Growing connections: The challenges and opportunities of achieving ubiquitous 5G mobile connectivity in the UK

BRIEFING PAPER

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This briefing assesses the economic, social and environmental gains that enhancing the UK's mobile network infrastructure and ubiquitous 5G mobile connectivity could deliver for the UK, and provides a brief overview of the key challenges holding back the UK from reaping those rewards.

KEY POINTS

- Increasing the UK's growth rate is the new government's primary mission. Mobile connectivity and the infrastructure that enables it can make a key contribution to achieving that ambition.
- Successive new generations of mobile technology have boosted economies in the past. The introduction of 5G is no different. Studies suggest that, by 2035, widespread availability and use of 5G could add £159 billion to the UK economy.
- The primary economic benefits that 5G brings will be felt by businesses, through its role in supporting operational efficiencies and the diffusion of innovations across industries. As a result, consumers will mainly benefit indirectly.
- If 5G becomes ubiquitous, it is also expected to drive gains in the efficacy of the delivery of public services and help deliver a plethora of environmental benefits.
- Despite repeatedly stated aspirations to be world-leading in 5G, the UK is far behind the "global frontier" and a number of peer European economies. Data suggests that the users of 5G in the UK only have access to it around 10% of the time. By contrast, in India, users have access over 40% of the time.
- Consistent with Labour's plan for boosting growth, there is considerable scope for the private sector to invest more in next generation mobile connectivity. However, a number of factors including previous policies towards the mobile telecoms sector have unintentionally hindered investment.
- These factors include policies that have unintentionally helped to inhibit investment in 5G. For instance, the approach to spectrum and some of the efforts to try cut the cost of building infrastructure. Specifically, measures aimed at making it cheaper for MNOs to operate mobile masts have resulted in less land being supplied for infrastructure and an unprecedented rise in the number of disputes between landowners and infrastructure builders along with a significant increase in costly litigation.

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BETTER MOBILE CONNECTIVITY CAN MAKE A MAJOR CONTRIBUTION TO BOOSTING THE UK'S ECONOMIC GROWTH

The new government has put boosting the UK's economic growth at the top of its political agenda by making it one of its key missions.[1] By drawing on existing research and in-depth interviews[2], this paper shows how getting the rollout of 5G right, and ensuring it becomes widely and reliably available to consumers and businesses in the UK, could make a major contribution to achieving that higher growth rate.[3]

The government has highlighted the importance of economically important infrastructure to its growth mission

In her first speech as Chancellor of the Exchequer, Rachel Reeves said that the government's growth mission rested on three pillars: stability, investment and reform.[4] The speech highlighted that one of the key areas where more investment was needed was in the UK's physical infrastructure. This would help boost growth both indirectly and directly. The former would come through the enabling role that good-quality infrastructure plays in boosting the wider productivity of the economy. [5] The latter would be a result of the activities of those that build and maintain infrastructure, which involves growth-generating actions such as employing people and investing in plant and machinery.

Mobile communications as a general purpose technology

Mobile connectivity is a General Purpose Technology (GPT). This is a term used to describe technologies important enough to have a protracted impact on an economy's productive capacity, e.g. electricity, steam power, the micro-chip, etc.[6] [7] [8] [9]

Efforts to measure this wider and deeper impact from mobile connectivity have found that for every £1 of value generated by the mobile telephone industry directly, £3 is generated for the wider economy.[10] The same analysis suggested that the total contribution of mobile connectivity to the UK economy in 2020 was around £112 billion, or 5% of GDP.[11]

Therefore, the shift to 5G connectivity could deliver even greater economic benefits, not least to the UK's long-run growth rate, if the potential it offers to the private and public sectors is fully taken advantage of.

Box 1: The evolution from 3G to 4G, and now 5G

3G arrived in 2003. It enabled data services to become central to mobile phone use. The advent of 3.5G facilitated the streaming of audio and video.[12] By 2012, the UK was starting to rollout 4G. The latter enabled even faster data speeds, reduced latency, and provided consumers and businesses with the opportunity to utilise a range of enhanced in-phone applications.[13]

It has been settled government policy that the UK should upgrade its mobile connectivity from 3G and 4G to 5G. The latter is faster, has even lower latency than 4G and greater capacity and resiliency, and is expected to deliver improved overall coverage.[14] For example, a 5G network can:

- Transport a huge amount of data much faster (5G's peak speeds can be up to 10 times quicker than 4G when using its high-frequency bandwidth), indeed it can operate at a greater speed than fixed-line broadband.
- Reliably connect an extremely large number of devices.[15]
- Enable network slicing i.e. allow dedicated network resources for specific purposes over defined geographies (e.g. a farm or factory) with guaranteed performance attributes.

These benefits are best derived from standalone networks with a 5G core. However, despite this being the optimum arrangement, much of the 5G infrastructure currently deployed is not standalone but rather adaptions of existing 4G infrastructure.[16]

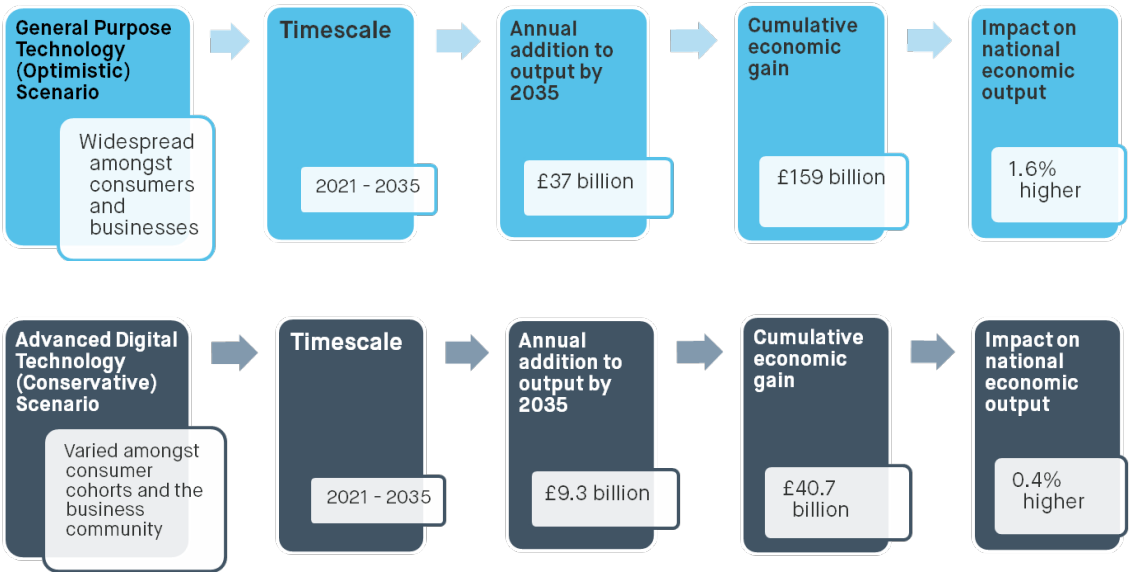
Maximising the potential of 5G to help bring about a faster growing economy will require the new government to follow through with the ambition set out in the previous administration's Wireless Infrastructure Strategy. That document called for there to be nationwide standalone 5G coverage for all populated areas by 2030.[17]

The positive economic impacts of upgrading to 5G mobile technology in the UK

Estimates of the aggregate gains to economic prosperity of widespread 5G adoption

There have been numerous attempts to estimate the likely macroeconomic gains that will accrue to the UK from a widespread rollout of 5G. Perhaps the most comprehensive can be found in a 2021 analysis commissioned by the then Department for Digital, Culture, Media and Sport (DCMS). It looked at the period up to 2035 and tried to gauge the scale of the economic benefits that would likely accrue.[18] Its key results are outlined in Diagram 1, below.

Diagram 1: Estimates of the likely economic gains from 5G take-up across the UK



Source: Cambridge Econometrics and Analysys Mason (2021)

By 2035, the additional economic output derived from widespread rollout of 5G under DCMS' optimistic scenario, has been projected to reach £37 billion. This would equate to around £529 in additional output per capita by that date.[19]

Other studies have looked at the potential gains that could cumulatively accrue to the UK economy up to 2030. Across five different assessments that we looked at, the average accumulated benefit for the UK was in the region of £62 billion. However, there was considerable variance in the predicted scale of the economic uplift presented in the different analyses.[20]

The greatest gains are likely to be made by businesses rather than consumers

The extensive adoption of 5G technologies will of course be of immediate benefit to smartphone users, who will be able to use considerably faster mobile internet services, more reliably, and at a much higher capacity than is currently feasible under 4G networks. However, the direct impact on consumers is arguably the least revolutionary aspect of 5G. It is widely predicted that 5G will have a transformational effect on a multitude of industries, enabling significant production and supply chain efficiencies and innovative new products and services to be developed.[21]

By virtue of the ability to handle a large number of devices in the same location for example, high-performing 5G networks are able to facilitate the rapid growth in the adoption of new technologies such as the Internet of Things (IoT). In fact, standalone 5G can support one million devices per square km compared to only 2,000 with 4G LTE.[22] Consequently, 5G is much better placed to enable the development of web-based artificial intelligence (AI) applications, autonomous vehicles, and other smart machines.[23]

Box 2: Potential economic applications of 5G

Smart factories

One of the most transformative effects of 5G could be how the technology shapes the manufacturing industry. 5G, alongside new tools such as AI, is set to enable factories to become more automated, efficient and flexible. For instance:

- 5G networks can facilitate the exchange of sensor data to inform decisions about equipment and operational performance, and enable large numbers of independently operating robots to perform complex tasks.
- Manufacturing and logistics businesses will be able to control operations in real-time by connecting sensors, machines and potentially the products themselves, to AI tools in the cloud. On a busy factory floor for example, drones and cameras that are connected to smart devices that use 5G can help locate and transport something more efficiently than in the past.[24] [25] The higher speeds and capacity of 5G networks, will allow robots to undertake more complex tasks. This can free up human labour for more specialised tasks, boosting productivity in this sector.
- 5G can also free up machinery from being tethered to a particular location by replacing cables with wireless connectivity, giving manufacturers a far greater degree of flexibility over the organisation of production.[26]

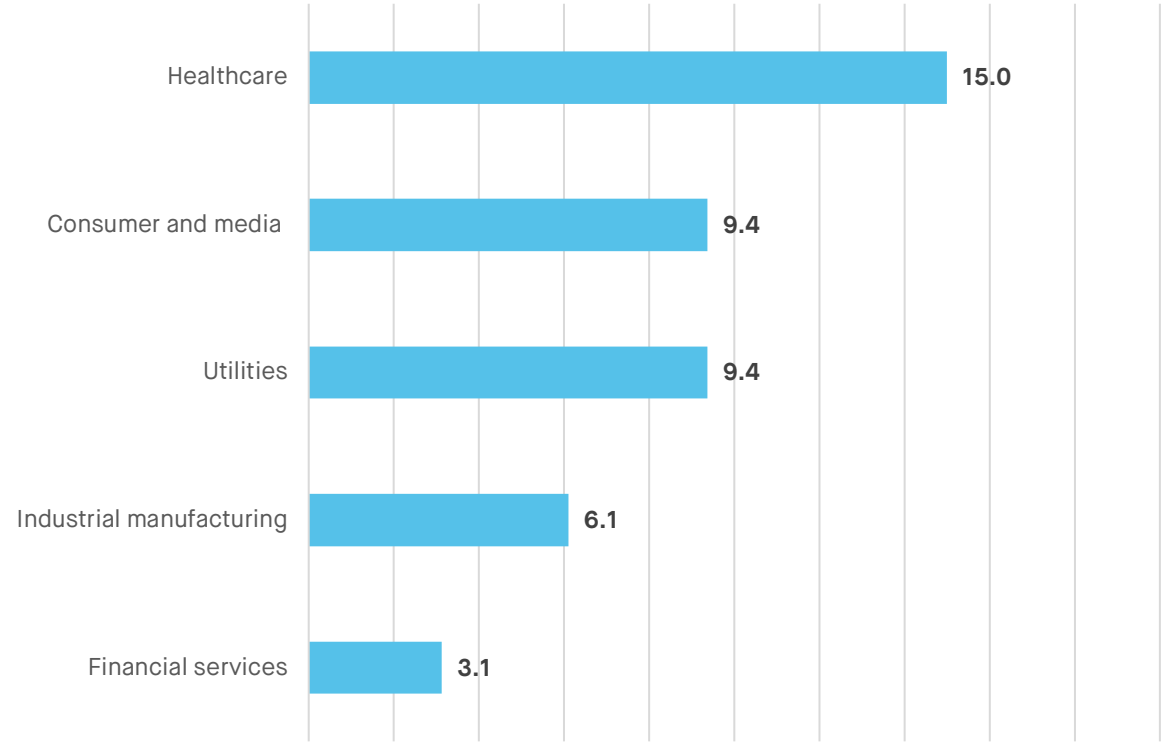
Smart agriculture

Deploying 5G networks in agriculture provides a range of opportunities to enhance productivity and yields. Many farming activities are highly labour-intensive and shortages of workers can cause significant difficulties for businesses in this sector. 5G can help overcome such labour shortages through automation. Sensors can replace manual data collection in the field, with real-time data enabling faster responses to ecosystem changes. Robots could carry out tasks such as weeding and harvesting, with autonomous vehicles taking on large-scale tasks such as ploughing and fertilising.

5G can also enable more precise farming. For example, the connectivity afforded by 5G networks could enable IoT applications to monitor things like soil content and nutrients, which in turn can help farmers optimise fertiliser and water use, decreasing costs.[27] [28]

The growth dividend from 5G is likely to be particularly pronounced in a number of high value-added industries. For example, Cambridge Econometrics and Analysys Mason estimate that high levels of 5G adoption in the manufacturing and logistics sectors alone could add £15 billion in gross value added (GVA) between now and 2035.[29] Similar work by PwC has highlighted the potential gains across a wider variety of sectors, over a shorter time period.[30]

Figure 1: Potential total impact of 5G on different sectors of the UK economy by 2030, £ billions



Source: PwC (2021)

The social and environmental benefits of ubiquitous 5G

Facilitating a healthier and more secure society

Supporters of 5G have highlighted how it can contribute to greater public safety and societal wellbeing through reduced loneliness and has been linked to improvements in life satisfaction metrics amongst users.[31] Some of these gains come from the role 5G can play in enhancing the quality of health and social care for the elderly (see Box 3).

Box 3: Potential applications of 5G in public service provision: health and social care

An ageing population and constrained resources have brought adult social care services "to its knees", according to the Public Accounts Committee.[32] As such, measures that effectively increase the quality and efficiency of health and social care provision are of immense and growing value to society.

One of the biggest challenges facing social care is recruitment, with over 100,000 vacancies in England alone.[33] 5G can help address this issue by enabling carers to provide better care more efficiently. For instance, 5G networks open up opportunities for non-intrusive and continuous monitoring

of residents with a range of specialist sensors, by tracking hydration and movement to when a resident is about to get out of bed. This enables early identification of issues, quicker and tailored interventions when needed, and improved health outcomes for individuals.[34] Rather than replacing the role of caring humans, 5G-enabled technology can help traditional care work be more effective and personalised to the recipient.

For example, the Liverpool 5G Create project deployed sensors under care home beds to monitor the vital signs of residents. This enabled more tailored care and reduced the number of falls and related injuries, a problem that costs the NHS more than £2.3 billion per year. This case elucidates how 5G can not only enable more and better care work to be done for less, but also help prevent minor issues from escalating into major ones, and avoid the concomitant detrimental health and psychological impacts such events can have on those that find themselves in such situations.[35] [36]

Enabling better management of the urban and suburban environment

By facilitating the creation of smart cities, 5G can improve city and town life and bring about efficiency gains in the delivery of public services in metropolitan areas. The enhanced wireless connectivity can enable smart grids, intelligent transportation systems, and real-time monitoring of public infrastructure. This can lead to improved energy management, reduced congestion, and improved data-driven decision-making.[37]

Reducing impacts on the natural environment

It has been suggested that extensive 5G rollout could also bring about considerable environmental benefits, including aiding efforts to reach net zero. Many of the prospective environmental benefits of 5G are linked to efficiency gains in transportation and the consumption of energy. These benefits include reductions in traffic congestion and greenhouse gas (GHG) emissions through more remote working, less energy use through smart grids and reduced water wastage.[38] [39] One analysis suggested that 5G use could reduce emissions in the energy and utilities sectors by 1.7 billion tonnes of CO2 globally between 2020-2030.[40] Other environmental gains might come from the role that 5G could play in enabling precision farming for example, and the consequent reduction in pesticide use.[41] [42]

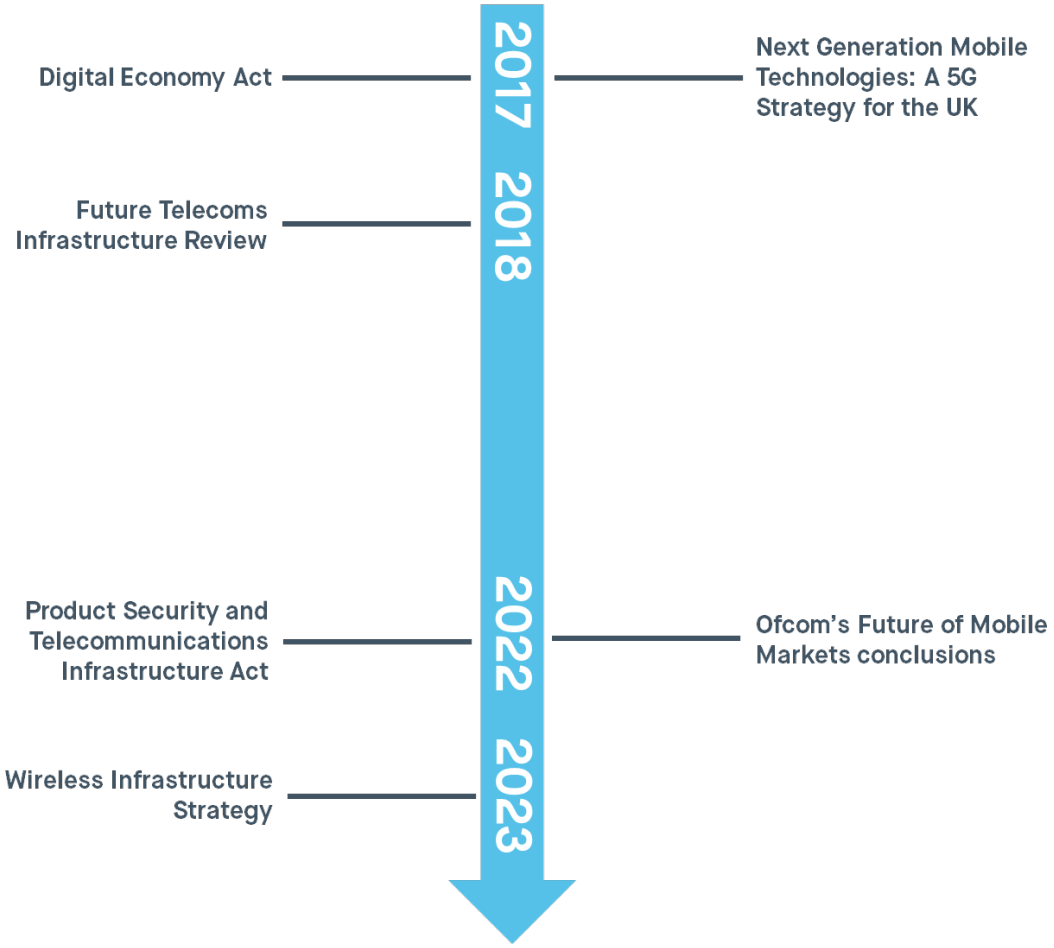
Despite laudable ambitions, the UK's record on 5G wireless internet connectivity has been comparatively poor

The scale of the benefits to be reaped from the implementation of 5G is entirely dependent on optimising the number, positioning and mix of macro and small cells.[43] The higher wavelengths that 5G operates at require a greater density of infrastructure. Therefore, for a given amount of coverage, the quantity of infrastructure will need to be greater than was the case with 4G, which implies a higher cost of coverage per square mile of the UK for those building and maintaining the 5G infrastructure.

A plethora of strategy and policy documents have been published by the government and Ofcom about how to encourage 5G

UK governments have been well aware of the potential of 5G for a long time. For instance, in 2017 the then government declared its ambition for the UK to be a global leader in 5G technology.[44] Since then there has been a phalanx of policy papers and strategy documents, all with the intent of advancing the UK's rollout of 5G infrastructure and boosting adoption (see Diagram 2 below). These culminated in 2023, with the Wireless Infrastructure Strategy, which set out the aim for the UK to have nationwide standalone 5G coverage in all populated areas by 2030.[45]

Diagram 2: Key milestones in 5G policy development, 2017 - 2023



Source: SMF analysis

The strategy behind the UK's 5G rollout to date has been a market-led one

The approach to the UK building its 5G infrastructure so far has been one where the telecoms industry has the primary role, while government and the regulator have a facilitating function; setting the conditions for the industry to deliver and occasionally making a limited intervention. Central to this market-led approach have been efforts to:

- Ensure the mobile sector is not unduly impeded in its infrastructure activities by reducing the cost of entry, minimising the complexity of building and upgrading

infrastructure and curtailing distortions to competition that might affect rollout. This focus on obstacle clearance has been reflected in measures to reform planning rules and ease restrictions around access to land to, for example, reduce mast site rental costs to Mobile Network Operators (MNOs) and Wireless Infrastructure Providers (WIPs).[46]

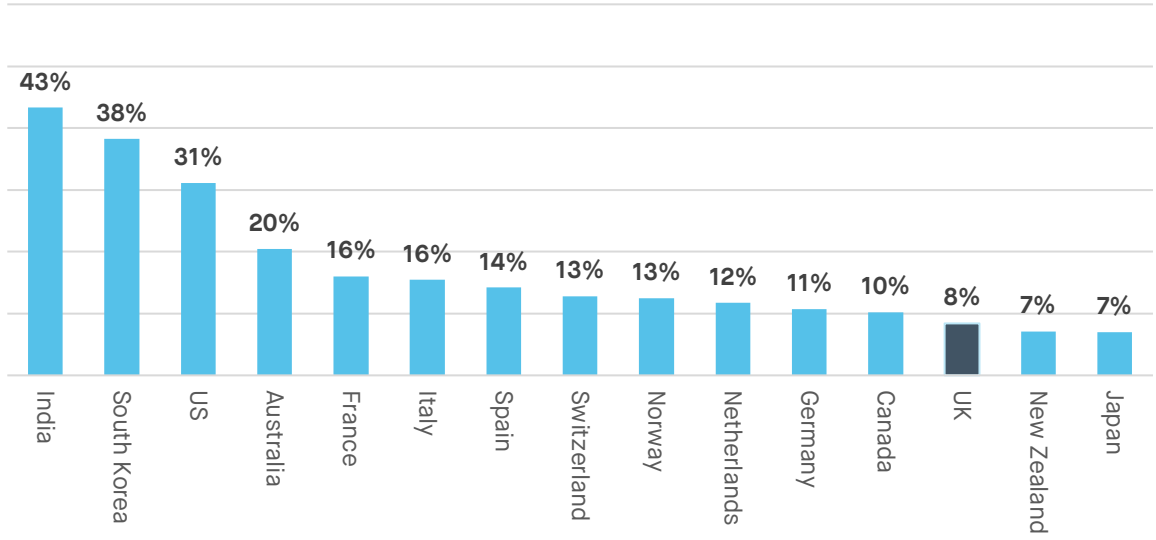
- Foster expectations of growing demand for 5G from consumers and businesses amongst MNOs by illustrating the use cases for 5G across a wide range of industry sectors, and help anticipate challenges to the deployment of 5G-enabled technology.[47]

The UK's comparative 5G rollout underperformance

The current approach to 5G looks like it will leave the UK falling short of those ambitions outlined by successive governments. One 2023 report has quantified how the real-world 5G experience compares across countries. The UK performs poorly despite being amongst the first populations to take up 5G technology and having the highest 5G-capable smartphone sales in Europe.[48]

In terms of 5G availability for example, measured by the proportion of time users spent with an active 5G connection, the UK trails many countries. These include India (43%) and South Korea (38%) who are global leaders. The UK is also behind a number of our European peers such as France (20.6%) and Italy (17.9%).[49]

Figure 2: 5G availability (% of time) across selected countries, Q4 2023

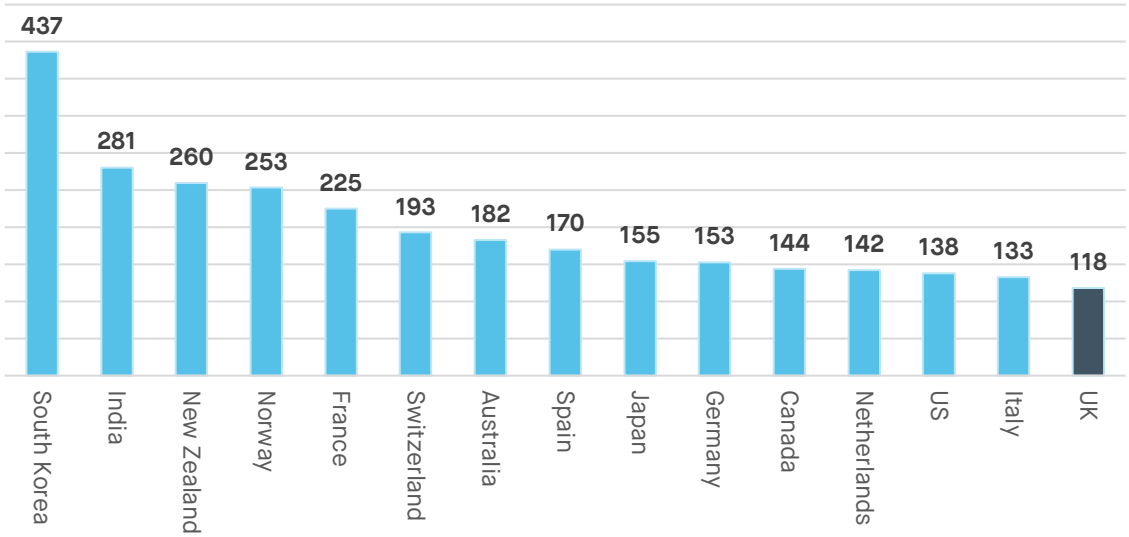


Source: OpenSignal (2023)

NB: US and Canadian data was collected in Q2 2023

Analysis of international 5G download speeds suggests that UK is amongst the slowest. Figure 3 presents average download speed data for a selection of countries. It shows that, in South Korea for example, average 5G download speeds are just under 437 Mbps. In the UK they are 118 Mbps.

Figure 3: 5G average download speeds across selected countries, Q4 2023



Sources: OpenSignal (2023)

NB: US and Canadian data was collected in Q2 2023

The evidence on download speeds presented in Figure 3 chimes with the findings of other analyses. One published in 2021 found that:

- The UK ranked 21st out of 25 developed markets in the median 5G download speed, which was slower than the Netherlands, France and Germany. [50]
- The big five European economies (UK, Germany, France, Spain, and Italy) were outperformed by "frontier countries" such as the UAE, South Korea, Singapore, and Qatar.[51]

As Figures 2 and 3 show, the UK lags behind many similarly developed countries, and indeed some developing economies. Combining both connection time and download speed into a "composite connectivity" metric allows a more rounded perspective to be taken on the UK's relative position on the issue of 5G rollout (Table 1).[52]

Table 1: Composite 5G Connectivity Index

Rank	Country
1	South Korea
2	India
3	Norway
4	New Zealand
5	France
6	Australia
7	US
8	Switzerland
9	Spain
10	Germany

11	Italy
12	Netherlands
13	Japan
14	Canada
15	UK

Sources: OpenSignal (2023) and SMF calculations

A multiplicity of factors lie behind the UK's mediocre 5G technology rollout record

The failures of the current policy approach

Consistent with Labour's plan for boosting growth, there is considerable scope for the private sector to invest more in next generation mobile connectivity and contribute to a higher growth rate both directly and indirectly. However, if the UK wants to exploit the full growth contributing potential of developments in mobile technology such as 5G, politicians and policymakers need to understand what is constraining investment. To that end, our interviews with a range of experts in digital infrastructure revealed a number of policy-related problems that have combined to impede investment in 5G infrastructure, alongside other factors such as the levels of current and future demand for 5G. The most salient of these challenges are briefly outlined below. Importantly, each will be explored in more depth in the final report of this project, due later in 2024.

The counter-productive effects of efforts to reduce the costs of accessing land

Mobile infrastructure is typically installed on third-party land, which is owned neither by the mobile operator nor by those installing or maintaining the infrastructure. Land access is vital for both building new and upgrading existing infrastructure (e.g. from 4G equipment to 5G).[53] [54]

The costs of renting land, for example, were seen by many as a key obstacle to mobile connectivity rollout. Therefore, the then May government brought in changes to the Electronic Communications Code (ECC), through the Digital Economy Act 2017, aiming to cut the cost of using private land for installing communication infrastructure. More specifically, it: [55]

- Introduced a new valuation system for the rent landowners receive for allowing communications infrastructure to be built on and operated.[56]
- Widened the definition of a "Code Operator" to include WIPs.
- Created a dispute resolution procedure to try and make it easier to resolve disputes between MNOs and landowners where they arose.

This new approach to land valuation saw it evaluated based on its value to the landowner without the presence of telecommunication equipment.[57] The consequent change to rents was intended to bring them in line with those paid by utility companies and providers of other essential services. The expectation was that the subsequent cost reductions would feed back to MNOs and bring about greater investment in the network. However, it is widely seen as having resulted in

unintended and counter-productive effects, such as reducing the supply of land for infrastructure, and made landowners less willing to engage with MNOs and created more litigation, which has then seen resources diverted away from infrastructure spending. For instance, over a thousand disputes have been brought in front of the courts and tribunals system since the 2017 modifications to the ECC. Symptomatic of this is the 109% growth in cases referred to the Upper Tribunal (Lands Chamber) between the years ending March 2021 and March 2023.[58] By contrast, in the decades prior to the ECC changes, only a handful of cases required court resolution. This rise in legal disputes appears to be a unique problem that has emerged in the UK and is not replicated elsewhere.

There are concerns amongst some that this issue of litigation will continue to generate more uncertainty around infrastructure investment. Indeed, the Upper Tribunal Lands Chamber Telecoms User Group expects the situation to worsen as the provisions of the Product Security and Telecoms Infrastructure Act 2022 are implemented. The Act extends the new valuation regime to approximately 15,000 rental agreements between operators and site providers that are governed by the Landlord and Tenant Act 1954 and the Business Tenancies (Northern Ireland) Order 1996.[59] The Upper Tribunal Lands Chamber Telecoms User Group estimates that the result of this will be a doubling of cases.[60]

The infrastructure value chain has evolved in such a way that it risks weakening the impetus to invest

The trend amongst MNOs to divest their passive infrastructure assets and the resulting emergence of WIPs has significantly altered the value chain of the industry.[61] This development has been welcomed by some as it removes a considerable source of costs from the balance sheet of MNOs. It is also considered by supporters as efficiency-enhancing, as specialist firms look after the wireless infrastructure. However, others argue that the split of the infrastructure from the MNOs, will reduce the impetus to invest in new (and upgrading existing) connectivity because it weakens the vertical integration between mobile services and infrastructure that creates the strongest incentive to invest.

This industry development has been accompanied by the aforementioned failure, in many instances, of the ECC-driven reduction in rents to feed through to MNOs and generate more resources for investment. Instead much of the value is captured by WIPs at the same time that the supply of land is falling due to the reduced rent landowners now receive for providing space for infrastructure.

In addition, several of our interviewees noted that the regulatory framework for mobile telecoms has failed to reflect the evolution of the sector in general and that this was holding back investment. Further, it was suggested that the growth of WIPs is a good example of the regulatory environment falling behind, with little evidence to date, of rethinking by the regulator about how sufficient expenditure on a more extensive 5G network might be ensured, as infrastructure ownership changes and, consequently, there are considerable uncertainties about the likely impact on investment.

The complexity of planning processes as a restraint on investment

Delays in the planning system along with outright refusals cause considerable problems for the building and upgrading of mobile infrastructure. They hinder the supply of infrastructure and ultimately increase its cost. Consequently, reforming planning rules to lessen such problems has been a central feature of the 2018 Future Telecoms Infrastructure Review. [62] For example, a large amount of ground-based mobile infrastructure falls into the category of permitted development, which curtails the ordinarily lengthy and costly local authority planning process.[63] However, despite this easement, the planning picture remains somewhat complex, and a number of interviewees pointed to ongoing planning challenges that could act as a drag on the need to build a more dense network of infrastructure for fully effective 5G.[64] Specific problems that were highlighted, included:

- "Prior approval" stipulations from local authorities over siting and appearance of new masts.
- Limitations on masts in urban areas, on public buildings and "street furniture".
- General height and width constraints on what can be done under permitted development rules.
- Tensions in the National Planning Policy Framework in England where there is both an embedded preference for minimising items of electronic infrastructure, and a requirement to support the spread of electronic communications.[65]

The disincentives to investment built-into spectrum policy

Underpinning mobile connectivity is spectrum.[66] The UK's approach towards spectrum is seen by many as hindering the expansion and modernisation of wireless infrastructure. In our expert interviews, it was specifically criticised for:

- The combined costs created by the initial auctioning and subsequent charges for using spectrum. For example, the auctioning of 4G spectrum cost £2.3 billion back in 2013, while the 5G spectrum auction process resulted in MNOs paying around £1.3 billion for shares of it.[67] [68] Further, between 2022 and 2030 it is estimated that spectrum fees will cost the four main MNOs around £3 billion.[69]
- The shortness of the spectrum licences that are awarded. While a spectrum licence is an asset, the limited timeframe for which an MNO has such a licence deters very long-term investment and simultaneously makes it less useful as an asset against which MNOs can raise external capital.

Questions over whether the structure of the UK telecoms sector inhibits infrastructure investment

The market structure of the mobile telecoms sector has also been identified as a factor constraining the rollout of 5G mobile infrastructure.[70] The evidence from the expert interviews we have conducted was that, on balance, the current market structure is a factor impacting levels of investment.

A debate has raged over whether higher market concentration is better because it ensures MNOs have sufficient resources to invest in their networks; or whether,

instead, less concentrated markets are optimal because they mean stronger incentives to compete and therefore more consumer choice and lower prices.[71]

In the UK, there have been calls for consolidation to address the comparatively low levels of profitability of the country's four mobile network operators, which is seen as limiting the investment that is needed. Overall, the evidence around the impacts of consolidation is mixed. Many experts sympathise with the position of MNOs seeking to merge, pointing to international evidence to conclude that the UK market is stuck on a path where a larger number of players has resulted in inadequate infrastructure investment.[72] Certainly Vodafone and Three, who in 2023 announced their intention to merge into a single company, argued that this move would not weaken competition and could unleash £11 billion worth of investment into the mobile network infrastructure.[73] [74] [75] However, the Competition and Markets Authority (CMA) raised concerns that the deal could lead to higher prices for consumers and reduced investment in Britain's mobile networks. In a 2020 discussion paper, Ofcom found significant limitations with the evidence supporting the case for consolidation.[76] [77]

Further, as noted earlier, changes in the infrastructure value chain as a result of divestments by MNOs and the emergence of WIPs for example, has added more complexity to the competitive dynamics of the sector and there is considerable uncertainty about how they might evolve, especially regarding the impact on investment.

Investment uncertainty resulting from a hesitant demand-side and insufficient revenues

The density of the infrastructure required for effective and extensive 5G coverage could see network costs double, according to some estimates.[78] The likely costliness of an extensive 5G rollout is reflected in one analysis which suggested that it could require up to £34 billion (£5.6 billion a year) in infrastructure investment to deploy a 5G network capable of enabling advanced use in all urban and suburban locations by 2030.[79]

However, MNOs in UK have seen their revenues and profitability eroded over the last decade, undermining their investment capacity.[80] Therefore, under the current approach of a market-led 5G rollout, for the private sector to take the risk and invest in 5G, MNOs need to see a realistic prospect of adequate future demand from consumers and businesses, including their willingness to pay for new 5G services, which will deliver sufficient returns in order to make it worthwhile.

As the UK government's 2023 Wireless Infrastructure Strategy highlighted the investment situation is a 'chicken and egg' problem.[81] [82] On the one hand, mobile data consumption is set to continue to grow steadily over the coming years, with average European mobile data consumption predicted to increase from 15 GB per month to 75 GB per month by 2030.[83] However, on the other, it is uncertain as to how much of the growth in data consumption will be through 5G and whether that growth can be monetised sufficiently to buoy MNO revenues, which are ultimately the source for future investment in infrastructure. The experiences of many MNOs with the rollout of 4G has made many of them cautious.[84]

ANNEX 1: EXPERT INTERVIEWEES

Table 2: Summary of expert interviewees

Name	Title and organisation
Dr Mike Short CBE	Former Chief Scientific Adviser at the Department for International Trade and Visiting Professor at the University of Surrey and the University of Strathclyde.
Dr Mani Manimohan	Head of Digital Infrastructure Policy and Regulation, GSMA.
Professor William Webb	Former President of the IET and Director at Ofcom and currently Visiting Professor at the University of Surrey and the University of Southampton, as well as CEO of Weightless SIG.
Tim Cowen	Chair of the Antitrust Practice, Preiskel & Co.
Professor Rahim Tafazolli	Director of the Institute for Communication Systems at the University of Surrey.
Richard Feasey	CERRE Senior Adviser, an Inquiry Chair at the UK's CMA and Member of the National Infrastructure Commission for Wales.
Jaynesh Patel	Head of Telecoms and Spectrum Policy, TechUK

ANNEX 2: ESTIMATES OF THE CONTRIBUTION OF THE SPREAD MOBILE TECHNOLOGY TO GROWTH ACROSS THE WORLD

Mobile telephony technology is what is often described as a general purpose technology. As such, since its introduction along with its subsequent upgrading, it has had considerable positive historical economic and social effects across the world.

Table 2 helps to illustrate the scale of the impact of mobile technology on the world by highlighting the results of two analyses that attempted to measure its contribution to international and European prosperity.[85] [86]

Table 2: Estimates of the contribution of mobile technology take-up and utilisation to global and European prosperity

Level of analysis	Timescale	Measure of impact	Description of contribution
Global	2000 - 2019	Cumulative GDP-per-capita growth	Accounted for 10% of the total
Global	2000 - 2019	Proportion of total annual economic income accounted for	Increased from 1.3% to 2.8%
Europe	2000 - 2019	Cumulative GDP-per-capita growth	Accounted for 8% of the total
96 developed	2008 - 2011	Average annual growth rate of GD-per-capita	10% higher 3G penetration rate

and developing countries			delivered a 0.15 percentage point boost

Source: GSMA (2020) and Deloitte and Cisco (2012)

ANNEX 3: THE ESTIMATED AGGREGATE BENEFITS TO THE UK ECONOMY OF THE ROLLOUT OF 5G BY 2030

Table 3 presents the results from four studies of the likely economic impact of widespread availability and use of 5G.

Table 3: Estimates of the possible economic gains by 2030 from 5G take-up across the UK

Source	Estimated benefit by 2030
Cambridge Econometrics and Analysys Mason	£2.7 - £16.3 billion
GSMA	£5.2 billion
PwC	£43 billion
Barclays	£51.9 - £89.6 billion
Future Communications Challenge Group	£164 - £198 billion
Average	**£62 billion**

Sources: Cambridge Econometrics and Analysys Mason (2021) and Future Communications Challenge Group (2017)

ENDNOTES

[1] "Chancellor Unveils a New Era for Economic Growth," GOV.UK, https://www.gov.uk/government/news/chancellor-unveils-a-new-era-for-economic-growth.

[2] Find the list of expert interviewees listed in Annex One.

[3] "GSMA | What Is the Impact of Mobile Telephony on Economic Growth? 2012 | Public Policy," https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/gsma_resources/impact-mobile-telephony-economic-growth.

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