Report for Ericsson

Future value of mobile in emerging markets

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1 Introduction

Analysys Mason was engaged by Ericsson to produce a detailed analysis of the costs and benefits of 5G deployment in 15 emerging nations, including Bangladesh, Brazil, Chile, Colombia, Egypt, India, Indonesia, Malaysia, Mexico, Morocco, Nigeria, Pakistan, South Africa, Thailand and Turkey, based on three deployment scenarios.

This study was conducted between March and October 2022, in collaboration with Ericsson's regional and local teams for 5G policy and technology for the markets under study.

The study was to quantify:

- the cost and extent of 5G coverage likely to be provided by commercially led 5G roll-out using available 5G bands, i.e. low band, mid band and millimetre-wave (mmWave),[1], over a timeframe from 2020 to 2035. This commercially led deployment is assumed to be mainly motivated by demand for consumer-driven use cases, including enhanced mobile broadband (eMBB) and fixed-wireless access (FWA). This is the 'baseline' scenario.

- the additional investment needed beyond the baseline to expand the footprint of low-band 5G and achieve wider geographical coverage. This expanded footprint is assumed to be useful for some industrial use cases (e.g. in sectors such as agriculture or freight and logistics) and for consumers located in rural areas. This is the 'low-band expansion' scenario, i.e. Scenario 1.

- the additional investment needed beyond the baseline to extend mid-band coverage to achieve similar geographical coverage to the low-band baseline footprint. We assume this will enable more advanced 5G use cases to be offered in the market (e.g. automation, augmented and virtual reality, high-quality video processing in industrial sectors). This is the 'mid-band expansion' scenario, i.e. Scenario 2.

- the consumer surplus that 5G is expected to generate from 5G-based MBB use, as a result of the availability of higher speeds and improved experience for a significantly lower cost per gigabyte (GB) than with previous generations of mobile technologies. Consumer surplus is quantified in the baseline scenario, while the additional surplus generated by the greater proportion of mobile subscribers covered by 5G is calculated in Scenario 1, and by having access to higher speeds across a larger mid-band footprint in Scenario 2.

- the incremental economic/gross-domestic-product (GDP) benefits that 5G coverage expansion brings, which are estimated based on 5G enabling use cases across five industry clusters, including smart factories, mining, construction, energy and utilities (Smart industry cluster), airports, ports, freight and logistics (Smart logistics cluster), agriculture (Smart rural cluster),

[1] In this report, low-band spectrum refers to sub-1GHz spectrum used to initially introduce 5G services (e.g. 600MHz, 700MHz). Mid-band spectrum refers to 2.3GHz unpaired, 2.6GHz unpaired or 3.5GHz spectrum. Millimetre-wave (mmWave) refers to spectrum between 24GHz and 40GHz.

municipal buildings and healthcare/hospitals (Smart public services cluster). Economic benefits are quantified for both Scenario 1 and Scenario 2, based on the expected contribution of low-band and mid-band spectrum (respectively) to those benefits.

The study also assessed qualitatively, in each benchmark country, the potential of 5G to help reduce greenhouse gas emissions in industrial sectors through achieving greater efficiency and productivity, and to enable a range of social benefits (social inclusion, safety and security, wellbeing).

This report provides a summary of the key findings of the study, and is structured as follows:

- Section 2 summarises the latest status of 5G deployment in each country
- Section 3 provides an overview of the framework used for the cost-benefit analysis in the study
- Section 4 describes our modelling approach to quantify the costs and benefits, and the main cost and benefit output
- Section 5 summarises the results of our analysis of the social and environmental benefits of 5G
- Section 6 sets out our conclusions and recommendations

2 Status of 5G deployment in emerging markets

Several mobile network operators (MNOs) have now launched initial 5G services in emerging countries, typically by adding 5G new radio (NR) to their 4G infrastructure. Commercial 5G services were available in Brazil, South Africa and Thailand as early as 2020, while MNOs in Chile and Malaysia (via national wholesale operator Digital Nasional Berhad, or DNB) switched on their commercial 5G networks in 2021. Most recently, Telcel in Mexico launched 5G in February 2022, MTN in Nigeria in September 2022, while Airtel and Jio switched on their 5G networks in key cities in India in October 2022. Figure 2.1 below provides an overview of publicly reported 5G launches to date by MNOs in emerging countries.

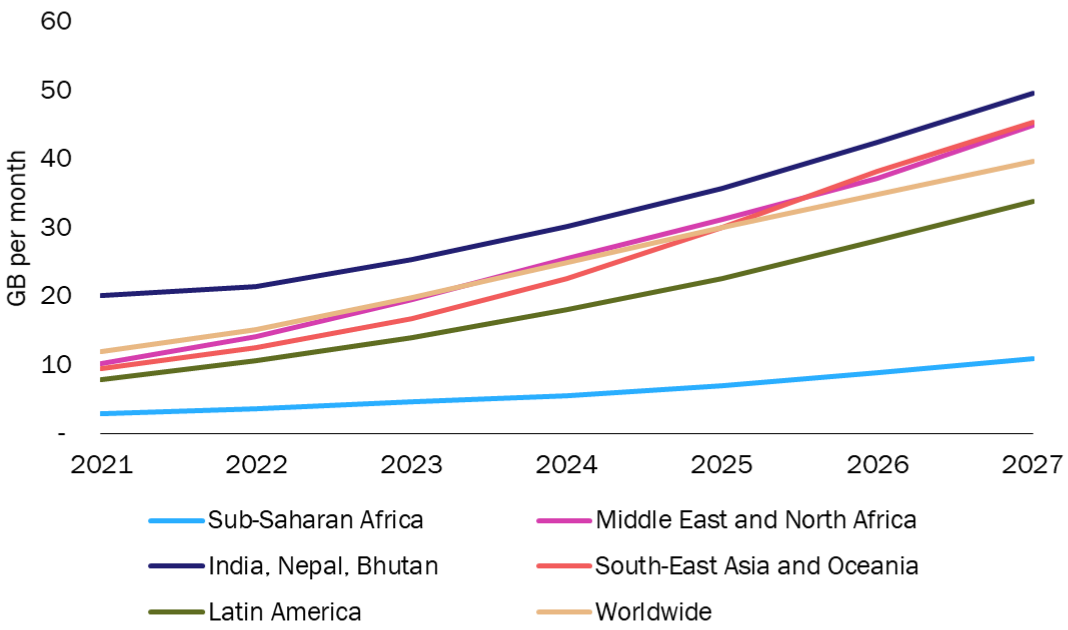
Figure 2.1: Commercial 5G availability in emerging markets, as of October 2022 [Source: Analysys Mason, 2022]

Country	Launch date	
Brazil	Q3 2020	Claro and Vivo launched 5G services using 700MHz, 1.8GHz and 2.6GHz via dynamic spectrum sharing (DSS) in July 2020
Chile	Q4 2021	Entel, Movistar and WOM launched 5G services using 3.5GHz spectrum in Q4 2021
India	Q4 2022	Airtel and Jio launched 5G services in several large cities in early October 2022
Malaysia	Q4 2021	DNB switched on its 5G wholesale network in December 2021 using both 700MHz and 3.5GHz frequencies
Mexico	Q1 2022	Telcel launched 5G services in February 2022 using 3.5GHz spectrum
Nigeria	Q3 2022	MTN launched 5G commercial services in September 2022 in some areas of Lagos, with plans to expand to other cities in the near term
South Africa	Q2 2020	Vodacom and MTN launched 5G non-standalone (NSA) in Q2 2020 using temporary concession spectrum (700MHz, 800MHz, 2.3GHz, 2.6GHz and 3.5GHz)
Thailand	Q1 2020	The regulator awarded unpaired 2.6GHz spectrum in early 2020, which AIS used to launch 5G services in February 2020

MNOs in Indonesia and Colombia are anticipated to introduce 5G services in 2023. No clear announcement of a timetable for spectrum allocation and deployment has been made so far in Bangladesh, Egypt, Morocco, Pakistan, and Turkey.

Initial 5G deployments have typically been driven by demand for mobile data services, and hence 5G has been used by MNOs to offer eMBB and FWA services to consumers, with higher speed and lower latency improving the overall experience of existing mobile services. The evolution of 5G networks to a standalone (SA), virtualised architecture, together with new associated technology developments such as edge computing and artificial intelligence (AI), is expected to generate further improvements in latency and bandwidth and expand the range of 5G use cases available (e.g. virtual reality for immersive broadcasting of live events, in-store shopping experience based on augmented reality, cloud gaming, video streaming in 8K resolution). These new uses will increase data intensity in telecoms networks, meaning that mobile data traffic is expected to grow quickly, with figures from the latest Ericsson Mobility Report[2] suggesting that the average mobile data traffic per smartphone could more than quadruple between 2021 and 2027 in emerging nations, reaching 34GB per month in 2027 in Latin America (up from 7.9GB per month in 2021), 45GB in South-East Asia and Oceania (up from 9.4GB per month in 2021), 11GB in sub-Saharan Africa (up from 2.9GB per month in 2021), 50GB in India, Nepal and Bhutan (up from 20GB per month in 2021) and 45GB in the Middle East and North Africa (up from 10GB per month in 2021).

Figure 2.2: Average monthly data traffic per smartphone subscriber [Source: Ericsson, 2022]



Beyond consumer use cases, the evolution of 5G will be a key enabler for a variety of industrial use cases that would be difficult to implement fully using previous mobile technologies. As a result, it is expected that once 5G SA networks are fully deployed, a large portion of the benefits of 5G to national economies will be generated by industrial use cases, either via economy-wide effects or by creating significant gains within economically important sectors. While the most economically important industry sectors will vary from one country to another, the range of applications and sectors where 5G technology might play a role is likely to be diverse. Figure 2.3 provides examples of live deployments and trials of industrial 5G use cases in a variety of sectors.

Figure 2.3: Examples of 5G use cases and their benefits [Source: Ericsson, 2022]

Vertical sector	Country	Case description	Benefits indicated by trials
Smart industry	USA	Highly automated factory from Ericsson producing 5G network equipment. The	Increased efficiency, improved visibility into

2 See further detail at: https://www.ericsson.com/49d3a0/assets/local/reports-papers/mobility-report/documents/2022/ericsson-mobility-report-june-2022.pdf

Vertical sector	Country	Case description	Benefits indicated by trials
		factory is a full-scale operation realising the potential of 5G with Industry 4.0 to enable intelligent automation and leverage real-time data across operations. Key initial use cases enabled in the factory include energy data management, environmental monitoring and augmented reality for remote support	energy consumption and reduction in energy bill, waste reduction, increase in machine uptime, reduction in travel and labour costs
Smart industry	Australia	In partnership with wireless edge networking equipment manufacturer Cradlepoint and Telstra, construction group Taylor Construction deployed, at selected construction sites, 5G-based high-speed connectivity to enable next-generation applications such as holographic building visualisation, wide-area safety scanning, real-time design display and IoT structural sensing	Improved existing network performance, driving improved cost efficiencies and increased client satisfaction
Smart rural	India	Global tool manufacturer Stanley Black & Decker worked closely with Ericsson and Deutsche Telekom to roll out a connected smart irrigation platform to manage, monitor and track connected solar-powered water pumps. Based on 2G today but with capabilities of 5G to support massive IoT, this type of low-band industrial case can be further cost effectively scaled	Optimised energy efficiency and water supply sustainability, reduction in energy bills for farmers
Smart rural	USA	Agricultural machinery manufacturer John Deere unveiled an autonomous tractor fitted with AI-enabled cameras, enabling the detection of obstacles and calculation of distances. Low-latency 5G connectivity is expected to play a key role in autonomous operations (e.g. by helping farmers remotely controlling tractors, or having real-time access to live video, images, metrics and notifications)	Improved productivity, reduction in labour costs, improved safety

The speed at which the benefits of 5G will be achieved for consumers will depend to a great extent on the pace at which MNOs invest in and implement a widespread roll-out of 5G networks. For industrial use cases, the benefits of 5G are dependent on the extent to which industrial sectors adopt new ways of working via digital transformation, of which 5G is a part.

In several benchmark countries in this study, 4G services have been launched relatively recently, which will likely limit the MNOs' incentive to invest significantly in the deployment of 5G before achieving a fair return on investment from their existing 4G networks. In Pakistan, for example, Jazz and Zong launched commercial 4G services in 2014, Telenor in 2016 and Ufone in 2019; in Egypt, all four MNOs launched commercial 4G services in 2017. Even among countries where 5G services are being planned for launch in 2022 or 2023, the overall adoption of 4G fluctuates significantly from one market to another and hence the extent of initial 5G roll-out might be uncertain. This is an especially important issue for policy makers which are looking to maximise the socioeconomic impact of 5G in their countries.

Incentivising operators to accelerate 5G deployment therefore requires a careful demonstration of the cost and benefits of achieving a widespread 5G footprint, which has been the core focus of this study and is discussed in the following sections.

3 Framework for the cost-benefit analysis in this study

The objective of this study has been to model the costs and benefits of the deployment of 5G in the 15 emerging countries considered, for 12 different use cases and under three deployment scenarios.

The baseline scenario considers the cost and extent of commercially led 5G eMBB and FWA roll-out using available 5G bands, i.e. low band, mid band and mmWave, between 2020 and 2035.

Scenario 1 quantifies the additional investment needed to expand the footprint of low-band 5G and achieve wider geographical coverage, to be used by some industries (e.g. agriculture, freight and logistics) and consumers in rural areas.

Scenario 2 evaluates the additional investment required to extend mid-band coverage beyond its baseline footprint to achieve similar geographical coverage to the low-band baseline footprint, to enable more advanced 5G use cases (e.g. automation, augmented and virtual reality, high-quality video processing in industrial sectors).

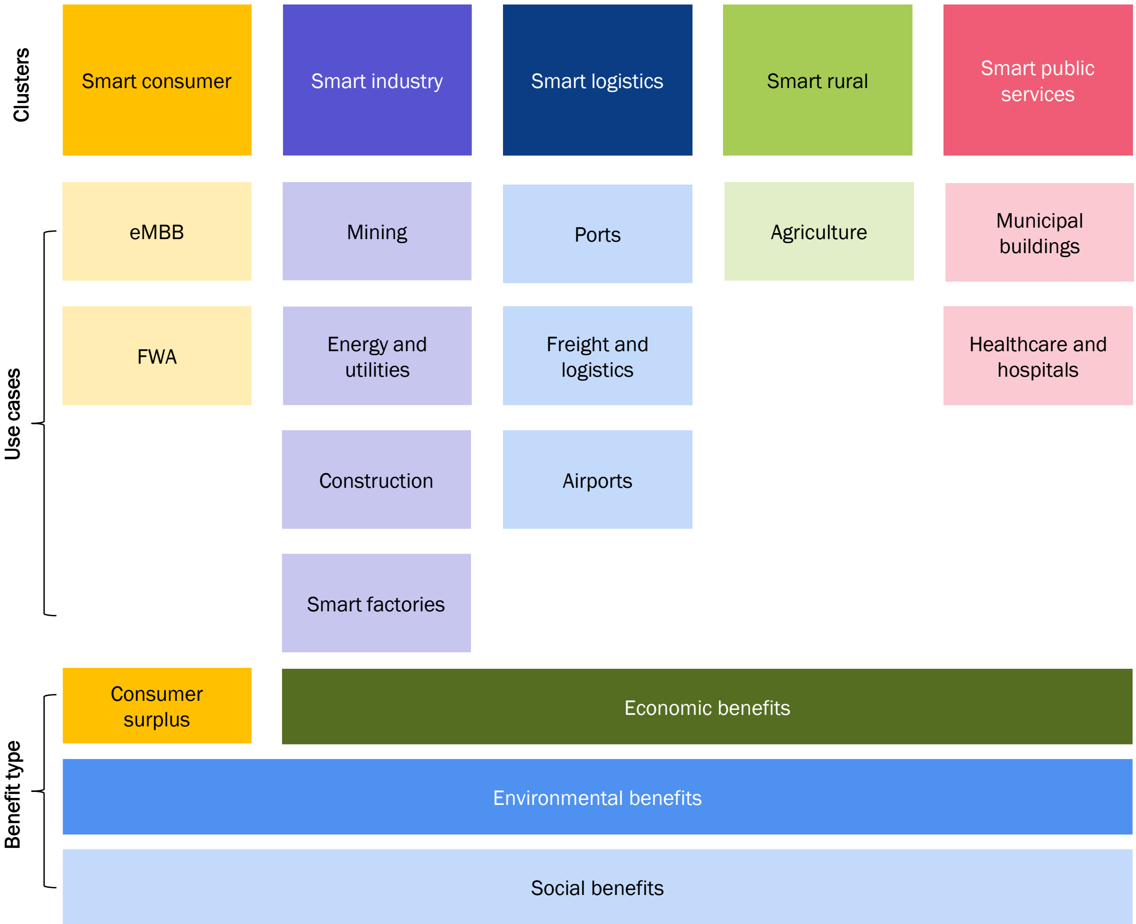
The study has considered four types of benefits, as illustrated in Figure 3.1 below:

- The consumer surplus that 5G is expected to generate, as a result of the availability of higher speeds and improved experience for a significantly lower cost per gigabyte (GB) than with previous generations of access technologies. Consumer surplus is captured under the 'Smart consumer' cluster.
- The incremental gross-domestic-product (GDP) benefits that 5G coverage expansion brings to use cases across four clusters, including 'Smart industry', 'Smart logistics', 'Smart rural' and 'Smart public services'. Incremental GDP benefits are quantified for both Scenario 1 and Scenario 2, based on the expected contribution of low-band and mid-band spectrum (respectively) to economic benefits.[3]
- The environmental benefits generated by 5G, based on its potential to help reduce greenhouse gas emissions in industrial sectors through greater digital transformation, of which 5G is a part.
- The social benefits associated with the use of 5G, including improved social inclusion, safety and security, increased wellbeing, etc.

The consumer surplus and incremental GDP benefits have been estimated via quantitative analysis, while the environmental and social benefits have been estimated qualitatively.

[3] Note that Malaysia is a unique case: 5G is being rolled out by a single wholesale network operator, DNB, with a commitment to deploy a nationwide 5G network. In agreement with Ericsson, we have considered any further expansion (Scenarios 1 and 2) of this baseline deployment to be outside the scope of our analysis, and have associated the economic benefits of 5G to the baseline deployment only.

Figure 3.1: Overview of 5G clusters, use cases and benefit types in the study [Source: Analysys Mason, 2022]



4 Costs and benefits of 5G deployment

This section provides a description, for each deployment scenario, of our modelling approach and main assumptions, and a discussion of the key results.

4.1 Baseline scenario

4.1.1 Modelling approach and assumptions

The baseline roll-out model is used to estimate the costs and benefits of commercial deployment using available 5G bands in the market in question, including in low band (e.g. 600MHz, 700MHz), and mid band (e.g. 2.3GHz unpaired, 2.6GHz unpaired, 3.5GHz). We also consider the future availability of mmWave spectrum (e.g. 26GHz) to provide FWA services and to be used by small cells deployed in some urban areas. Our modelling excludes the impact of re-farming of existing mobile bands in sub-1GHz and 1–3GHz spectrum that are currently used for 2G, 3G or 4G and instead focuses on the costs of rolling out 5G NR in new 5G spectrum: 4G traffic is expected to account for over 50% of mobile data traffic until at least 2029 in most benchmark countries, pushing back the timeframe for any re-farming of existing mobile bands to the very end of the forecast period considered in this exercise; in net present value terms, any cost incurred in this later part of the forecast period would be significantly discounted, considerably reducing the impact of re-farming on the overall cost of roll-out.

We have assumed low-band 5G is rolled out across all existing sites in each market, such that long-term population coverage matches historical long-term 4G population coverage. For mid-band spectrum, we have assumed roll-out across all urban and suburban macro sites, which we have modelled to be areas above a population density of 600 people per km^2 in most markets.[4] We have also assumed the deployment of 26GHz alongside the mid-band footprint to provide FWA services, as fibre to the home (FTTP) is unlikely to be deployed extensively in many emerging markets. Spectrum in the 26GHz band is also assumed to be used for localised coverage provided by small cells in areas qualified as "urban hotspots.[5]

For each country, we have applied a 5G population coverage profile, with roll-out going up to 100% of the long-term coverage achieved by type of band over a defined period. Our modelling assumes that low-band and mid-band deployment will achieve 100% of long-term coverage within six to nine years from the initial launch, depending on the country considered.

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4 In most markets, we have applied a threshold value (600 people per km^2) for mid-band roll-out. We have used a higher population density threshold (up to 1800 people per km^2) in Pakistan and Bangladesh where mobile connectivity ARPUs are significantly lower (up to 4–5 times lower) than in most other countries considered. For Malaysia, we have used a lower density threshold value (100 people per km^2) for mid-band roll-out to reflect DNB's commitment to provide access to data throughput of at least 100Mbit/s to 5G subscribers across Malaysia.

5 We have modelled 'urban hotspots' as urban locations with over 200 000 inhabitants.

Population coverage, alongside detailed population distribution data and cell-radius assumptions, has been used as input to calculate the number of 5G sites required to cover each country. More specifically, population distribution data for each market is contained within a grid of area squares (commensurate with cell size); these squares are then ranked by population density to calculate population-area curves and to determine urban, suburban and rural site classifications (or 'geotypes'). The number of macro sites for coverage in each geotype is estimated based on the cell radius per site for different frequency bands, with roll-out occurring from highest population density to lowest, up to long-term population coverage. The number of sites used for long-term population coverage, combined with the total number of macro sites available per country, is then used to estimate the number of remaining sites that can be used for capacity, which we assumed to be distributed across the coverage grid according to population.

Unit cost figures (capex and opex) are applied for the projected number of sites to estimate the cost of 5G roll-out. The total cost of deployment per market is calculated by multiplying the cost incurred by a hypothetical MNO by an adjusted number of MNOs per country. The adjustment factor is an assumption we have developed to reflect the number of operators in a market taking account of any publicly reported active sharing agreements for 4G or 5G.

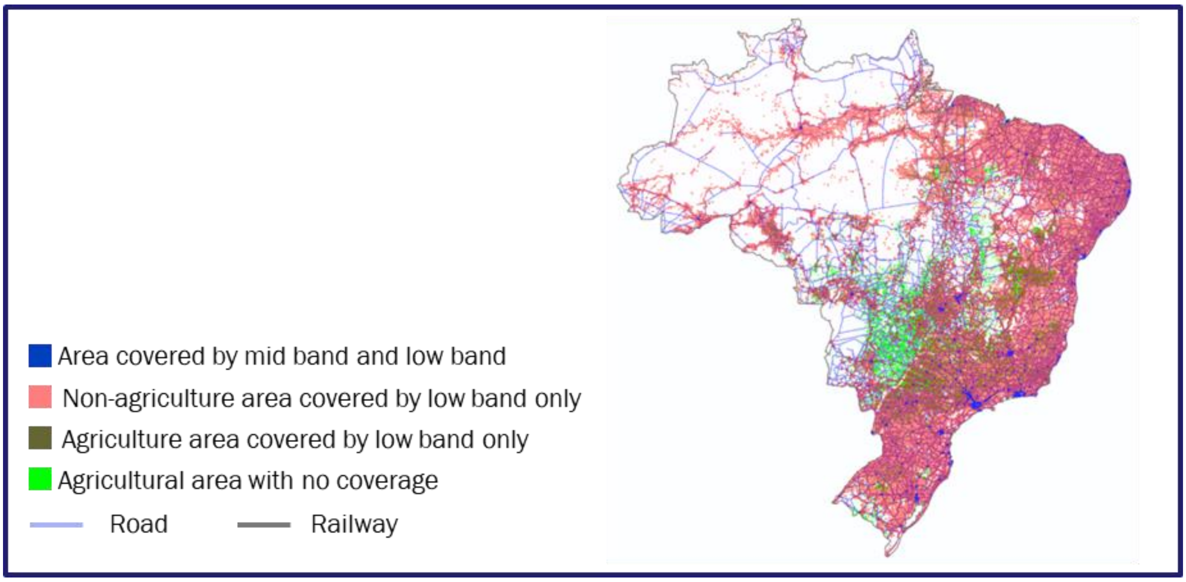
Economic benefits in the form of sectoral GDP uplifts are expected to be less relevant to the deployment of an initial eMBB network and have not been considered in the baseline scenario.

The consumer surplus has been calculated by estimating the difference between an assumed cost per GB of mobile data that a 5G mobile subscriber would be willing to pay for 5G services, and an estimate of the actual cost per GB incurred, multiplied by the average mobile data traffic generated by that subscriber. The cost per GB of data varies between markets, as does the average data traffic per subscriber, and both affect the magnitude of the consumer surplus generated per 5G subscriber. The overall consumer surplus has then been extrapolated by multiplying the surplus per subscriber by a projected total number of 5G subscribers over time.

4.1.2 Key results

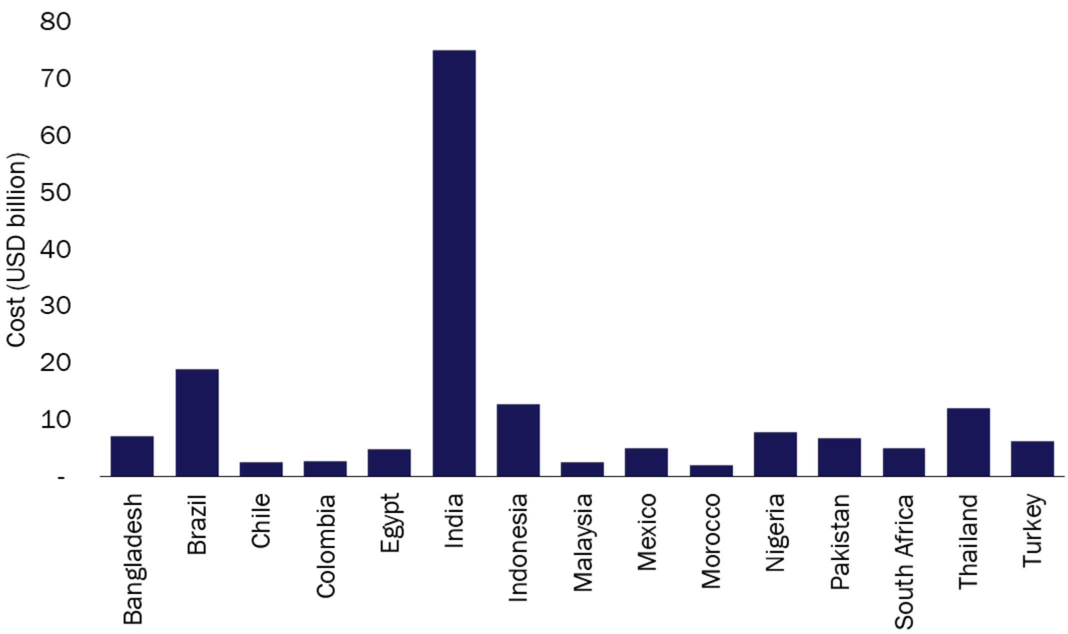
Our modelling suggests that when low band is deployed across the entire grid in all countries, it typically achieves population coverage above 90% by 2030, in line with long-term 4G coverage. Geographical coverage is driven by the distribution of population across the land area, and as a result varies significantly across countries. Because mid-band 5G is typically deployed in urban and suburban areas, mid-band coverage is expected to cover only 40–70% of the population in the long term, i.e. less than 6% of the country's land area. As an example, Figure 4.1 shows the low-band mid-band coverage footprint at maturity for Brazil in the baseline scenario.

Figure 4.1: Baseline scenario coverage – Brazil [Source: Analysys Mason, Meta, OpenStreetMap contributors, World Bank, 2022]



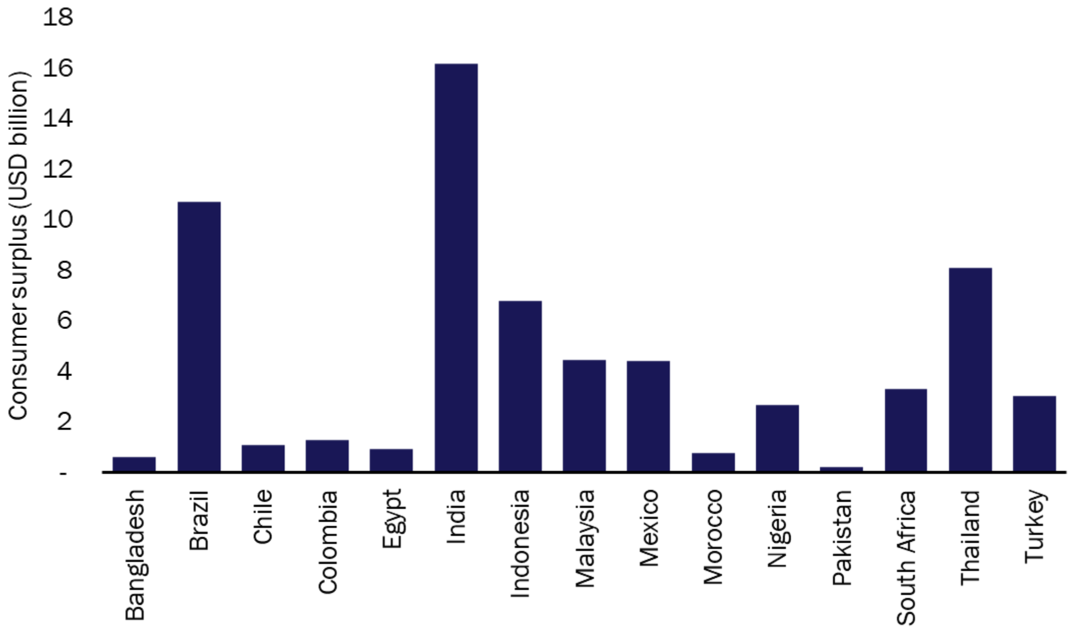
We estimate the aggregated cost of 5G roll-out to be USD3–8 billion in most benchmark countries, and up to USD75 billion in India, as shown in Figure 4.2 below. Most deployment costs are incurred by 2028–29, by which point 5G is fully rolled out across the existing network grid in most countries.

Figure 4.2: Cumulative net present value of 5G roll-out costs by country across all MNOs, 2020–35 [Source: Analysys Mason, 2022]



Our results indicate that the introduction of 5G networks can generate consumer surplus totalling ~USD1–10 billion per country, as illustrated in Figure 4.3 below.

Figure 4.3: Cumulative net present value of consumer surplus, 2020–35 [Source: Analysys Mason, 2022]



4.2 Scenario 1 – extending low-band 5G coverage

4.2.1 Modelling approach and assumptions

From the baseline scenario, we have estimated the incremental costs of extending the footprint of low-band 5G to all rail, road and agriculture areas. This expanded footprint is assumed to be driven by industrial demands to address some use cases that 5G can enable across vertical clusters (e.g. agriculture, freight and logistics) as well as to provide population coverage in rural areas.

We have assumed the deployment of a single network infrastructure between 2026 and 2032 for low-band coverage beyond the baseline, with active sharing between MNOs in each market. We have also assumed that building greenfield sites in these areas carries higher unit costs (due to difficulty of installation, cost of providing power, etc.).

Economic benefits have been calculated by estimating the sectoral GDP connected to a 5G-enabled use case and the long-term uplift enabled by 5G. As low-band 5G is expected to be most relevant for use cases requiring mobility over wide areas (e.g. massive sensor networks deployed over wide areas) and/or with more modest capacity requirements, only a portion of the full long-term GDP uplift enabled by 5G has been assumed to be addressable by low-band spectrum. Estimates have been informed by published reports providing approximations of 5G-enabled sectoral GDP uplifts.

We have assumed the long-term uplift to be phased in across a period of time, in line with 5G roll-out speed and adoption. In particular, the complexity and cost of implementing bespoke 5G-enabled industrial use cases may be relatively high in early years, which would limit adoption initially.

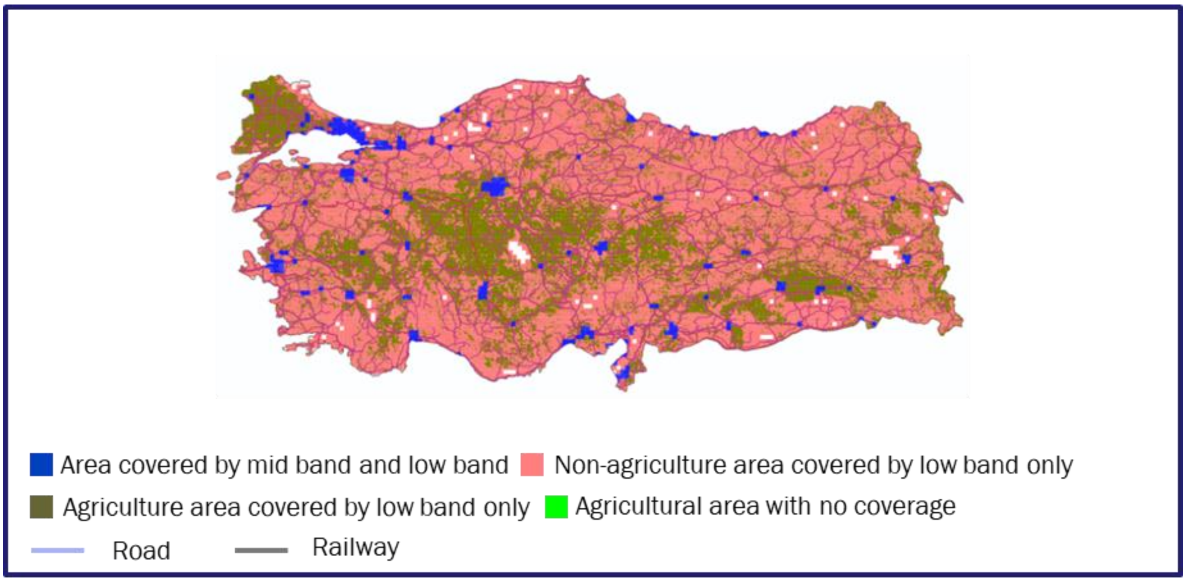
It should be noted that the GDP uplift represents a 'best case' scenario on the basis that there will be significant take-up of 5G use cases from enterprises across a variety of sectors. In reality, a number of barriers to adoption will exist (e.g. cost and complexity of deployments, business case, skills, limited supply ecosystem availability). In addition, some sectors are likely to have a limited degree of industrialisation and digitalisation in some emerging nations (e.g. industrialisation within the agricultural sector is slow in many markets). Our estimates assume that 5G will prompt and/or accelerate industrialisation. Wider government policies (which are not 5G specific) to accelerate industrialisation more generally are also important, in addition to 5G-specific policies.

4.2.2 Key results

Our modelling suggests that building new low-band macro sites beyond the baseline footprint to achieve coverage alongside all rail, road and agriculture areas, would result in an additional ~3–12% investment needed per market (assuming a single infrastructure roll-out, as noted previously).

Figure 4.4 shows the mapping output of our modelling exercise for Scenario 1 for Turkey, with low-band 5G covering all rail, road and agriculture areas (at maturity).

Figure 4.4: Scenario 1 coverage – Turkey [Source: Analysys Mason, Meta, OpenStreetMap contributors, 2022]



We estimate the economic benefits from this extended low-band deployment could amount to ~USD1–3 billion per country. The agriculture sector is the largest contributing sector to GDP across all countries considered, driving the magnitude of the economic benefits achieved in the Smart rural cluster.

Most countries are expected to generate economic benefits that are three to ten times higher than the incremental cost of extending low-band coverage, as illustrated in Figure 4.5 below.

Figure 4.5: Cumulative net present value of incremental costs and economic benefits by country, Scenario 1, 2020–35 [Source: Analysys Mason, 2022]

Country	Costs (USD billion)	Benefits (USD billion)					Benefit-to-cost ratio
		Smart industry	Smart logistics	Smart rural	Smart public services	Total	
Bangladesh	0.1	1.1	0.2	1.3	<0.1	2.6	18.5
Brazil	2.3	1.9	0.2	2.2	0.1	4.4	2.0
Chile	0.1	1.2	0.1	0.2	<0.1	1.5	10.2
Colombia	0.3	0.5	0.1	0.5	<0.1	1.1	3.2
Egypt	0.3	0.8	0.1	0.9	<0.1	1.8	7.0
India	1.9	5.2	0.9	9.4	0.1	15.6	8.4
Indonesia	0.6	2.8	0.3	2.4	<0.1	5.6	8.8
Mexico	0.7	2.3	0.2	0.8	0.1	3.3	5.1
Morocco	0.1	0.2	<0.1	0.2	<0.1	0.4	2.8
Nigeria	0.2	0.3	0.1	0.7	<0.1	1.1	6.1
Pakistan	0.6	0.3	0.1	0.9	<0.1	1.3	2.0
South Africa	0.4	1.2	0.1	0.2	<0.1	1.4	3.3
Thailand	0.1	0.8	0.2	0.8	<0.1	1.7	11.7
Turkey	0.5	1.4	0.2	1.0	<0.1	2.6	5.0

It should be noted that Bangladesh's population is distributed across its land area, leading to significant low-band geographical coverage (64%) in the baseline scenario. Due to its small land area, the incremental number of sites required to achieve full road/rail/agriculture geographical coverage and implied cost for low-band extension are relatively limited, contributing to a high benefit-to-cost ratio (18.5).

Extending low-band coverage will slightly increase the share of population covered, as well as the proportion 5G subscribers (out of the population covered by 5G) by the end of the forecast period, as the more consistent availability of higher speeds over a wider geographical area may incentivise more consumers to migrate to 5G. This generates additional consumer surplus, estimated to add up to ~USD50–300 million per country.

4.3 Scenario 2 – extending mid-band 5G coverage

4.3.1 Modelling approach and assumptions

In this scenario, we have modelled the extent and cost of additional mid-band deployment beyond the mid-band footprint calculated in the baseline scenario.

While low-band spectrum will be sufficient to address the technical requirements of some use cases, the most advanced 5G use cases will require additional functionality (in terms of capacity, latency, upload/download speeds, etc.). This can be achievable only by expanding mid-band MIMO[6] coverage outside of its baseline footprint and deploying additional macro sites and small cells in localised areas.

We assume bespoke 5G-enabled use cases exist within the agriculture, freight and logistics, construction, energy and utilities and mining sectors that will require higher capacity and low-latency capabilities. We have assumed a single, multi-use case mid-band mMIMO network can simultaneously serve multiple use cases via bespoke network slices. We have assumed that existing eMBB sites within the low-band baseline footprint would be upgraded to include mid-band spectrum, with some level of densification (i.e. new macro sites) required to achieve contiguous coverage. We have not assumed any additional deployment outside of the low-band coverage footprint, due to the high cost of deploying new sites in hard-to-reach areas.

Bespoke use cases within smart factories, ports and airports are expected to have stronger uplink capacity requirements compared to consumer eMBB. We have assumed the deployment of new dedicated mid-band mMIMO UL/DL[7] macro sites in those locations.

We have assumed the deployment of small-cell networks to support use cases in sectors such as healthcare, municipal buildings and smart factories, driven by requirements for indoor coverage, and high-reliability/low-latency requirements.

Economic benefits have been calculated following a methodology similar to that used in Scenario 1, assuming that a portion of the full long-term uplift enabled by 5G is addressable by mid-band spectrum.

4.3.2 Key results

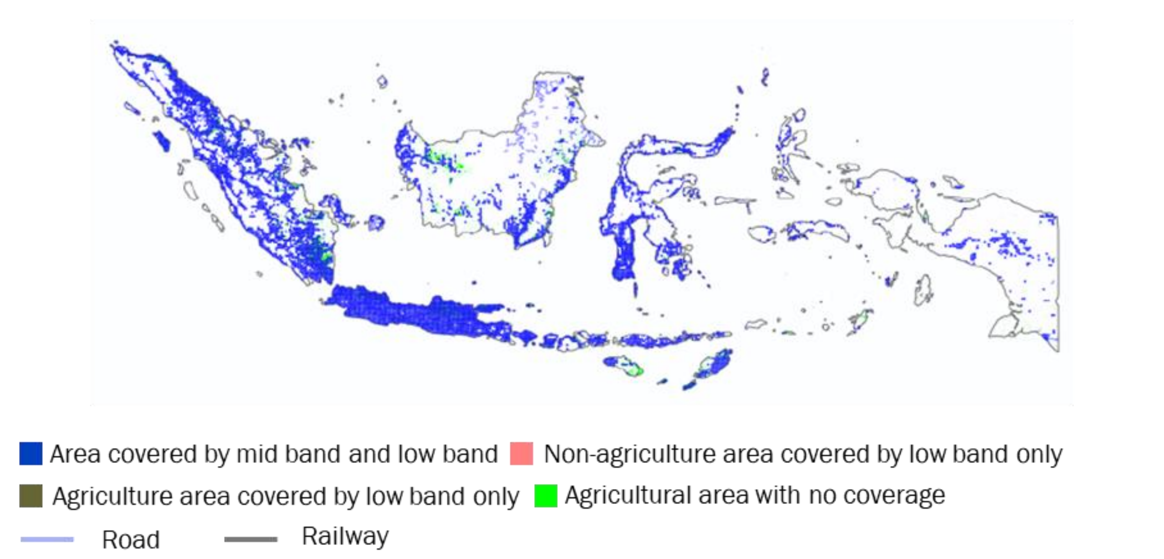
Our modelling exercise estimates that deploying additional mid-band massive MIMO macro sites to achieve similar geographical coverage to the low-band baseline footprint, and adding bespoke coverage in specific locations to enable advanced use cases (e.g. mMIMO UL/DL macro sites and small cells), would result in an additional ~15–25% investment per market.

Figure 4.6 provides the output of our modelling for Scenario 2 in Indonesia, whereby mid-band coverage has been extended to achieve a similar footprint (at maturity) than that of the low-band footprint in the baseline scenario.

6 Multiple in multiple out.

7 Uplink and downlink.

Figure 4.6: Scenario 2 coverage – Indonesia [Source: Analysys Mason, Meta, OpenStreetMap contributors, 2022]



Economic benefits from extended mid-band deployment are estimated to be ~USD5–12 billion per country. The economic benefits generated by the Smart industry and Smart rural clusters together account for ~85–90% of the total economic benefits in each market. This is primarily driven by the relative importance of the industry sectors connected to these clusters (e.g. agriculture, manufacturing, construction) to the economy of the benchmark countries considered in this study.

Most countries are expected to generate economic benefits that are three to seven times higher than the incremental cost of extending mid-band coverage, as illustrated in Figure 4.7 below.

Figure 4.7: Cumulative net present value of incremental costs and economic benefits by country, Scenario 2, 2020–35 [Source: Analysys Mason, 2022]

Country	Costs (USD billion)	Benefits (USD billion)					Benefit-to-cost ratio
		Smart industry	Smart logistics	Smart rural	Smart public services	Total	
Bangladesh	0.7	4.2	0.7	2.7	0.2	7.8	10.8
Brazil	4.1	7.1	0.8	4.7	1.5	14.1	3.4
Chile	0.4	4.2	0.2	0.5	0.3	5.2	12.6
Colombia	0.7	1.8	0.2	1.0	0.3	3.3	4.5
Egypt	0.5	2.9	0.4	1.9	0.3	5.5	12.0
India	6.4	19.2	3.7	20.0	1.9	44.8	7.0
Indonesia	2.5	10.1	1.2	5.2	0.5	17.0	6.8
Mexico	1.7	8.7	0.7	1.7	0.5	11.7	6.8
Morocco	0.4	0.6	0.1	0.4	0.1	1.2	3.0
Nigeria	1.0	1.1	0.2	1.5	0.1	2.9	3.0

Country	Costs (USD billion)	Benefits (USD billion)					Benefit-to-cost ratio
		Smart industry	Smart logistics	Smart rural	Smart public services	Total	
Pakistan	1.1	1.1	0.3	1.9	0.1	3.4	3.2
South Africa	1.0	4.1	0.3	0.3	0.3	5.1	5.0
Thailand	0.9	3.2	0.6	1.6	0.2	5.7	6.1
Turkey	1.6	5.3	0.7	2.1	0.4	8.6	5.4

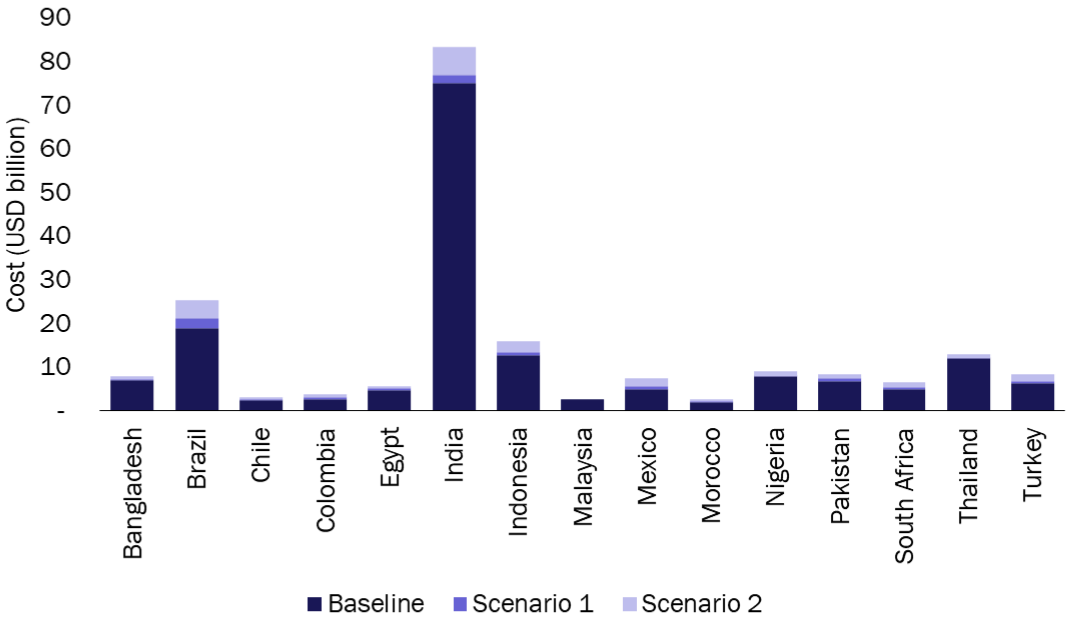
Extending mid-band coverage will provide consumers with access to higher speeds from 5G-enabled devices, and we have assumed consumers would be willing to pay a slightly higher premium for these higher speed connections. The difference between this premium and the actual cost per GB that we anticipate consumers will pay is expected to generate additional consumer surplus, which we have estimated would add up to ~USD0.2–1.5 billion per country.

4.4 Overall results

Overall, our modelling suggests that a baseline 5G deployment is estimated to cost ~USD3–8 billion per country, with an additional ~20–35% investment required to extend coverage.

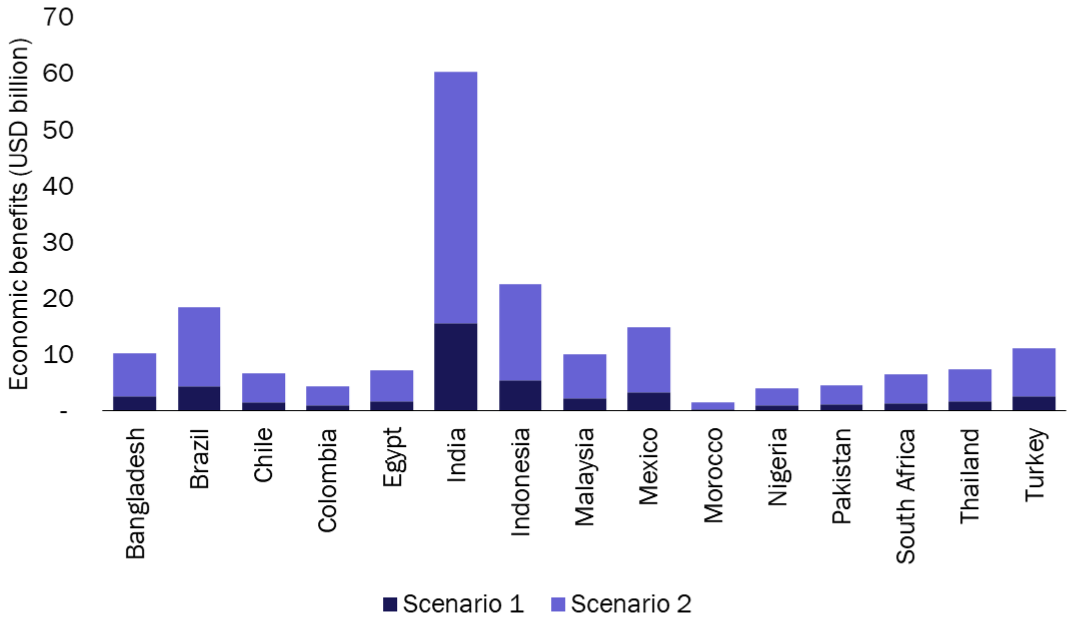
As illustrated in Figure 4.8 below, while Scenario 1 requires the deployment of new sites in remote areas, the incremental cost of 5G deployment tends to be higher in Scenario 2 than in Scenario 1. This is because whilst the larger geographical area to extend low-band coverage to rural areas is expected to require 15–25% additional geographical coverage on top of the low-band baseline, the mid-band extension requires 35-50% additional geographical coverage on top of the mid-band baseline; as a result, there are more sites to upgrade in Scenario 2 (with higher upgrade costs), compared to the additional sites in Scenario 1. Furthermore, the cost of additional bespoke deployments at use case locations (e.g. ports, airports) is also a contributing factor in Scenario 2. In addition, Scenario 1 assumes that a single MNO would be responsible for the deployment in remote areas, while Scenario 2 assumes that some mid-band upgrades would be duplicated across all MNOs.

Figure 4.8: Cumulative net present value of costs by country (2020–35) and scenario [Source: Analysys Mason, 2022]



Extending coverage beyond the baseline footprint can generate significant GDP benefits from industrial adoption of advanced 5G use cases other than MBB, especially from mid-band coverage extension (see Figure 4.9 below). Mid-band spectrum is a key enabler of advanced 5G use cases (e.g. high-quality video processing, automation, AR/VR) that are expected to have a significant impact in terms of business benefits (e.g. greater productivity, cost savings). As a result, the economic benefits generated by extending mid-band coverage across the entire low-band baseline footprint in Scenario 2 are considerably higher than those generated by extending low-band coverage in hard-to-reach areas in Scenario 1.

Figure 4.9: Cumulative net present value of economic benefits by 5G roll-out scenario (2020–35) [Source: Analysys Mason, 2022]



Most countries are expected to generate overall economic benefits three to seven times higher than the incremental cost of extending coverage. Because Scenario 2 carries significantly higher costs (and generates higher benefits) than Scenario 1, the overall benefit-to-cost ratio across both scenarios is more reflective of the benefit-to-cost ratio of Scenario 2.

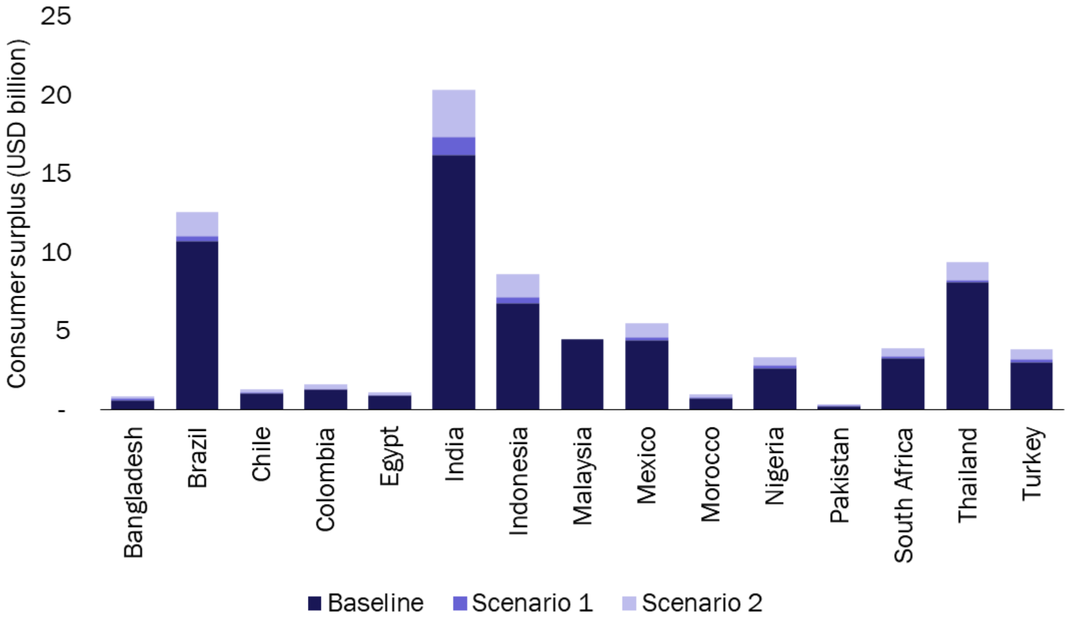
Figure 4.10: Cumulative net present value of incremental costs and economic benefits and benefit-to-cost ratio by country, Scenarios 1+2 [Source: Analysys Mason, 2022]

Country	Costs (USD billion)	Benefits (USD billion)					Benefit-to-cost ratio
		Smart industry	Smart logistics	Smart rural	Smart public services	Total	
Bangladesh	0.9	5.3	0.8	4.0	0.2	10.3	12.0
Brazil	6.4	9.0	1.0	6.9	1.6	18.5	2.9
Chile	0.6	5.4	0.3	0.7	0.3	6.7	11.9
Colombia	1.1	2.3	0.3	1.5	0.3	4.4	4.1
Egypt	0.7	3.6	0.6	2.8	0.3	7.3	10.2
India	8.2	24.4	4.6	29.4	2.0	60.5	7.3
Indonesia	3.1	12.9	1.5	7.6	0.5	22.5	7.2
Mexico	2.4	11.0	0.9	2.5	0.6	15.0	6.3
Morocco	0.5	0.8	0.1	0.6	0.1	1.6	2.9
Nigeria	1.2	1.4	0.3	2.2	0.1	4.0	3.5
Pakistan	1.7	1.4	0.4	2.8	0.1	4.7	2.8
South Africa	1.5	5.3	0.4	0.5	0.4	6.5	4.5

Country	Costs (USD billion)	Benefits (USD billion)					Benefit-to-cost ratio
		Smart industry	Smart logistics	Smart rural	Smart public services	Total	
Thailand	1.1	4.0	0.8	2.3	0.3	7.4	6.9
Turkey	2.1	6.7	0.9	3.1	0.4	11.2	5.3

Our results suggest that 5G MBB can generate consumer surplus totalling ~USD1–10 billion per country, with coverage extension giving 20–30% extra consumer surplus. As shown in Figure 4.11, extending low-band coverage (Scenario 1) could marginally increase the proportion of 5G subscribers (out of the population covered by 5G) by the end of the forecast period, as the more consistent availability of higher speeds over a wider geographical area may incentivise more consumers to migrate to 5G. Extending mid-band coverage (Scenario 2) is expected to provide consumers with access to higher speeds, which we have assumed consumers would be willing to pay a slightly higher premium for. The difference between this premium and the actual 5G cost per GB is expected to generate additional consumer surplus.

Figure 4.11: Cumulative net present value of consumer surplus by 5G roll-out scenario (2020–35) [Source: Analysys Mason, 2022]



5 Social and environmental benefits of 5G

5.1 Assessment of social benefits

Beyond generating economic (GDP) benefits for industries and additional surplus for consumers, 5G is expected to have a significant impact on society, for example by:

- offering a better mobile experience in terms of video quality, latency and speed (e.g. eMBB)
- increasing safety and security (e.g. in factories, mines, construction sites, ports, airports, freight and logistics) through better-performing, real-time connectivity
- enhancing social inclusion (e.g. through access to 5G-based FWA broadband, better healthcare through digital applications, and so forth)
- improving sustainability for key industries in rural areas (e.g. agriculture)
- enhancing the efficiency of collaboration (e.g. through better-performing connectivity within municipal buildings)
- helping energy companies optimise energy grids (e.g. energy and utilities), improving energy efficiency for households.

As it is difficult to robustly quantify the social benefits of 5G, we have assessed them qualitatively, by considering the importance of each use case within the long-term visions and national plans set by governments and the potential for 5G to create new benefits.

Overall, our assessment suggests that the social benefits enabled by 5G will be greatest from 5G-based FWA, smart factories, freight and logistics, agriculture and healthcare use cases, as shown in Figure 5.1 below. Note that we have not allocated 5G social benefits to a specific scenario.

Figure 5.1: Assessment of social benefits of 5G, by country and use case[8] [Source: Analysys Mason, 2022]

Country	Smart consumer		Smart industry				Smart logistics			Smart rural	Smart public services	
	eMBB	FWA	Smart factories	Mining	Construction	Energy and utilities	Ports	Airports	Freight and logistics	Agriculture	Healthcare	Municipal buildings
Bangladesh	••	•••	•••	•	••	•	•••	••	•••	•••	•••	••
Brazil	••	•••	•••	••	••	•	•••	••	•••	•••	••	•••
Chile	••	•••	••	•••	••	•	•••	••	•••	•••	•••	•••

8 • • • = high benefits, • • = medium benefits, • = lower benefits. The highest priority use cases are shown with a grey background and a blue border.

Country	Smart consumer		Smart industry				Smart logistics			Smart rural	Smart public services	
	eMBB	FWA	Smart factories	Mining	Construction	Energy and utilities	Ports	Airports	Freight and logistics	Agriculture	Healthcare	Municipal buildings
Colombia	••	•••	•••	••	•••	•	••	••	•••	•••	•••	••
Egypt	••	•••	•••	••	•••	••	••	•	•••	•••	••	••
India	•••	•••	•••	••	••	••	••	••	•••	•••	•••	••
Indonesia	••	•••	••	•••	••	•	••	•	••	•••	••	••
Malaysia	•••	•••	•••	••	•••	••	•••	••	•••	•••	•••	••
Mexico	••	•••	•••	••	•••	••	••	•	••	•••	••	••
Morocco	••	••	•••	••	••	•	••	•	••	•••	•••	••
Nigeria	••	••	•••	••	••	•	•••	••	•••	•••	•••	••
Pakistan	••	•••	•••	•••	••	•	••	•	••	•••	••	••
South Africa	•••	•••	•••	••	••	••	••	••	•••	•••	•••	••
Thailand	••	•••	•••	••	••	•	••	••	••	•••	•••	••
Turkey	••	••	•••	••	••	••	•••	••	•••	••	••	••

5.2 Assessment of environmental benefits

The use of 5G as an enabler of industrial use cases is also expected to help organisations across sectors to reduce their greenhouse gas emissions, for example by:

- enabling a better utilisation of time and materials (e.g. factories)
- reducing unnecessary travel/journeys (e.g. healthcare, freight and logistics)
- improving energy use and reducing waste (e.g. construction, energy and utilities, agriculture)
- enhancing air quality monitoring (e.g. mining)
- reducing transport congestion (e.g. airports, ports).

Our assessment of environmental benefits has been based on the contribution of each sector to greenhouse gas emissions and the potential for 5G to reduce those emissions.

Overall, our analysis suggests the environmental benefits enabled by 5G will be greatest in agriculture, freight and logistics, smart factories and construction, as shown in Figure 5.2 below. Note that while 5G can contribute to digital transformation within the industries shown, we do not account for changes in pace of industrialisation, but indicate the benefits that 5G can deliver, if industries undergo digital transformation, and adopt 5G.

Figure 5.2: Assessment of environmental benefits of 5G, by country and use case[9] [Source: Analysys Mason, 2022]

Country	Smart consumer		Smart industry				Smart logistics			Smart rural	Smart public services	
	eMBB	FWA	Smart factories	Mining	Construction	Energy and utilities	Ports	Airports	Freight and logistics	Agriculture	Healthcare	Municipal buildings
Bangladesh	n/a[10]	n/a	•••	•	•••	••	••	•	•••	•••	••	••
Brazil	n/a	n/a	•••	••	•••	••	••	•	•••	•••	••	••
Chile	n/a	n/a	•••	••	•••	••	••	••	•••	•••	••	••
Colombia	n/a	n/a	•••	••	•••	••	••	•	•••	•••	••	••
Egypt	n/a	n/a	•••	••	•••	••	••	•	•••	•••	••	••
India	n/a	n/a	•••	••	•••	••	••	•	•••	•••	••	••
Indonesia	n/a	n/a	•••	••	•••	••	••	•	•••	•••	••	••
Malaysia	n/a	n/a	•••	••	•••	••	••	••	•••	•••	••	••
Mexico	n/a	n/a	•••	••	•••	••	••	••	•••	•••	••	••
Morocco	n/a	n/a	•••	••	•••	••	••	••	•••	•••	••	••
Nigeria	n/a	n/a	•••	•••	•••	••	••	•	•••	•••	••	••
Pakistan	n/a	n/a	•••	••	•••	••	••	•	•••	•••	••	••
South Africa	n/a	n/a	•••	••	•••	••	••	••	•••	•••	••	••
Thailand	n/a	n/a	•••	••	•••	••	••	••	•••	•••	••	••
Turkey	n/a	n/a	•••	••	•••	••	••	••	•••	•••	••	••

9 • • • = high benefits, • • = medium benefits, • = lower benefits. The highest priority use cases are shown with a grey background and a blue border.

10 Note that we have assumed the environmental benefits generated by consumers to be negligible in comparison with industry sectors.

6 Conclusions and recommendations for policy makers

Our modelling exercise suggests that it is possible to deliver additional mid-band infrastructure meeting demand for bespoke 5G industrial use cases at a cost of ~USD1.0–4.0 billion by country. To provide extended geographical coverage using low-band 5G, our modelling suggests a further ~USD0.3–0.7 billion investment (for a single network infrastructure). Economic (GDP) benefits in Scenario 1 are three to ten times higher than the incremental investment, and three to seven times in Scenario 2.

While this implies that it is possible to achieve a benefit-to-cost ratio above 1, actions from policy makers will be needed to promote 5G development and have the right conditions in place for 5G to make a significant contribution to the economy and to society. A summary of our recommendations to policymakers are provided in Figure 6.1 below.

Figure 6.1: Recommendations from the study [Source: Analysys Mason, 2022]

Type	Enabler	Description
Supply side	National 5G strategy	• Publish a holistic national roadmap for 5G implementation, detailing how 5G will be introduced to the market, the services that might be offered and timescales for any preparatory work to plan for spectrum release • Encourage the public sector and industry bodies to assess how their services and end users can benefit from 5G connectivity • Put in place an economy-wide 5G ready strategy to accelerate the pace for 5G transition
	Spectrum availability	• Prepare spectrum award processes to enable national MNOs to gain 5G licences in low, mid and high bands to support 5G deployment in different environments • Consider trading off spectrum fees for deployment targets that meet connectivity policy objectives • Ensure flexibility for MNOs to re-purpose spectrum licensed for previous generations of mobile technology, to support greater spectrum efficiency and accelerated deployment from the latest generations of technology (i.e. 4G/5G)
	Infrastructure build-out facilitation	• Amend or simplify procedures to streamline site upgrade procedures and to remove any bottlenecks in site planning, so to support rapid 5G roll-out • Ensure the fees to use public sites are orientated on a cost recovery basis
		• Encourage an open environment in which MNOs can share infrastructure with other industries as needed (e.g. fibre networks used by utilities or alongside railways, public sites for towers) • Consider appropriate policy measures to reduce the cost and accelerate the deployment of 5G (in particular in rural/underserved areas)
		• Issue national-level guidelines to facilitate the acquisition of new macro sites and to accelerate small-cell deployments

Type	Enabler	Description
		• Streamline planning processes to avoid lengthy deployment delays
	Coverage	• Collaborate with MNOs to develop effective solutions for coverage in areas where commercially led solutions are not viable, including public funding where there is clear evidence of market failure (such as to reach the most remote locations) • Consider offsetting fees (e.g. spectrum auction or recurring spectrum fees) against coverage commitments (e.g. indoors, in rural areas) and for funding of data capacity improvements where end user needs are not being met
	Energy efficiency	• Engage with MNOs to ensure that MNOs can deploy 5G networking solutions with high energy efficiency, to optimise power consumption and reduce operational costs
	FWA	• Include gigabit capable FWA as a complement to fibre as a means of achieving national broadband targets, especially in areas underserved by fixed infrastructure
	Tax breaks	• Incentivise the roll-out of 5G infrastructure by offering tax credits, noting in its Regional Economic Outlook for Europe published in April 2021, the International Monetary Fund (IMF) advocated that governments give infrastructure investment a boost by providing temporary investment tax credits to accelerate investments, for example for digital and sustainable technologies • Seek international benchmarks of possible approaches. For example, the Japanese government provided a 15% tax credit to organisations investing in and using 5G infrastructure (between April 2020 and end of March 2022)
Demand side	Enterprise and industrial policies	• Give a prominent role to 5G as a key enabler of the digital transformation agenda of major vertical sectors (e.g. manufacturing, agriculture, healthcare, utilities) • Provide clear guidelines on 5G deployment, and the importance and role played by 5G in delivering different use cases
	Public sector	• Encourage public authorities to make 5G-specific investments (e.g. in next-generation connectivity plans) • Encourage 5G use by the public sector, for example in municipal buildings (e.g. facilities management, provision of public services, maintenance of public spaces), and to support education and tourism
	Carbon abatement	• Promote the use of 5G-based solutions by vertical sectors • Highlight the role 5G can play to support efforts to achieve environmental commitment roadmaps and zero net carbon emissions
	Targeted subsidies	• Allocate direct funds to further accelerate research and facilitate tests and trials between MNOs, suppliers and enterprises from multiple vertical sectors • Offer subsidies to promote industry collaboration and the creation of a strong supply ecosystem, to support the development of 5G use cases, and to help stimulate demand for 5G-based solutions