perform remote surgery. Haptic feedback in remote surgery is another possibility in the future. These applications will improve healthcare options for locations that lack trained specialists, as well as for populations without the means to travel to main hospitals, moving care closer to patients and caregivers.

Thus, mmWave 5G technologies, providing low latency and high-speed data rates, can generate a variety of much-needed improvements for the region's healthcare system. It can provide increased availability and access to quality services where local resources are inadequate, and by giving more resources to primary care physicians, it can benefit diagnostics and healthcare management. As a result, mmWave 5G can contribute to the overall health outcomes for nations in the region.


www.gsma.com/spectrum

Floor 2, The Walbrook Building
25 Walbrook, London EC4N 8AF UK
Tel: +44 (0)207 356 0600

spectrum@gsma.com
www.gsma.com

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