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REPORT FOR ERICSSON AND QUALCOMM

COST–BENEFIT ANALYSIS ON FULL 5G DEPLOYMENT – UK RESULTS

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1 Abstract

This report was requested by Ericsson and Qualcomm and has been developed in collaboration with the 5G policy and technology teams at Ericsson and Qualcomm. The report is based on a study conducted by Analysys Mason for Ericsson and Qualcomm on costs and benefits of full 5G deployment in Europe.

The aim of the report is to provide a detailed analysis of the costs and benefits of 'full 5G' deployments in the UK. The analysis focused on a series of possible use cases for 5G, beyond the initial enhanced mobile broadband (eMBB) services for consumers that many mobile network operators (MNOs) have launched to date on top of 4G networks. This summary report describes the results of the study for the UK.

A full 5G deployment is envisaged to use the latest 5G specifications to drive fundamental changes in the way that mobile networks are built, using a 5G standalone architecture with network automation, virtualisation and tailoring of services via network slicing to match the functionality required by different industries (or verticals).

In this report, we set out to answer the following questions:

- Which uses and use cases of full 5G deployment might be the most relevant from a UK market perspective, taking account of policy priorities and the industries that might benefit most from 5G capabilities around low latency, high reliability and massive machine-type connections?
- What are the social, environmental and economic benefits of extending 5G networks to deliver new uses and use cases, and what are the 5G network deployment costs to deliver these benefits?
- Is there an opportunity for UK policy to shape future full 5G deployment and what are the key priorities for future 5G policy?

The focus of this report is on the innovative new use cases and the different environments that 5G is designed to support, rather than the speed and capacity increases 5G can provide for consumers using eMBB built on existing 4G mobile broadband (MBB). These new use cases, which include the use of ultra-reliable and low-latency communications, and massive machine-to-machine communication, will be supported by a move towards full (standalone) virtualised 5G networks.

Many of the benefits of new 5G use cases are yet to be realised on a large scale and much of the assessment of the impact of new use cases is based on limited published evidence to date. Our study to which this report refers has referred to existing published information discussing the qualitative benefits of the new 5G use cases. We have also undertaken detailed bottom-up modelling of costs, and economic benefits, of delivering new 5G use cases, with the aim of bringing new insight to the debate around the impact of 5G in shaping the digital future.

2 Executive summary

The overall aim of the study for Ericsson and Qualcomm on costs and benefits of full 5G deployment in Europe has been to analyse the cost and benefits of 'full 5G' use cases , to help to support future development of 5G policy. This report refers to the UK findings from that study.

Several spectrum bands are being made available for 5G in the UK, meeting coverage and capacity requirements:

- the 700MHz band and the 3.5GHz band are being made available via nationwide licences for 5G coverage and for capacity
- spectrum in higher bands (e.g. 26GHz) is available for localised use, and will enable very high capacity in locations where traffic demand is highest, taking account of the diverse requirements for 5G use cases in different environments.

Our approach to the study has been to provide a cost–benefit analysis to inform the development of 5G goals towards full 5G deployment (using standalone architectures, and addressing all 5G use cases), and to aid economic recovery and growth post 2020.[1] We have developed inputs and assumptions on 5G deployment and evolution towards full 5G that take account of published industry experience from 5G trials and initial deployments and reflect current technological trends of virtualisation, automation and end-to-end slicing.

Ericsson and Qualcomm commissioned Analysys Mason to conduct this study during March 2020 and the study was completed in September 2020.

2.1 Status of 5G deployment in the UK

MNOs in the UK, as in several markets across Europe, have now launched initial 5G services, which are based on 4G infrastructure. Further technological evolution within the UK 5G networks is expected, with migration to stand-alone, virtualised 5G architectures.

The estimated 5G population coverage in the UK was c.30% as of Q3 2020, placing it near the average for European countries where 5G has been launched.

1 Economic recovery in Europe following the COVID-19 pandemic in 2020

Figure 2.1: 5G coverage in the UK and European countries, Q3 2020 [Source: GSMA Intelligence, 2020]

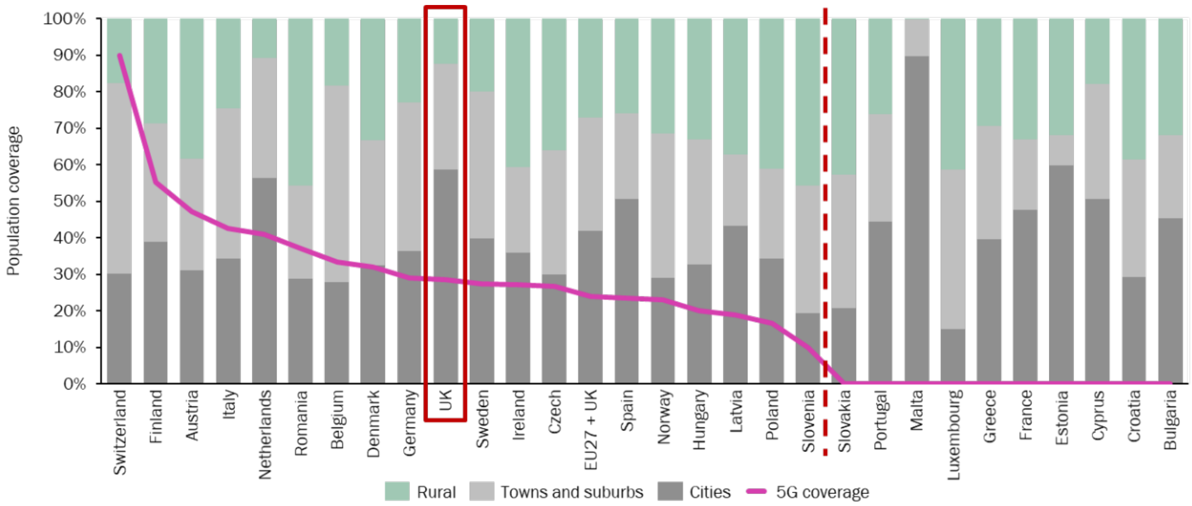


Figure 2.1 above shows the total 5G population coverage in different countries in Europe (pink line), overlaid on a classification of the population into three geotypes: urban, suburban and rural. The chart does not indicate the split of 5G coverage across these geotypes (e.g. there may be some 5G coverage of rural areas). For this estimate, we have assumed network deployments generally roll out coverage in more densely populated areas first (i.e. in urban areas, then moving to suburban and then rural areas).

Although initial developments were limited to non-standalone 5G technology, evolution to standalone, virtualised 5G architectures is now underway, which will increase data intensity in networks with addition of multiple low-latency, ultra-reliable use cases (see Figure 2.2). We note that all four MNOs in the UK have now launched commercial 5G mobile services in selected (mainly urban) areas using spectrum in the 3.4–3.6GHz band. Further spectrum in the 700MHz and 3.6–3.8GHz bands will be auctioned in early 2021. Part of the 26GHz band is currently available for indoor 5G on a local basis. Ofcom is yet to confirm a 5G licensing framework for other portions of the 26GHz band. The current state of 5G spectrum allocations in the UK is shown in Figure 2.3 below.

Figure 2.2: Mobile traffic and usage evolution with 5G standalone architectures [Source: Ericsson, Qualcomm, Analysys Mason, 2020]

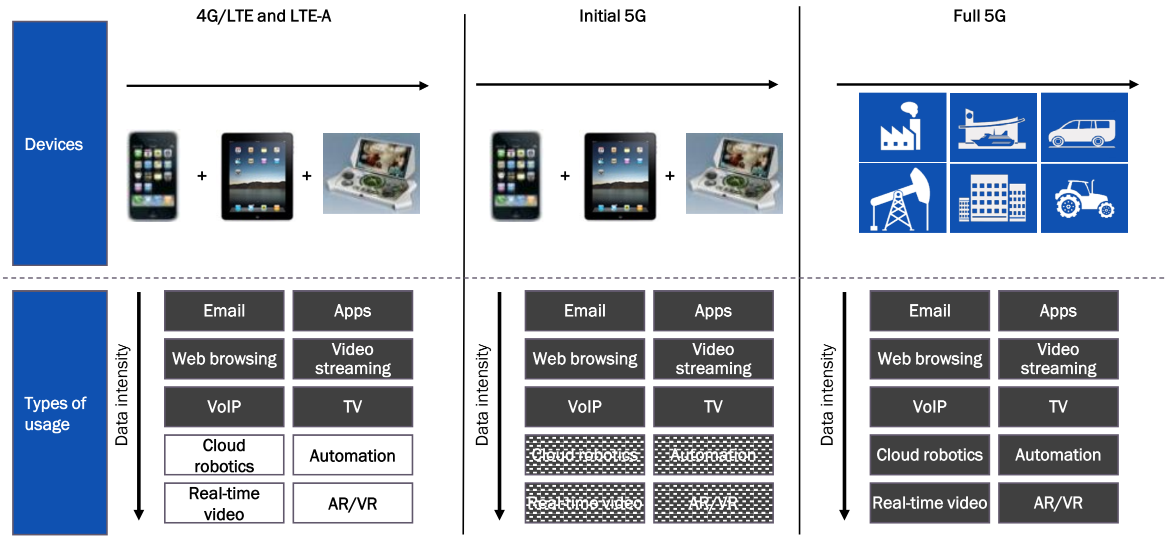
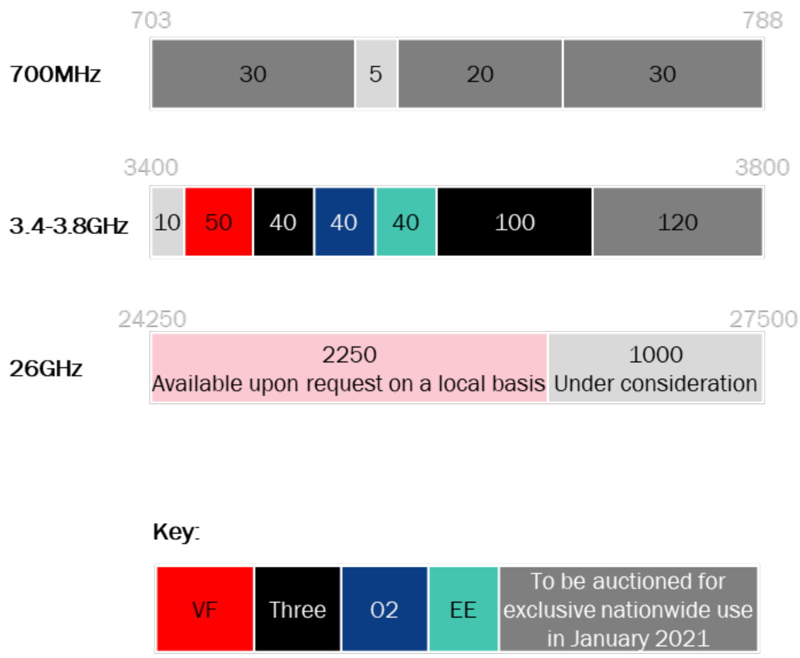


Figure 2.3: Current allocation of 5G spectrum in the UK [Source: Analysys Mason, 2020]



Full 5G capabilities will significantly broaden the uses of 5G networks into multiple verticals with new applications enabled through end-to-end slicing (e.g. collaborative robots, automated machinery, autonomous transport). These applications will be enabled through use of the UK's 5G pioneer bands (700MHz, 3.4–3.8GHz and millimetre-wave (mmWave) spectrum in 26GHz).[2]

2 These are fully defined in the 5G Action Plan (5GAP)

Our analysis of the potential benefits of full 5G deployment has taken into account published evidence, including benefits indicated by several European 5G trials. Examples of such trials, conducted by Ericsson and Qualcomm, are described in Figure 2.4 below.

Figure 2.4: Examples of European 5G trials and their benefits [Source: Ericsson, Qualcomm, Analysys Mason, 2020]

Benefits indicated by trials	Description of the trial
Productivity, efficiency and safety in the utility sector	• Ericsson, UK water utility provider Northumbria Water and UK MNO O2 are partnering in trials of 5G-augmented reality (AR) technology to remotely inspect assets and enable remote guidance of on-the-ground teams through relaying real-time data and instructions • The trial also demonstrates use of 5G AR technology to provide 3G representation of buried assets, helping utility teams manage hazards and risks in real time[3]
Safer and efficient driving via network-based and direct cellular vehicle to everything (C-V2X)	• Qualcomm and Ericsson, together with Audi, have tested and demonstrated use cases of C-V2X, including vehicle-to-vehicle and vehicle-to-infrastructure direct communication operating in the 5.9GHz ITS spectrum and vehicle-to-network services leveraging 5G (e.g. network slicing and geo-casting) [4] • Trials have included communication across trans-European borders (France, Luxembourg and Germany)
Improved maintenance, production and logistics using industrial 5G	• Ericsson's 5G Port of the Future project pilots 5G virtual reality (VR), AR and artificial intelligence (AI) to improve port operations and efficiency and lower environmental impact • 5G technology has been used for real-time information exchange leading to reduction in movements during cargo handling, resulting in lower fuel consumption and associated CO_2 emissions[5] • Qualcomm is deploying standalone 5G networks in industrial environments in Germany, using the 3.7–3.8GHz band[6]
Enhanced Internet of Things (IoT) in a smart city environment	• The data capacity, speed and low latency that 5G technology delivers will benefit smart city infrastructure in Europe, enabling better data analytics, more efficient public transport operation and new forms of mobile, on-demand services • Together with edge processing solutions, infrastructure in urban environments can be made safer, more efficient and more innovative[7]

3 See https://www.ericsson.com/en/news/3/2020/ericsson-and-o2-partner-with-northumbrian-water-to-harness-the-power-of-5g

4 See https://www.qualcomm.com/news/releases/2018/07/04/convex-consortium-hosts-europes-first-live-c-v2x-direct-communication

5 See https://www.ericsson.com/en/blog/2020/7/5g-port-of-the-future-jul-14-20202

6 For example, 5G manufacturing trials have been conducted by Qualcomm in partnership with Siemens (https://www.qualcomm.com/news/releases/2019/11/26/qualcomm-technologies-and-siemens-set-first-5g-private-standalone-network) and Bosch (https://www.qualcomm.com/news/releases/2019/11/25/qualcomm-technologies-bosch-rexroth-showcase-time-synchronized-industrial)

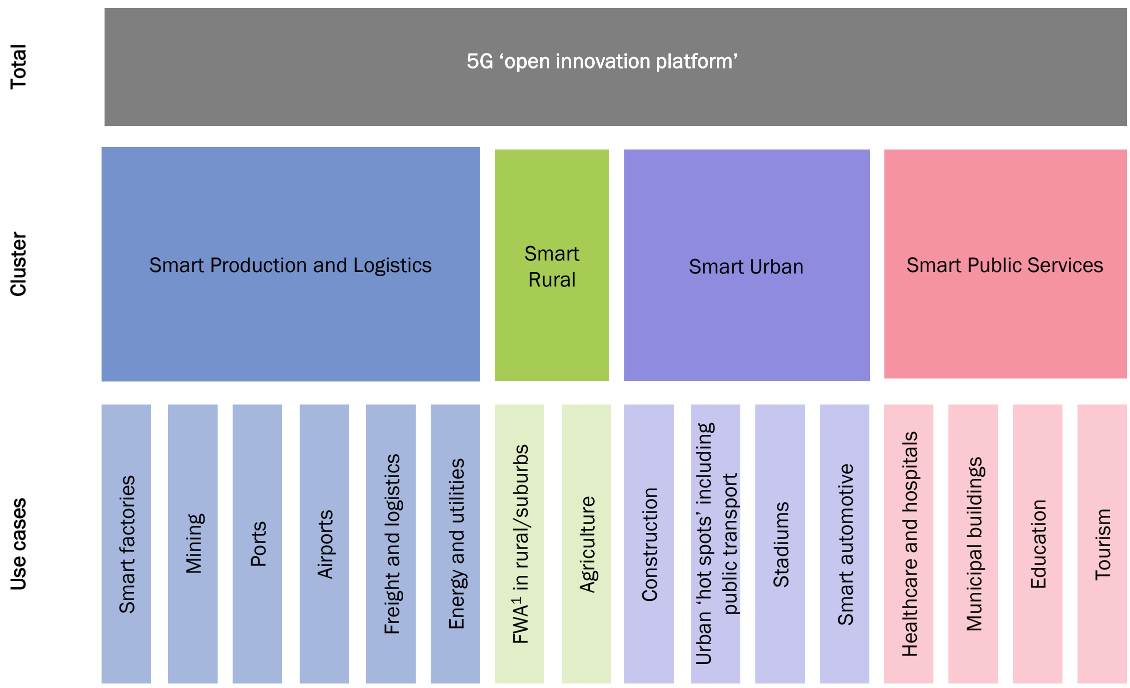
7 See https://www.qualcomm.com/products/smart-cities. See also https://www.vodafone.com/content/dam/vodcom/files/public-policy/gigabit-society-5g-04042017.pdf

2.2 Framework for cost–benefit analysis in this study

A key part of the study has been to develop a view of 5G as a flexible 'open innovation platform' supporting cross-sector use cases and environments (see Figure 2.5). We have grouped similar 5G use cases into the following 'clusters':

- Smart Production and Logistics
- Smart Rural
- Smart Urban
- Smart Public Services.

Figure 2.5: Overview of 5G open innovation landscape considered in the study [Source: Analysys Mason, 2020]



[1] Fixed-wireless access

The basis of our modelling approach is that full 5G networks can support a wide range of possible innovations in different market and industrial sectors, which collectively can be considered as an overall 'open innovation platform'. The study considers the social, environmental and economic benefits of these use cases, with quantified estimates of economic benefits for each cluster, based on a selection of the use cases within each.

Aggregating similar use cases and network environments into clusters helps to align our conclusions with different policy themes and provide results which can be more easily interpreted. The individual use cases form the foundations of the cost–benefit analysis, and provide structure for the various input assumptions and data sources.

Summaries of the use cases considered in the four clusters and the associated benefits of these use cases are provided in Annex A.

2.3 Summary of modelling approach

The model we have built estimates both the network costs and the economic benefits for many of the use cases in each cluster. The calculation flows, at a high level, are summarised in Figure 2.6 and Figure 2.7 below.

Figure 2.6: Calculation of the cost of providing the new use cases [Source: Analysys Mason, 2020]

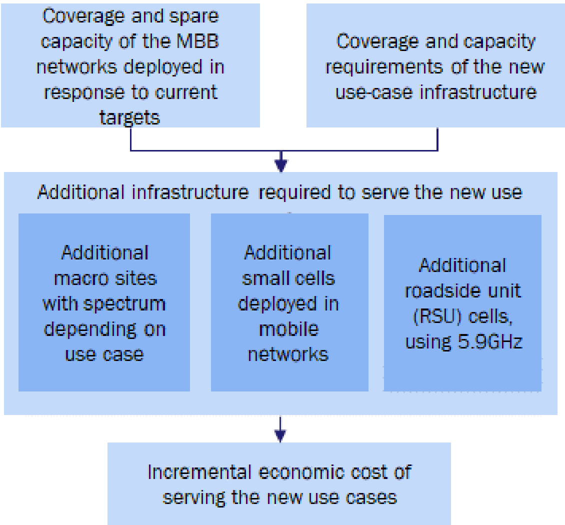
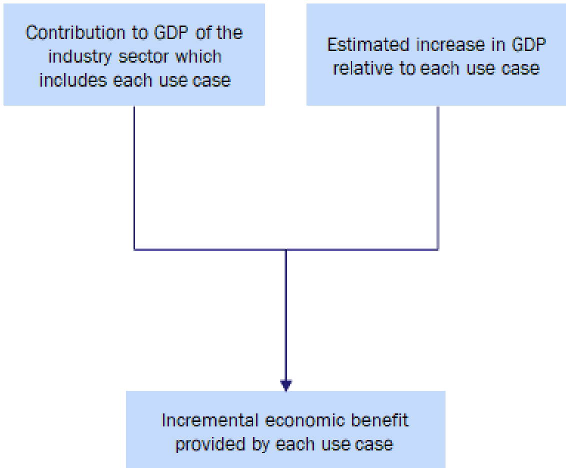


Figure 2.7: Calculation of the benefits of new use cases [Source: Analysys Mason, 2020]



The additional costs, and associated benefits from using 5G to deliver the new use cases are calculated with reference to the 5G networks assumed to be deployed in the UK as at 2025. Costs and benefits considered in the study are incremental to these current deployments (i.e. the costs and benefits associated with initial 5G deployment for consumer use are excluded from our analysis). The characteristics of 5G eMBB networks in 2025 assumed in the base case are summarised in Figure 2.8 below.

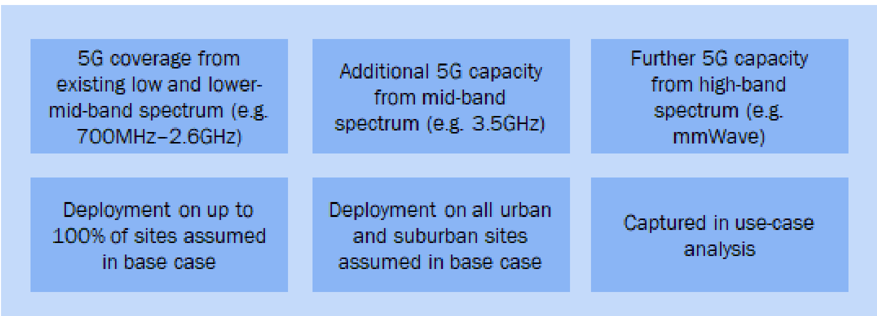


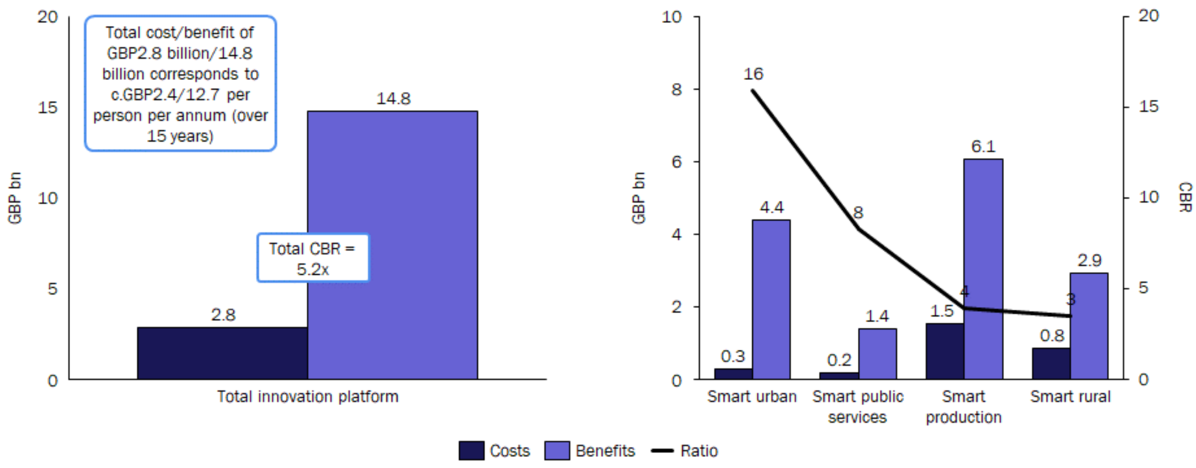
Figure 2.8: Characteristics of 5G eMBB networks in 2025 assumed in the base case [Source: Analysys Mason, 2020]

2.4 Key results

Our modelling indicates that, as a total 'open innovation platform', 5G networks in the UK can deliver c.GBP15 billion in benefits at a cost of c.GBP3 billion (which equates to a cost–benefit ratio (CBR) of 5.2 benefit to cost). The Smart Production and Smart Urban clusters have the largest net benefit (i.e. benefit minus cost), of c.GBP4.1 billion and c.GBP4.5 billion respectively, although the CBR of the Smart Production cluster is four times lower than that of the Smart Urban cluster, reflecting its substantially higher costs.

Modelling results for the total open innovation platform and individual clusters in the UK are shown in Figure 2.9 below.

Figure 2.9: Total open innovation platform and clusters: 5G upgrade cost, benefit and CBR, UK [Source: Analysys Mason, 2020][8]



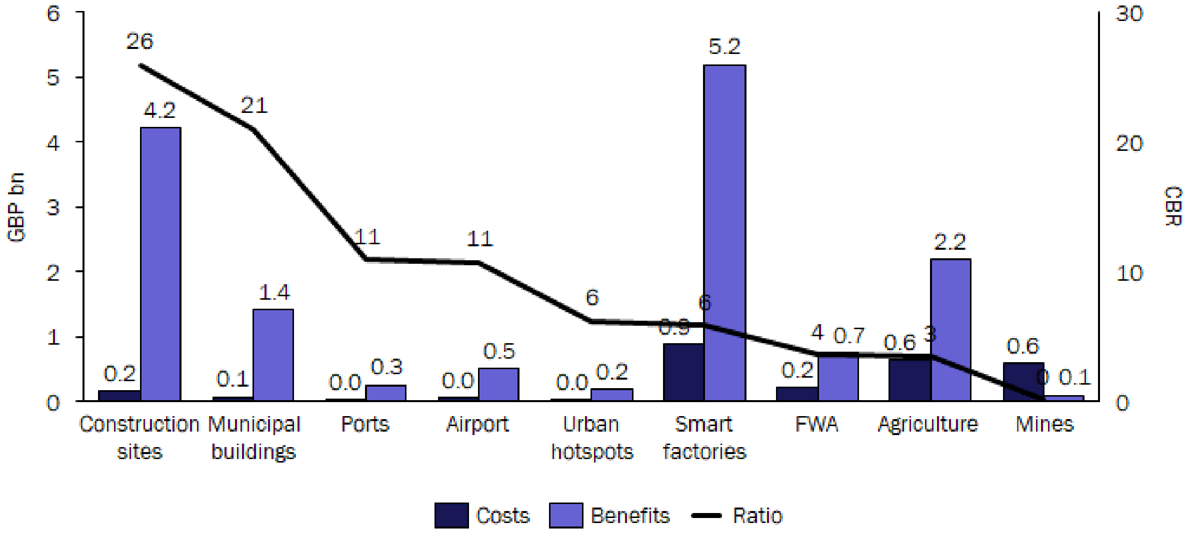
The benefits and costs shown in Figure 2.9 are in addition to the benefits and costs associated with the initial 5G eMBB network investments in the UK – i.e. the benefits and costs shown here are for the expansion of 5G networks to 'full 5G' capability in accordance with our open innovation platform concept.

At the use-case level, the largest benefit-to-cost impact in the UK stems from 5G deployment in smart factories, construction sites and agriculture. We have assumed smart factory 5G deployments use small cell infrastructure, whereas the agriculture and construction site use cases are assumed to use 3.5GHz macro cells (for agriculture, we assume deployment of additional rural sites beyond the current UK MNO network footprints).

Results for individual use cases are shown in Figure 2.10 below. We have assumed limited synergies between the coverage needs (and thus costs) of different use cases due to localised demand, and have not included any common cost from the MBB network (since we assume that MNOs will make 5G MBB available in any event, due to competitive pressure).

8 Results are based on 5G networks assumed to be deployed in European markets in 2025

Figure 2.10: Use cases: 5G upgrade cost, benefit and CBR, UK[9, 10] [Source: Analysys Mason, 2020]



As mentioned previously, the costs and benefits shown in Figure 2.10 above are incremental to the costs and benefits associated with initial 5G deployment and also from any pre-5G mobile deployments (e.g. using 4G technology). Hence, total mobile benefits are likely to be significantly larger than that shown above up to 2025, when also considering consumer MBB services plus other 4G/5G connectivity up to 2025. For example, Analysys Mason modelling for the 5GAA[11] suggests c.EUR3–4 billion of European benefit from C-V2X (i.e. smart automotive) by 2025, rising to c.EUR20 billion by 2030. This benefit is not captured in the charts above.

2.4.1 Commercial investment versus public funding

Many of the use cases we have considered as part of our full 5G assessment are expected to be delivered commercially (i.e. by MNOs, independently of any government targets). In some environments and for some types of deployment where commercial investment is not viable, use cases are likely to require public funding. Use cases and their potential public funding requirements are shown in Figure 2.11 below.

9 There are several use cases not shown here that our study has considered, and we have captured in our network costs, but for which we have not modelled a GDP benefit. We have considered the benefits of 5G to these use cases qualitatively in terms of the potential environmental and social benefits (these include healthcare and hospitals, smart automotive and stadiums). We note that consumer benefit will be generated from these use cases, which we have not modelled, but which several other published studies refer to.

10 FWA is assumed to serve 5–20% of the broadband market outside of areas with fibre to the premises (FTTP) in each country (guided by current propensity to use FWA services).

11 https://5gaa.org/wp-content/uploads/2018/06/2.-Presentation-on-cellular-V2X-socio-economic-benefit-study-08022018.pdf

Cluster	Use case	Requires public funding
Smart Production and Logistics	Smart factories	No
	Mining	No
	Ports	No
	Airports	No
	Freight and logistics	No
	Energy and utilities	No
Smart Rural	FWA	Yes[12]
	Agriculture	Partly[13]
Smart Urban	Construction	No
	Urban hotspots including public transport	Partly[14]
	Stadiums	No
	Smart automotive	Yes
Smart Public Services	Healthcare and hospitals	Yes
	Municipal buildings	Yes
	Education	Yes
	Tourism	Yes

Figure 2.11: 5G use case and whether public funding is required [Source: Analysys Mason, 2020]

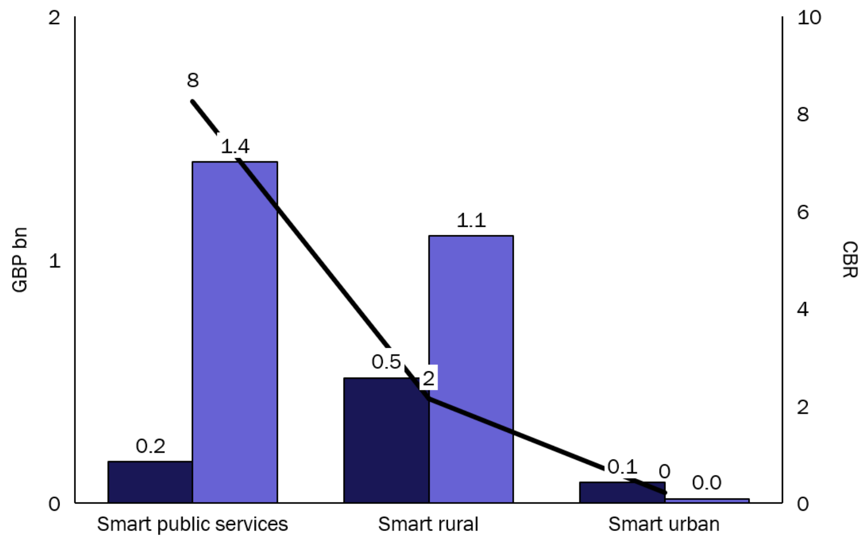
For the use cases where public subsidy is needed, we estimate that over GBP2.5 billion of benefit can be delivered in the UK for less than GBP800 million of funding. We note the UK Shared Rural Network (SRN) will invest GBP500 million of public funds to build mobile infrastructure in current 'total not-spots' (i.e. locations uncovered by any MNO network currently) and that there will be some overlap between this figure and the GBP800 million of funding required. This cannot be quantified however as location and number of new sites to be built as part of the SRN is not yet known. The costs and benefits of clusters likely to require public funding are shown in Figure 2.12 below.

12 Commercially deployed FWA is assumed as part of initial 5G deployment, but in the 5G FWA use case here we specifically consider additional targeted investment (primarily non-commercial FWA deployments in suburban or remote areas).

13 We assume that the agricultural use case would be delivered commercially if the agricultural environment is within the coverage area of our modelled MBB networks. However, we assume that public subsidy would be required for agricultural environments outside the coverage area of our modelled MBB networks.

14 The urban hotspots use case is assumed to include provision of connectivity for public transport in urban areas (e.g. for provision of real-time passenger and other travel/tourist information). The public transport portion of the cost associated with this use case (estimated to be around 10%) would require public funding.

Figure 2.12: Clusters likely to require public funding: 5G upgrade cost, benefit and CBR, UK [Source: Analysys Mason, 2020]



As previously noted in Footnote 9, there are several use-cases requiring public finding which our study has considered (e.g. healthcare and hospitals and smart automotive), but that we have not modelled an economic benefit for as part of this study and so are not included in Figure 2.12. However, it should be noted that government funding for 5G infrastructure to support the healthcare and smart automotive use cases will be highly beneficial and should form part of any UK 5G policies.

2.4.2 Conclusions on future 5G policies

Realising economic benefits

In terms of GDP benefit, our model suggests the UK's 5G policy should focus on:

- Accelerating the availability and uptake of 5G infrastructure for use in the Smart Production and Logistics sectors
- Extending 5G coverage further into rural areas
- Encouraging operators to roll out high-density networks to provide very high capacity for 5G in Smart Urban applications (such as construction).

Our policy recommendations are listed in Figure 2.13 below (by cluster and in order of priority):

Figure 2.13: Recommendations on the UK's 5G policies [Source: Analysys Mason, 2020]

Priority order	Recommended full 5G policies in the UK
1. Smart Production and Logistics policies	• Put the appropriate policies in place to ensure large industrial players in the UK can deploy 5G public or private solutions and continue to promote use of 5G for these use cases via 5G CREATE • A priority might be putting measures in place to encourage UK industries to be primary drivers of further 5G roll-out

2. Smart Rural policies	• Continued partnership between UK MNOs and Government to make further 5G rural coverage deployment feasible via SRN and related projects in the UK nations and regions (e.g. Scottish Government 4G in-fil) to provide connectivity for rural communities, rural industry and rural transport routes, which will benefit rural industries including the agriculture sector • Ensure 5G FWA is considered equitably as part of solutions for next-generation access broadband services
3. Smart Urban policies, including urban transport corridors	• Trial 5G-based AI solutions in UK cities (e.g. 5G infrastructure for transport, logistics, smart estates, stadiums) • Aim to bring mmWave bands such as 26GHz into use in the UK by 2025 • As per smart production and logistics, a priority might be measures to encourage 5G usage by local authorities to be a primary driver of further 5G roll-out
4. Smart Public Services policies	• Ensure public authorities can make specific 5G investments (e.g. in next-generation connectivity plans and funding), such as for facilities management, provision of public services, maintenance of public spaces • Continue to promote 5G cost reduction and lowering barriers to deployment

In addition, continuing to accelerate 5G roll-out for consumer use will be important up to 2025, including making the remaining 5G spectrum available in the UK and a renewed focus post-COVID on reducing barriers to deployment.

Realising environmental and social benefits

In regards to realising environmental and social benefits, high priorities for UK policy are improving 5G coverage in the Smart Rural cluster, and enabling 5G use in the smart factories, and in the freight and logistics use cases. A summary of the environmental and social benefits associated with 5G connectivity for the clusters is provided, separated by use case, in Figure 2.14 below. Use cases with the highest benefit have been shaded green, those with medium benefit are shaded orange, and lower benefit cases are shaded yellow. The highest-priority use cases (i.e. factories, freight and logistics, and use cases in the Smart Rural cluster) have been indicated with a red border.

Figure 2.14: Summary of environmental and social benefits by use case[15] [Source: Analysys Mason, 2020]

Cluster	Use case	Environmental benefit from 5G connectivity	Social benefit from 5G connectivity
Smart Production and Logistics	Ports	Logistics efficiency leading to carbon emission reduction	Increased security, safety and technology-skilled workforces
	Airports	Reduced congestion	Increased security, safety Less time waiting in airports/

15 Green = highest benefit, orange = medium benefit; yellow = lower benefit. The highest priority use cases are shown with a red border

Cluster	Use case	Environmental benefit from 5G connectivity	Social benefit from 5G connectivity
			enhanced passenger experience
	Mining	Real-time monitoring in mines e.g. air quality, risk of hazards	Increased security, safety, technology-skilled workforces
	Smart factories	Better use of time and materials, leading to reduced energy use Industrial process and equipment monitoring enabling improved equipment lifetimes	Increased security, technology-skilled workforces
	Freight and logistics	Facilitate 'just-in-time' supply chains, efficient transport of goods	Increased safety/reduction or prevention of accidents
	Energy and utilities	Remote monitoring/remote inspection enabling better control of energy use	Encourage good energy use through real-time awareness of energy being used
Smart Rural	5G FWA	Reduced journeys (e.g. working remotely plus connectivity in rural transport corridors)	Social inclusion/reducing the digital divide Slow or reverse rural population declines Support for rural businesses to operate digitally
	Agriculture	Increased efficiency/lower carbon farming	Sustained rural industries Ability to market products beyond local area
Smart Urban	Construction	Fuel efficiency/reduced carbon emissions	Safety-related benefits, e.g. reduction in accidents Reduced driving times/ wellbeing
	Urban hotspots including public transport	Improved public transport operations Smart buildings/ support for green building initiatives	Improved city living experience Better access to information and media whilst travelling
	Stadiums	Support for green initiatives in stadiums	Better enjoyment/experience
	Smart automotive	Better energy use/less waste Support for green construction policies, e.g. remote management of machines	Increased safety of automobiles

Cluster	Use case	Environmental benefit from 5G connectivity	Social benefit from 5G connectivity
Smart Public Services	Healthcare and hospitals	Reduced journeys (e.g. ambulances to hospitals or patient journeys to GP surgeries)	Highly reliable remote consultation and triage
	Municipal buildings	Fewer journeys needed to monitor or resolve social problems) Better energy use/less waste	Collaboration or interaction (e.g. 5G connectivity for social or business hubs)
	Education	Support for green school and university initiatives, e.g. energy-saving or other environmental projects	Increased availability and access to education/remote learning in schools and universities Remote access to experts
	Tourism	Conservation benefits, e.g. enabling tourists to better understand environmental challenges via VR/AR experience	Virtual walk-throughs of tourist sites/improved quality of experience Educational benefits

Annex A Use cases considered in the four clusters and their associated benefits

Summaries of the use cases considered in the four clusters and their associated benefits are provided in Figure A.1–Figure A.4 below.

Smart Production and Logistics

The Smart Production and Logistics cluster is expected to deliver a wide range of social, environmental and economic benefits, with 5G enhancing or enabling new uses. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure A.1 below.

Figure A.1: Summary of use cases considered in the Smart Production and Logistics cluster and their associated benefits[16] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Smart factories	Machinery monitoring for predictive maintenance and remote-control: reduced downtime Real-time supply chain visibility X-reality guided procedures and repairs Ultra-high definition (UHD) surveillance	Increased security and safety Increased technologically skilled workforce	Real-time monitoring of processes to reduce energy and materials consumption Reduced equipment replacement/ maximised equipment lifetimes	GDP contribution uplift due to increased productivity
Mining	Drone-based video inspections Autonomous vehicles Predictive maintenance UHD surveillance	Increased security and safety Increased technologically skilled workforce	Better air quality monitoring/ reduced risk of hazards (e.g. through real-time monitoring within mines)	GDP contribution uplift due to increased productivity

16 We do not consider jobs created/displaced as part of our assessment

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Ports	Real-time inventory and asset tracking UHD surveillance Robotic control of machinery AR guided repairs	Increased security and safety Increased technologically skilled workforce	Reduced carbon emissions through greater logistic efficiency and equipment efficiencies	GDP contribution uplift due to increased productivity
Airports	Autonomous airside vehicles and collision avoidance AR guided repairs and maintenance Edge computing and AI for passenger ID and security Augmented shopping experience	Increased security and safety Less time spent waiting in airports	Reduced congestion and reduced emissions (e.g. autonomous airside vehicles)	GDP contribution uplift due to increased productivity
Freight and logistics	Non-line-of-sight accident sensing Autonomous freight vehicles Sensor data sharing for smart fleet management	Increased safety	Efficient just-in-time supply chains, reduces unnecessary journeys and transportation of goods	Improved work processes and productivity (not modelled) Possibility of new business models (not modelled)
Energy and utilities	Smart load balancing and detection of peaks/surges Smart fault sensors Management of sending energy back to the grid	Encouraging good energy behaviour within homes and businesses (including for use of electric vehicles)	Better energy consumption management by more closely matching supply and demand	Improved work processes (not modelled)

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
	Predictive maintenance of assets (e.g. wind turbines) AR-guided maintenance/repairs		Lower greenhouse gas (GHG) emissions (e.g. due to increased use of remote monitoring)	

Smart Rural

5G-based connectivity is expected to enable the Smart Rural cluster to deliver benefits to people and businesses, helping to sustain rural living and aid working remotely. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure A.2 below.

Figure A.2: Summary of use cases considered in the Smart Rural cluster and their associated benefits[17] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits
FWA in suburban and rural areas	High-speed broadband connectivity for consumers and business in areas not reached by full-fibre networks Could also support implementation of other 5G use cases, such as remote monitoring/remote healthcare	Increased social inclusion; reduced digital divide Could slow or reverse decline in populations living in rural areas/ contribute to maintaining rural communities. Ability for local businesses to access wider markets for their products via e-commerce, supporting rural sustainability Ability to work from home/create a better work–life balance Alternative to fixed broadband (FBB) and/or resilience (e.g. use of a mobile device when FBB is not available)	Reduced journeys (e.g. from being able to work remotely)
Agriculture	Massive sensor network for crops (pest detection and moisture levels) and livestock Untethered surveillance drones Autonomous machinery	Rural sustainability (support for local industries including fishing, tourism and farming in remote areas) Ability of rural producers to market products beyond local area (e.g. using e-commerce platforms)	Increased efficiency (e.g. lower carbon farming) Potential for reduced waste/reducing unnecessary use of products (e.g. fertiliser) Reduction in land requirements for livestock

Smart Urban

5G in the Smart Urban cluster, together with edge computing, is expected to deliver benefits across multiple use cases, by enhancing existing use cases and creating new uses. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure A.3 below.

Figure A.3: Summary of use cases considered in the Smart Urban cluster and their associated benefits[18] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Construction	UHD surveillance Remote sensor monitoring of equipment, machines and materials Autonomous vehicles and equipment Collaborative robots	Increased safety and security of building sites	Better energy use/less waste Support for green construction practices (e.g. remote management of machines)	GDP contribution uplift due to increased productivity
Urban 'hot spots' (including public transport in urban centres)	Always-on connectivity for communications and e-commerce – enabling more people to be connected to real-time services (including video) Optimised public transport networks (e.g. improved route planning, real-time information,	Wellbeing benefits for those living in cities: better access to entertainment/ e-commerce while travelling Lower journey times on public transport and better information	Reduced emissions from optimised public transport networks Smart buildings/green building initiatives More efficient public transport journeys	GDP contribution uplift due to increased productivity

18 We do not consider jobs created/displaced as part of our assessment

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
	passenger infotainment)			
Stadiums	New immersive experiences (e.g. multi-view AR/VR) Social video sharing UHD video surveillance Real-time smart parking	Enjoyment/ experience (e.g. ability to replay live video, interact with the event) Additional viewing content (e.g. behind the scenes)	Support for green initiatives in stadiums	New business models/ financial benefits for the sports club (not modelled)
Smart automotive	Real-time optimised routing and advanced traffic management Increased real-time situational awareness for driver Non-line-of-sight accident sensing	Safety-related benefits (e.g. reduction in accidents) Optimised driving patterns and reduced journey time create a wellbeing benefit	Increased fuel efficiency and reduced emissions (e.g. due to access to real-time map updates, real-time parking data, making journeys shorter)	New business models (not modelled)

Smart Public Services

The Smart Public Services cluster is expected to enable enhancements in communication for a range of public services, plus new capabilities and tools. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure A.4 below.

Figure A.4: Summary of use cases considered in the Smart Public Services cluster and their associated benefits[19] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Healthcare and hospitals	Remote monitoring of patients/early warning of changes in vital signs Video, medicine and 'tactile internet'[20] Smart objects (e.g. real-time management of medical resources)	High-reliability remote consultation and triage Increase in social inclusion and wellbeing; improved care	Reduced journeys (e.g. ambulances to hospitals or journeys to GP surgeries) More preventative care/less pressure on hospitals and healthcare providers	Reduced expenditure (e.g. time or money) due to preventative healthcare, leading to lower healthcare costs/ increased capacity (not modelled)
Municipal buildings	Highly available and low-latency connections providing capacity to support more users with higher-speed services (including real-time video)	Better energy use/less waste Collaboration/interaction (e.g. social or business hubs)	Possible reduction in journeys (e.g. fewer journeys for monitoring and resolving social problems)	GDP contribution uplift due to increased productivity
Education	Remote/home-based teaching via interactive platforms	Increased availability and access to education, including	Green school initiatives (e.g. high-speed, low-latency connectivity to	-

19 We do not consider jobs created/displaced as part of our assessment

20 Remote monitoring also requires connectivity to be available for patients in their home environment – we note this could be part of the benefit delivered through 5G FWA provided in suburban/rural areas.

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
	Immersive augmented/virtual-based learning Remote native-language speakers/ additional remote expert education	remote learning in schools and universities Remote access to experts	support energy saving; environmental projects in schools or universities)	
Tourism	Enhancement of tourism experiences through VR/AR	Virtual walk-throughs of tourist sites/quality of experience Educational benefits	Conservation benefits (e.g. enabling tourists to better understand environmental challenges via VR/AR)	New business models from immersive tours