INTERIM EVALUATION OF 5G TESTBEDS AND TRIALS

A report for the Department for Science, Innovation and Technology

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AUTHORS AND ACKNOWLEDGEMENTS

This study was carried out by RSM UK Consulting LLP. The RSM project team comprised Jenny Irwin (Lead Partner of RSM Economics Consulting, and Quality Director for this evaluation), Cristian Niculescu-Marcu (RSM Consulting Director, and Project Director for this evaluation), Matt Rooke (Associate Director, and Project Manager for this evaluation), Kristine Farla (Associate Director), Polly Jackson and Tim Porteous (Senior Consultants), and Adekunle Adekunbi, Gregory Choi, Ella Cowin, Curtis Finister, Ryan Harding, Sarah Mustapha, and Vivek Rao (Consultants). Our academic advisor was Professor Dimitra Simeonidou from the University of Bristol.

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EXECUTIVE SUMMARY

Introduction to 5GTT, the evaluation and the programme Theory of Change

The 5G Testbeds and Trials programme (5GTT) was announced in 2016 as part of the Autumn Statement and established in 2017 as part of the National Productivity Investment Fund[1]. Its purpose is to **maximise the prospective benefits that 5G could bring to the UK economy through timely deployment and effective utilisation of 5G technology**. £199m of capital funding was allocated to the programme and £140.1m was spent between 2017/18 and 2022/23 (70% of target). DCMS[2] allocated funding to a range of 37 projects exploring many different aspects and challenges with 5G delivery and deployment in different sectors. It also supported the creation of a national innovation network, "UK5G", to build, connect, and inform the UK 5G ecosystem[3].

This report is an interim evaluation of the 5GTT programme and data collection took place when some projects were nearing completion. All projects were completed by March 2023. The longer-term impacts of the projects, through wider adoption and use of the new technologies and techniques are yet to be realised and will be assessed as part of a final evaluation in 2025.

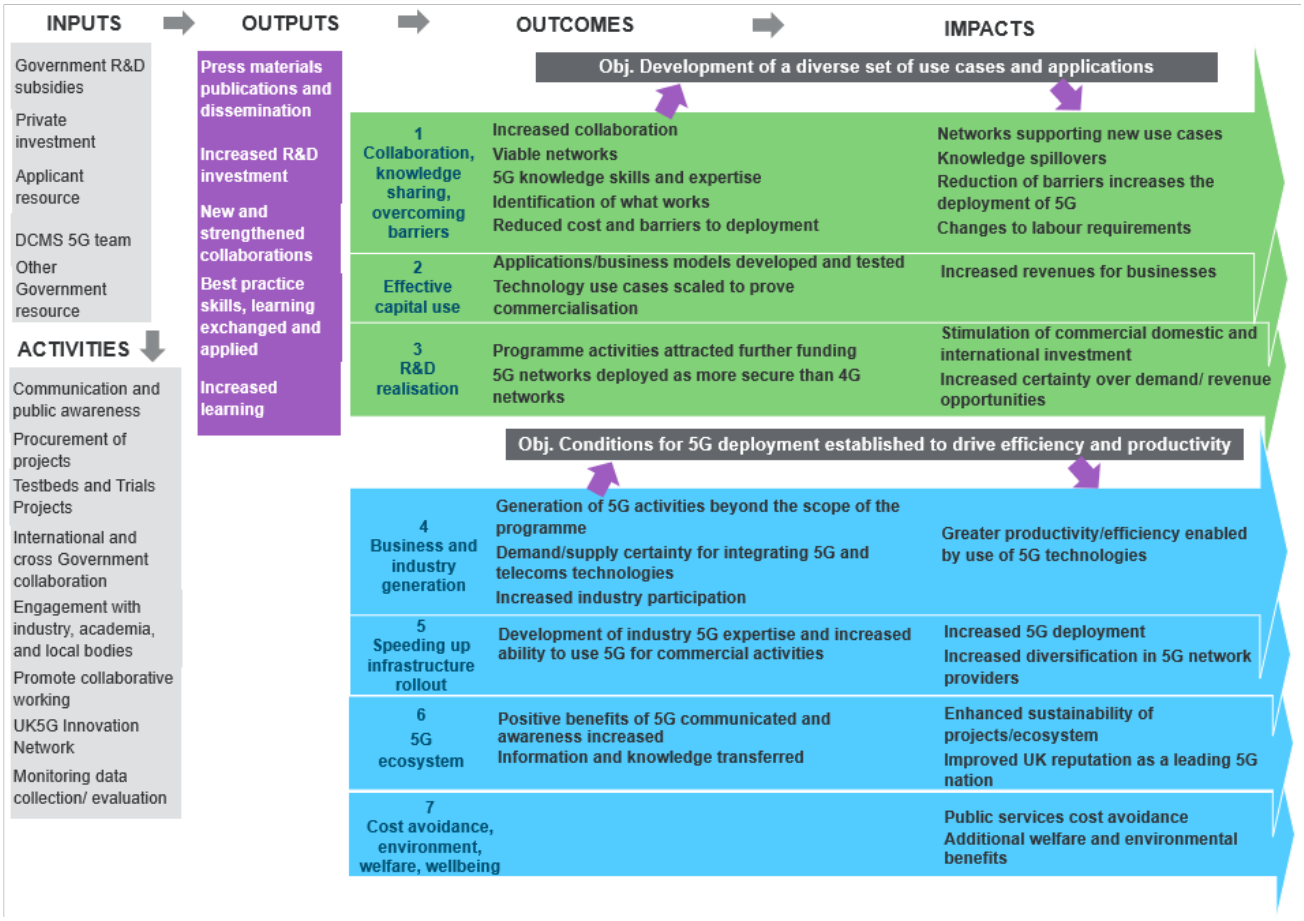
The study used a **Theory-Based** evaluation approach to investigate and explore the causal chains delivering impacts that can be attributed to 5GTT. These causal chains have been tested through interviews with stakeholders involved in programme design, management, and delivery, interviews and surveys of funded and non-funded companies, case studies of projects representative of the programme and document reviews. The Theory of Change (ToC) that underpins the evaluation is presented in the diagram below. The ToC informs the process evaluation works strand and the impact evaluation work strand. The ToC summarises the Key Performance Indicators (KPIs). Some KPIs align with targets set out in the programmes' business case. The evaluation evidences the extent to which targets were met.

[1] Autumn Budget 2017 - GOV.UK (www.gov.uk)

[2] The 5GTT programme that ran from 2017 to March 2023 was delivered by DCMS. In February 2023 a government restructure moved the programme team into the newly formed Department for Science, Technology and Innovation

[3] UK5G Innovation Network - Events, News & Resources

Summary Figure 1: 5GTT programme Theory of Change



Results from the process evaluation

The process evaluation looked at how effective and efficient the delivery of the 5GTT programme has been and how the delivery of the programme could be improved.

Was programme delivery effective and efficient?

Programme processes that have been delivered effectively and efficiently are:

- The **funding competition processes**. The calls were designed to meet sectoral demand and diversify the portfolio. The application process was considered effective by some DCMS officials we spoke to and by a majority of applicants.
- DCMS **project support**. The majority of projects saw DCMS as supporting their projects, especially the input from the Technical Design Authorities. DCMS staff thought that they worked well as a team – broadly.
- The **benefits realisation process.** Despite challenges in data collection and overall monitoring, this worked well when projects were supported by DCMS to identify indicators that were beneficial for their own project management.

There were also two areas where the processes worked less well:

- **Financial processes** caused problems for delivery. The grant claiming process was sometimes slow, which was a particular problem for resource-constrained small firms. This was exacerbated by the change request process, which was felt to be applied inconsistently and could be slow. There were nearly 300 change requests across all later stage projects, which added to programme complexity and intensity of tasks. Projects often had to submit multiple change requests and the overall scope of projects substantially changed.
- **Programme efficiency** was a problem, as running costs were large by comparison with innovation programmes from other Government sources (e.g. UKRI). The services provided by the extra resource (project

support, technical support, ongoing monitoring and evaluation, and in particular network building and ecosystem development) have contributed to the programme running well and/or are valued by project delivery partners but such resourcing does increase running costs. The programme **underspent** against its allocated budget by 30%. Technological readiness and external barriers (specifically COVID) each had an impact on this. Project beneficiaries also commented negatively on the level of staff turnover of project officials.

How could delivery be improved?

Areas for improvement are:

- Future programmes **should allocate more resources to support departmental level financial processing**, if possible, as delays have affected delivery.
- More **clarity should be provided around the process** and workflow for change requests within DCMS. DCMS could track the processing time for change requests and set targets for completion time. We also suggest **reformatting the structure for submitting** the information required for change requests to avoid misunderstandings and the need for rework.
- Reduce the need for change requests in the first place by **relaxing or rethinking the nature of the link between grant payment and initially agreed milestones**, as innovative projects do sometimes change scope in flight and require funding to adapt.
- The department should consider **outsourcing some programme management activities** if that could make the programme run more efficiently.
- The department should **focus on mechanisms to minimise disruption from staff changes**, for example by ensuring effective handovers.
- As there were **a lot of applications and many unfunded projects**, there may have been an opportunity for DCMS to be less "risk averse" and award funding to more projects.

Results from the impact evaluation

The impact evaluation assessed the benefits to programme participants and the wider socio-economic impacts, including impact on infrastructure rollout, the 5G ecosystem and the UK's reputation as a leading 5G nation. It also included an assessment of the degree to which the programme has reduced barriers to 5G deployment.

Reducing barriers to 5G deployment and technological progress

The programme sought to diversify the market and tackle issues around information and awareness. Most progress was made towards tackling information and awareness barriers by developing expertise in the deployment of private networks, as well as reducing costs by address challenges with spectrum licensing and planning regulations.

Summary Table 1: Progress on barriers to 5G deployment

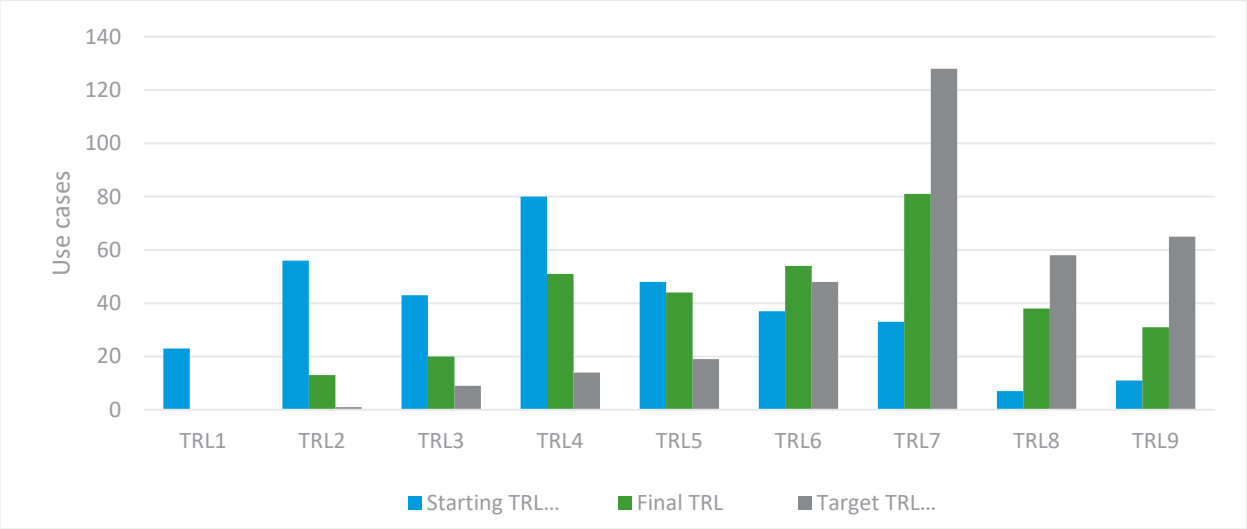
Barrier	5GTT programme barrier busting	Remaining challenges	Wider impacts from addressing this
Cost barriers	A specific aim of the programme was around learning about the conditions under which 5G could be deployed more cost efficiently. For example, the Smart Junctions project achieved a deployable network that was 75% cheaper than a traditional vendor, although it is not yet market ready. This was done using OpenRAN technologies and small cell equipment. (Source: Project Interview)	Cost remains a barrier to deployment (see chapter 5)	Addressing cost barriers would allow other players to enter the market, generating competition and further innovative activity.

Barrier	5GTT programme barrier busting	Remaining challenges	Wider impacts from addressing this
	WM5G IA reported a reduction of 3-6 months in time to deploy 5G networks in the West Midlands. (Source: Closure Report)		
Cost/time saving - Spectrum Licensing	Ofcom made spectrum available through Shared Access Licenses (SAL) and Local Access Licenses (LAL) for 5GTT projects, which allowed for the installation of private networks with less involvement from large MNOs (Source: Ecosystem Interview, Programme Technical Report). MK5G reported that because they had learned about the spectrum licence process and configuration/integration of devices within the network, their follow-on project was attracting significant further investment from the private sector (Source: Project Interview) Six interviewees mentioned that the programme had made good progress: Through freeing up the N77 band Through access to shared spectrum licences	The license application process is cumbersome and iterative. The spectrum allocated was more suitable for use outside than for indoor environments.	Development of private networks without MNO involvement, challenging business models of larger MNOs and creating opportunities for smaller ones.
Adoption/ implementation challenge: Lack of expertise to deploy private networks by non-MNOs	The programme allowed participants to develop this understanding and expertise. More than 1,000 private sector business employees have been involved in the programme. Knowledge and expertise has been shared through the UK5G ecosystem (Source: BRs – see Sustainability Annex)	It will take time for information and knowledge to be shared more widely within sectors such as construction, manufacturing, public services and healthcare. The technology readiness of equipment is still evolving and other DSIT projects address this (FRANC, Open Networks etc). Momentum around sharing information needs to be maintained.	Opportunities to support businesses deploying networks; develop more 5G ready radio equipment. Wider economy benefits through the greater facilitation and innovation role that 5G deployment can play across different sectors that rely on telecoms as an input to drive value added activities.

Barrier	5GTT programme barrier busting	Remaining challenges	Wider impacts from addressing this
Cost and adoption challenge - Planning Regulations	These barriers included lack of understanding about the infrastructure required on the local authority side, for example. This had meant that MNOs were able to achieve higher rates of success with planning applications for 5G infrastructure (Project interviews). Projects such as WM5G Infrastructure Accelerator addressed issues around planning permission and legal agreements for deploying 5G infrastructure. This included providing training to local authority staff on the Electronic Communications Code, and standardising engagement processes between LA staff and MNOs (Source: Closure Report).	Still likely to experience challenges to applications in some areas although the programme has helped to inform local authority staff about issues and address misinformation about 5G.	Speeding up the deployment of 5G infrastructure and reducing costs to local authorities of potential planning tribunals (Monitoring data from the WM5G project suggests that £100k in tribunal costs are incurred when a case is brought by an MNO. An estimated £500k was mitigated.)
Adoption challenge - Technological Readiness of Equipment	The programme helped to improve TRLs of equipment, on average TRLs increased by 1.7 (Source: BRs – see Sustainability Report).	Equipment is still evolving and further DCMS/DSIT programmes are more focused on this aspect.	More reliable 5G networks that are quicker and cheaper to deploy; potential to create new UK-based businesses to supply equipment. These can also drive facilitation of wider economic activity.

The average starting TRL for use cases was 4.2, which on average advanced by 1.7 points by the end of the grant, and 95% of projects were assessed as having made good progress against TRLs by June 2022. The range of starting TRLs is wide compared to other innovation programmes.

Summary Figure 2: Change in TRLs



Use cases and applications

The programme has resulted in the development of a diverse set of use cases and demonstrated applicability across sectors and geographic areas. We provide some illustrative examples below, which show:

- 5GTT encouraged collaboration across organisations that may not have otherwise been inclined to work together. It also strengthened previously existing collaborations. Data for 37 projects suggests that just over 1,300 people were involved from the private sector (on average 37 people per project), 101 stakeholders from the public sector, and 65 university departments
- Private sector participants gained knowledge about overcoming barriers and cost effective deployments. The range of use cases and processes showed the potential of 5G in the private and public sectors, alongside urban and rural communities
- 107 telecommunication networks were deployed and tested, of which 70 are known to be still in use
- Data available for 36 projects suggests that 345 use cases were identified at the project outset. On average, the starting TRL of use cases was 4.2 and the average improvement in TRL of the 5GTT programme was 1.7
- 20 of 37 (54%) projects resulted in a solution being brought to market. 29 of 37 (78%) projects resulted in consortium members benefiting from having adopted process innovations
- The programme resulted in £262.8m in further private and public investment. For every £1 of government funding the programme leveraged £1.65 in further funding, £1.32 when known public funding is not counted. This ratio falls in line with that of other comparator R&D programmes

Enabling wider benefits

5G ecosystem development was also a key accomplishment, through DCMS networking activities, the UK5G Innovation Network, and through DCMS's support to create project consortiums.

Survey evidence also suggests that the programme has had a positive impact on the reputation of the UK as a key player in the sector. We were also told by DCMS that 5GTT may have influenced the early commercial roll out of 5G in the UK.

The programme has also demonstrated some very promising early signs of how it has generated benefit to the wider economy across the areas identified as targets by DCMS. As many of the projects had only finished in 2022,

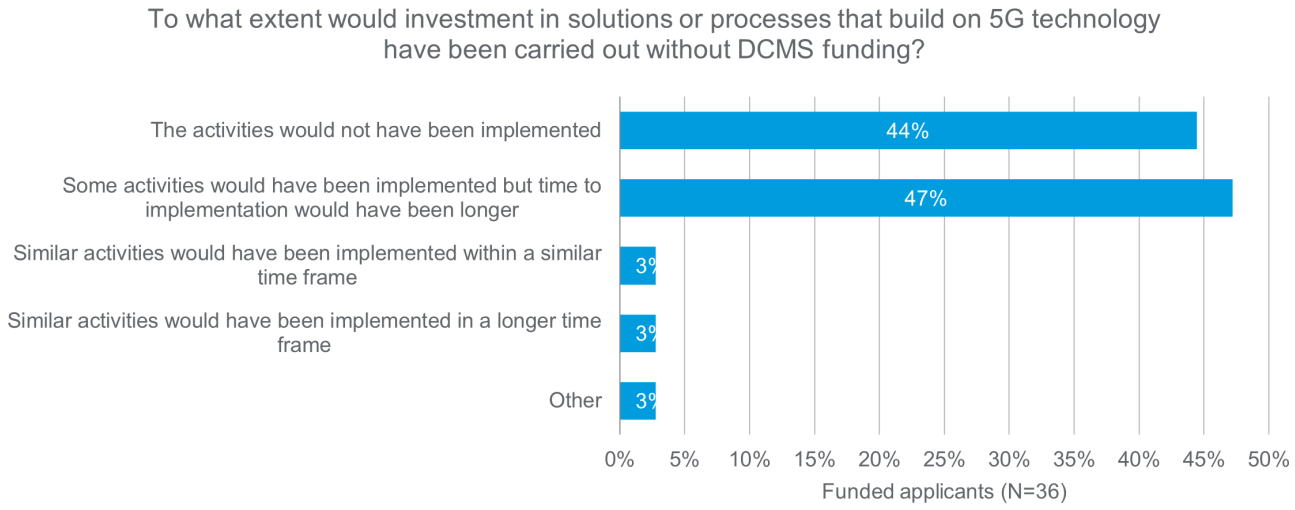
the wider benefits will take some time to diffuse across the wider 5G ecosystem and the overall economy. There have however been spillover benefits into sectors and areas not directly related to the 5GTT programme

- Project delivery partners were able to enhance their knowledge and skills in deploying secure and resilient networks and share this learning with the ecosystem more widely.
- Projects considered the environmental impact of their use cases and 13 of 37 projects (35%) have had environmental impacts, such as in transport. Environmental considerations can lead to more efficient and sustainable practices, and reduction of environmental damage increases wellbeing in the wider public.
- 5GTT has produced applications to improve health and wellbeing directly, and also to provide enjoyable experiences that people might not otherwise have access to. 19 of 37 (51%) projects have resulted in wider benefits to the community

To what extent can we attribute these impacts to the 5GTT programme?

As part of our evaluation, almost all the project interviewees and firms surveyed were clear the projects they carried out would either not have occurred or would not have been developed to the same extent were it not for the 5GTT programme. This is supported by the figure below which shows nearly half of the activities funded by the 5GTT programme would not have been implemented without this funding. This is based on evidence from 36 surveyed private sector project participants. Evidence is based on self-reporting and is not backed by a robust counterfactual.

Summary Figure 3: Additionality of 5GTT programme based on survey data



Determining the overall value of the programme

The total cost of the 5GTT programme has been significant in absolute terms, though this represents only approximately 0.60% of UK Gross Expenditure on R&D (GERD) in 2019[4]. Furthermore, this expenditure has taken place over four years from 2018 to 2022, and is non-recurring, so even the figure above is a significant overestimate of actual yearly economic burden.

There are plans to conduct a final evaluation once 5GTT projects have had more time to generate the full intended outcomes and impacts, such as any impact of 5G adoption on revenue growth and additional 5G related investment. The final evaluation would benefit from a mixed methods approach including qualitative analysis of stakeholder consultations of beneficiaries, that have brought a solution to market, and impact case studies. A Cost Consequence Analysis (CCA) and/or Cost Benefit Analysis (CBA) can help build a (more complete) VfM analysis. The limitations and challenges encountered during this project will provide key learnings to take into a final

[4] Gross Expenditure on R&D (GERD): Total - Office for National Statistics (ons.gov.uk)

evaluation. Knowledge about likely challenging response rates, and timing of collaboration tool deployments will be critical to develop the framework to carry out quantitative analysis.

The expected wider spillovers of the programme will be pivotal in bringing connectivity to previously underserved areas and this can help generate business. The overall amount spent on the programme has the potential to generate **returns which are many times larger than the initial outlay due to the nature of 5G.** The development of 5G over previous generation technologies has potential to support the UK economy to adopt further innovation and benefit from that.

CONTENTS

1. INTRODUCTION

1.1 This report

The 5G Testbeds and Trials programme was announced in 2016 as part of the Autumn Statement and established in 2017 as part of the National Productivity Investment Fund[5]. Its purpose was to maximise the prospective benefits that 5G could bring to the UK economy through timely deployment and effective utilisation of 5G technology.

£199m of capital funding was allocated to the programme (although this budget has changed over the programme duration, see Chapter 2) and £140.1m was spent between 2017/18 and 2022/23. This funding has been allocated to a range of projects exploring many different aspects and challenges with 5G delivery through competitions covering research institutions, urban and rural community connectivity programmes, creative industries, industry and transport. It also established a national innovation network for the 5G sector, "UK5G", to build, connect, and inform the UK 5G ecosystem.

This report is **an interim evaluation of the 5G Testbeds and Trials programme**, henceforth referred to as the 5GTT programme. It has been written at a point where all funded activity was being completed[6]. However, the longer-term impacts of the projects, through adoption and use of the technologies and techniques that have been tested, are still playing out.

This interim evaluation is one of three evaluations of the Programme.[7] The initial evaluation, focusing on process elements and early impacts, took place in 2019-20 and the final evaluation will be conducted in 2025. A Scoping and Baseline study was also published in 2019[8] as well as an initial study of the WM5G project and Urban Connected Communities Programme[9]. This evaluation employs a similar methodology to the initial evaluation, and we refer to it to make comparisons, where appropriate. We also make recommendations around how the 2025 final evaluation should be conducted.

This evaluation includes three workstreams.

1. A **process evaluation**, building on the initial evaluation from 2019/20 to set out how effective the programme management and governance has been.
2. An **impact evaluation** combining two perspectives:
   - **Bottom-up.** This uses detailed qualitative case studies of selected 5GTT projects to gain insights into how and why the programme has been able to generate impacts. This approach uses a **theory of change** to assess the extent to which the programme led to the observed outputs and outcomes, and the potential for eventual impacts in the wider economy. It is supported by surveys of funded businesses, and comparable unfunded businesses in the 5G ecosystem, on their 5G research and innovation activity.
   - **Top-down.** This approach builds an economic narrative for the wider economic impacts of 5GTT, based on higher-level thinking about the key productivity benefits which it enables. The analysis is linked to interviews with delivery partners and other stakeholders with knowledge of the UK telecoms ecosystem, surveys of businesses in the 5G ecosystem and the wider economy more broadly on the value of 5G and challenges for adoption, along with analysis of programme management information, other studies of 5G, and external market data.
3. A plan, and early-stage impact research, for an **economic evaluation** and assessment of programme Value for Money. The full evaluation will be carried out at the final evaluation stage planned for the first half of 2025.

[5] Autumn Budget 2017 - GOV.UK (www.gov.uk)
[6] The final funded project, Factory of the Future, was completed in March 2023.
[7] Scoping and Evaluation reports for the 5G Testbeds and Trials Programme - GOV.UK (www.gov.uk)
[8] 2020-09-30_-_5G_Evaluation_Scoping_-_Final_1__2__1_.pdf (publishing.service.gov.uk)
[9] ICF "WM5G Project and UCC Programme: Fact finding study", 23 April 2021. The study took stock of the project at the midway point and was shared with stakeholders involved.

The remainder of this chapter introduces the 5GTT programme, and the methodology used in this evaluation. The remainder of this report is structured as follows:

We have also written a set of technical annexes that accompany this report. These provide more information on the research that has been carried out and is summarised or referenced in this report.

Annex 1: Methodology, key performance indicators, and consultation tools
Annex 2: Results from the UK5G Innovation Network survey and the sustainability report
Annex 3: 5GTT programme case studies

1.2 Methodology

The report is based on findings from a programme of research and analysis designed to support an overarching theory-based evaluation methodology (following HM Treasury Magenta Book Guidance). Contribution analysis was used to understand why different programme results were realised and this also involved documenting the role of external factors such as the impact of Covid-19 and technological barriers.

A **Theory of Change was developed** and this sets out how the inputs to the programme (such as funding and support), and the funded activities, are expected to lead to delivery of immediate **outputs**, medium-term **outcomes**, and longer-term **impacts**. The RSM evaluation team held a workshop with DCMS's 5GTT project management team to help develop this.

Table 1: Overview of key data sources and use

Data sources	Main purpose
Consultation with stakeholders in programme design, management, and delivery	Evidence the processes and challenges encountered by the programme delivery team
Review of monitoring information (Benefit Realisations documents, final reports) and other project documentation	Document the level of match-funding, evidence project activities, project outputs and outcomes including progress along Technology Readiness Levels
Interviews with representative funded project participants	Evidence challenges faced and drivers of success
Follow-up interviews with a selection of project partners	Develop in-depth case studies of 16 projects that are representative of the activities of the programme (such as their urban or rural focus, the relevant industrial sectors, and the network technology employed).
Surveys of funded and unfunded companies	Evidence outcomes and impact on private sector participants and investigate attribution of results to 5GTT
Survey of UK5G Innovation Network members	Understand the benefits of UK5G, including knowledge sharing
Review of publicly available company data	Understand the usefulness of such data for comparing impact on private sector participants, relative to a counterfactual

Data sources	Main purpose
Desk research on 5G adoption and other wider literature sources	Gauge developments in the wider sector

More detail is provided in the Annex summarising the methodology.

In total, we conducted 79 qualitative interviews with different stakeholder groups as summarised in the table below. We have spoken to at least one representative from all later stage (Phase 2 – 31 projects) projects and have conducted (20) additional interviews with other consortium members of later stage projects. Topic guides were tailored and not all interviewees responded to all questions (the sample is not consistent). Topic guides for all stakeholders are provided in the Annex to this report.

Although the target number of interviews was not reached, we have spoken to some interviewees that took on multiple responsibilities.

- 16 interviewees were involved in multiple initiatives
- 2 DCMS officials interviewed at the familiarisation stage and as part of the fieldwork.
- There were 6 Phase 1 projects and 5 Phase 1 project leads who went on to manage later stage projects. Initial contact was an interview mostly focusing on their more recent project, followed up via an email focusing specifically on their Phase 1 project.

Table 2: Qualitative interviews by stakeholder group

	Target	Number of interviews
Funded phase 2 projects	31 initial project lead interviews + 15-30 case study follow ups	51
Phase 1 projects	6	6
5GUK Test Networks	3	2
Unsuccessful applicants	10	13
DCMS Staff	15	15 in main fieldwork + 4 familiarisation interviews
Partner organisations involved in more than one project	5	3
Wider Ecosystem	5	9
Total	90-105	79 interviews

End of project monitoring data was reviewed for all (37) projects.

The analysis of private sector participants is based on a combination of surveys, interviews, monitoring information and other secondary data. Surveys were carefully designed with regular feedback from DCMS to ensure that they retain the correct balance of questions we needed to carry out our analysis, while not being either too lengthy or overly complicated to dissuade otherwise willing participants from responding.

Overall, 211 firms received funding as part of the 5GTT programme and 214 firms unsuccessfully applied for funding. The survey was sent to all successful and unsuccessful applicant firms for which we could source contact information (from secondary databases or from the project documentation submitted by the consortiums to DCMS). The table below presents an overview of the companies surveyed and includes the number of responses from funded applicants, unfunded applicants, and a wider representative population of SMEs. Response rates were lower than initially hoped for and responses may not reflect the views of the broader population. Also, several respondents submitted a partial response and fewer responses were collected to questions on turnover and further investment. This created a non-response bias. As a result of this limitation, data for the unfunded applicants is not included in any of the visual presentations. We do include visualisations of funded applicant data.

As part of the interview programme presented above, we interviewed 35 of 211 private sector participants, which includes four firms that were unsuccessful in one of their applications. We also interviewed another five firms that were unsuccessful in all of their application(s).

Secondary data analysis is based on data from Orbis, which leverages Company House data, and the Beauhurst database, which contains data on high growth SMEs in the UK. Out of the 211 firms that participated in the programme, we found data in Orbis for 188 firms, although not all firms have data on all variables. For example, data on turnover is available for 89 of the participants and data on employment is available for 152 participants and most firms have not reported every year. The analysis of this data provided insight into the potential usefulness of secondary sources for the final evaluation. Secondary data was also sourced for a matched sample of 1,905 non-applicant firms. The matching between project participant data and non-applicants was done using data on employee numbers from 2018, turnover from 2018, and primary sector. For a small number of firms, including larger firms, matching was not possible because a good match could not be identified (this is because the overall population of larger firms is relatively smaller).

Table 3: Surveys and secondary data

Group	Overview of data type	Population (firms)	Number of responses (firms)
Source: Survey			
Treatment group	Funded applicants – all firms that received funding as either part of a Phase 1 or a Phase 2 project	211	34 (16%)
Comparison groups	Unfunded applicants - firms that applied for funding as either part of a Phase 1 or a Phase 2 project but were not successful	214	13 (6%)
	Omnibus SME survey - senior decision-makers of companies with less than 250 employees, data collected by Opinium	-	500
Treatment group	Survey of UK5G Innovation Network members	136 (ca. 8% response rate)	
Source: Orbis			
Treatment group	Funded applicants – all firms that received funding as either part of a Phase 1 or a Phase 2 project	211	188
Comparison group	Unfunded applicants - firms that applied for funding as either part of a Phase 1 or a Phase 2 project but were not successful	214	151
Comparison group	Wider comparator group – unrelated non-applicant firms with matching characteristics as the funded applicants	1,905	1,905

Source: RSM analysis of primary and secondary data collection.

Limitations of the findings are presented alongside summaries of evidence. The major limitation to the study has been the reliance on self-reported data from project delivery partners and such data may be subject to bias.

2. THE 5G TESTBEDS AND TRAILS PROGRAMME

2.1 Overview of the programme and projects funded

2.1.1 Programme policy context and rationale

The £200m 5GTT programme was announced in 2016 as part of the Autumn Statement, and established in 2017 as part of the National Productivity Investment Fund (NPIF).

The 2017 Conservative Manifesto, the Government's Industrial Strategy, the Future Telecoms Infrastructure Review, and the National Infrastructure and 5G Supply Chain Diversification Strategies all highlight the importance of mobile connectivity and 5G technology to the future strength of the UK economy.

The programme was established to help ensure that the UK remains globally competitive, and that 5G deployment occurs at least as rapidly as the progress of other advanced economies. Relative to other countries, the UK began to adopt 5G technology quickly, and the first public 5G network was rolled out in May 2019. However, it was found that investment in new technologies such as 4G[10] and 5G[11], has been slow in the UK mobile connectivity market, in part because this is dominated by four large Mobile Network Operators (MNOs). MNO operating margins for UK operators are lower than EU countries and the US and incentives to deploy networks in rural and other hard to reach areas are not strong.[12] The most recent Connected Nations report[13] shows 5G coverage provided outside of premises by at least one MNO increased from 42-57% in 2021 to 67-77% in 2022. This coverage is mostly concentrated in Urban areas. Data traffic over 5G also increase from 3% to 9% in the same time period and around 1 in 5 handsets are 5G capable.

DCMS market research and engagement (2020)[14] identified that some of the factors contributing to the long-term consolidation of the market for network equipment and services, and the corresponding lack of diversity of supply in this market, are:

- Economies of scale that benefit the dominant incumbent suppliers;
- Operators' preference for established, reliable, scale and stable suppliers;
- High levels of R&D investment required to compete; and
- Lack of interoperability which promotes incumbent 'lock-in'.

The ability for governments to use direct support for R&D and innovation to address 5G related market failures and system failures is recognised in the academic literature, and there are various other instruments implemented across Europe with similar objectives (e.g. the Connecting Europe Facility-telecom strand, Digital Europe Programme). The table below sets out some of the failures addressed by R&D and innovation support in Europe: they are in good alignment with the factors identified by the DCMS market research and engagement.

Table 4: Overview of select market and systems features in the 5G context

Market /systems feature	5G context
Economies of scale and scope	High initial investment costs make investing in 5G infrastructure development and deployment risky in an environment where networks, capacity and uptake are uncertain.
Asymmetric information	Business cases may be pushed by equipment suppliers (and other stakeholders that see value) but Mobile Network Operators lack certainty.

[10] Analysis Mason "Lowering Barriers to 5G deployment" July 2018
[11] Frontier Economics "The Investment Gap to full 5G rollout", Sept 2022
[12] Ofcom "Ofcom's future approach to mobile markets: A discussion paper", February 2022
[13] Ofcom "Connected Nations 2022: UK report" Dec 2022
[14] Supporting research referred to in the 5G supply chain diversification strategy

Infrastructure failures	Mobile Network Operators lack incentive to invest in less populated rural areas.

Source: adapted from Blind and Niebel (2020)[15]

The evidence collected by DCMS, and the supporting evidence from market failures in other jurisdictions set out above, provide the rationale for the 5GTT programme. The programme was developed based on the expectation that without intervention, the prevailing market and systems failures will prevent markets from investing in a way that will open up the market and produce the optimum benefits to the UK economy.

The programme funds collaborative R&D projects that test innovative use cases for 5G. Initial objectives of the programme were:

1. To explore the benefits and challenges of deploying 5G technologies.
2. Help to establish the conditions under which 5G can be deployed in a timely way to drive efficiency and productivity, and maximise the chances of the UK being amongst the leading 5G countries.
3. Foster the development of a diverse and varied set of 5G use cases and applications to ensure that the UK and UK businesses are well placed to maximise the benefits of 5G.
4. To support the implementation of the Government's Future Infrastructure Telecoms Review.

These objectives were later refined to focus on objectives 2 and 3[16] in the above list (see Theory of Change diagram in the next chapter.

Despite an initial economic case based on consumer adoption of 5G, the programme was always focused on developing a diverse set of use cases and testing business model applications of 5G. This was to try to drive roll out and adoption beyond dense urban areas, for which there was already a clearer business case. The programme aimed to provide the same benefits of 5G to people in rural areas.

The programme aimed to explore properties of 5G that could support a range of use cases. The private and public sector programme participants played an important role here. While consumers benefit from faster connection and greater bandwidth for downloading data, for the average mobile phone user it is not transformatively different. Businesses and other (public and third sector) organisations however can benefit more from these features; lower latency and greater bandwidth should allow for safer, more reliable operation of a greater number of connected devices.

One of the challenges for wider adoption of 5G technologies was a lack of demand from organisations due to a lack of understanding about how it can benefit them. The business case and logic model developed by DCMS was therefore updated to reflect this emphasis in April 2020[17].

Central to the programme were the **5G Testbed and Trial projects,** which were procured competitively and the programme has funded a diverse set of projects. Beneficiaries have included private sector firms, universities, and other types of organisations. The market failure rationale is that if consortiums are provided with funding to overcome the high investment costs of R&D, they will be able to develop business cases which demonstrate the potential value of 5G to equipment suppliers, potential customers, and MNOs, and provide MNOs with the confidence to invest in infrastructure. The programme also supported other workstreams such as the development of the UK5G innovation network, university test networks and other projects as described below.

2.1.2 Programme design

The University test network was directly awarded in July 2017 with cover from Treasury ahead of the full business case for the 5GTT programme. A portfolio of 6 Phase 1 projects received funding in 2018 and concluded in March 2020. During the implementation of the first phase of the project, further funding was secured to the UK5G Innovation Network. Following this first phase, 31 further projects covered a range of different timespans: they

[15] Blind and Niebel (2020) 5G roll-out failures addressed by innovation policies in the EU, Technological Forecasting & Social Change 180 (2022) 121673

[16] Business Case Update V3.

[17] 5GTT Programme Success Measures Review: Findings and Proposals Paper for 5GTT Board, April 2020

began between 2019-2021 and lasted anywhere from 18 months to over two years, with most projects having been completed in 2022. The last project completed in mid-March 2023.

Table 5 below sets out the objectives of the different strands and the main competitions are highlighted.

Table 5: Summary of the different strands of the 5GTT programme

5GTT projects	Year	Funding	Objectives
5GUK university test network	2017/19	£16m	Test network to trial 5G technologies and applications. The network was open for business and available for use for trialling further 5G applications and technologies, supporting numerous other projects. Delivery partners are: 5G Innovation Centre (5GIC) at the University of Surrey, the University of Bristol and King's College London (KCL) and Digital Catapult's London 5G Testbed (Future Networks Lab)
2018 portfolio (6 projects)	2018-2020	£27.2m (average £4.5m each)	To explore innovative radio technologies and applications that help to change rural economies, deliver low-cost healthcare solutions into homes, and enhance productivity in manufacturing. Projects could use the university test network if they wanted to but were not required to do so
UK5G	2019-2023	£1.7m	UK5G Innovation Network – To promote research, collaboration and the commercial application of 5G in the UK
West-Midlands 5G (6) / Urban Connected Communities	2019-2022	£21.5m (average £3.6m each)	A programme within the wider programme with multiple sub-projects testing 5G networks and use cases within a smart city environment • To test models for cost-effective deployment of 5G infrastructure in highly populated urban areas, and remove barriers to deployment. • To explore and prove the potential for 5G to enable economic and social benefits, for example through cost savings and service improvements in the public sector. • To develop and test new applications and services that use 5G capabilities, and commercial business models. • To inform and test West Midlands and national digital policy and regulation.
Create 1 (6) and Create 2 (9) – 5G Trials in Industry Sectors and Public Services	2020-2022	£30m (average £1.8m each)	To explore the potential for 5G in a range of industry sectors and public services. Developed new use cases, business models, 5G technical capabilities and commercial prospects.
Rural Connected Communities (7)	2020-2022	£24.9m (average £3.6m each)	To trial innovative use cases and technical solutions to build the business case for investment in rural connectivity and explore the capabilities of 5G to benefit rural communities and demonstrate demand from a variety of economic sectors and rural communities for 5G technologies. It invested in use cases covering a broad range of activities including: agri-tech, aqua-tech, transport, digital classroom, tourism, health and environmental monitoring.
Industrial (3)	2018-2022	£6.5m (average £2.2m each)	To test the application of 5G in the manufacturing industry. Industrial competition projects are 5GEM and 5G Encode, and £1.3M to the Digital Catapult for various activities including pre-market engagement.
International project (1)	2019-2022	£1m	UK and South Korea government collaboration that supported businesses to develop 5G-ready content and services for people using transport systems
Other projects/ Initiatives (8+)		£10.4m	Initiatives include reporting activities related to Rail and Roads, cross cutting work on Security, underground railway communications (SubConnect project), 5G Ambulances[18] and others. It includes work on Neutroran which was continued under the Open Network Fund.
Total	**2018-2023**	**£140.1**	

[18] Funding was offered for this, but declined by the NHS.

The 5GTT projects involved a diverse range of organisations including private sector firms, universities, and other types of public bodies and non-profits (see Table 6 below). Lead organisations oversee project activities of their respective consortiums. This analysis does not include the University Test Networks and other project Initiatives. The projects are central to this evaluation.

Table 6: Organisations involved in 5GTT, by type

Organisation Type	Number of organisations	Percentage	Number of lead organisations	Lead organisations, percentage
Private	211	73%	21	58%
Public Bodies	36	11%	10	28%
Universities	40	12%	4	11%
Catapults	8	2%	1	3%
Non-Profit organisations	6	2%	0	0%
Total	**335**	**100%**	**36**	**100%**

In addition to the 5GTT projects, the programme supported the creation of a **UK5G Innovation Network (2019-2022)**[19] which was dedicated to the promotion of research, collaboration and the commercial application of 5G in the UK. It was created to facilitate and encourage the engagement and coordination of organisations working on 5G activities across the UK, and was delivered by Cambridge Wireless, with the Knowledge Transfer Network and TM Forum[20]. It enhanced links between ongoing R&D and other activities being undertaken by organisations across telecoms and other sectors. The network had over 5,000 registered users from 1,800 organisations.[21] In 2020 a Supplier Directory of 180 vendors who wanted to support DCMS's 5G innovation projects was added to the network. Vendors could publicise their offer to potential 5G trialists, and to enterprises wishing to develop private network solutions. This particular action aimed to increase the efficiency of building effective 5G innovation trials within the UK, and to support the promotion of UK capability internationally. In total, DCMS spent £1.7m on the network.

In October 2022 UK5G closed and was handed over to UK Telecoms Innovation Network (UKTIN) to make this a sustainable initiative in the long-run[22]; this network is being delivered by Digital Catapult, Cambridge Wireless, University of Bristol and WM5G.

2.1.3 Overall expenditure and project outturn/success

Between 2018/19 and 2022/23, DCMS invested £140.1m in grant funding in the 5GTT programme, as well as the time and resources to run the programme and in delivering accompanying dissemination material. Additional investment has been made by project partners. The 5GTT programme budget has been subject to revision. It was initially costed at £169m in 2017/18 but the budget was revised to £200m at a subsequent spending review and finally costed at £199m at the 2020 spending review.

Some projects experienced slippage in timelines. Project mobilisation was slower than anticipated in 2017/18, which resulted in a reduction in spending in 2019/20. DCMS documentation explains that the initial underspend was caused by lockdowns during the Covid-19 pandemic, a lack of senior staff in place early in the project and by interventions not proceeding as planned, including:

[19] UK5G Innovation Network - Events, News & Resources

[20] TM Forum is an alliance of 850+ global companies working together to break down technology and cultural barriers between digital service providers, technology suppliers, consultancies and systems integrators. See About TM Forum | TM Forum

[21] https://uk5g.org/updates/read-articles/government-creates-new-body-to-make-uk-world-leader-in-telecoms-innovation/

[22] UK Telecoms Innovation Network Competition - GOV.UK (www.gov.uk)

- Trans-Pennine Initiative – completed a feasibility study which showed the project would not deliver value for money under the 5GTT programme[23].
- Urban Connected Communities- delayed launch due to mobilisation
- Rural Connected Communities - delayed launch due to 'shifting policy landscape'
- Industrial 5G - only funded £6m out of a pot of £30m. This competition received only 4 applications and only 2 were sufficiently developed at this point. These re-applied and were successfully funded through the Create competition.

DCMS commented that they had sought to mitigate underspending in later years by targeting a greater number of projects than budgeted for, and by using other initiatives to distribute funding effectively. One other such initiative that was proposed is the 5G Ambulances (£3m) with DHSC (under a Memorandum of Understanding), but DCMS representatives reported that ultimately this allocation remained unspent and was transferred directly back to Treasury (so still appears as a cost on the budget of DCMS).

In relation to the 2021 budget of £199m, there has been an overall underspend of £58.9m, which is 30%. The overall underspend is substantial; the view of DCMS representatives is that this is a reflection of the lack of market readiness and a signal of market failures. Interest from larger businesses was lower than originally anticipated, which resulted in scaling down the size of individual projects and redirecting engagement towards smaller businesses and researchers. An assessment of spending is included in Chapter 3 and Chapter 7.

Table 7: DCMS (5GTT) expenditure by Year

2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Grand Total
£16.0m	£27.0m	£17.6m	£33.9m	£44.2m	£1.4m	£140.1m (70% of target)

Source: DCMS Finance Team (June 2022)

[23] https://www.ispreview.co.uk/index.php/2019/01/government-scraps-5g-mobile-trial-on-trans-pennine-rail-route.html

3. THEORY OF CHANGE AND EVALUATION FRAMEWORK

3.1 Programme Theory of Change

In the context of the 5GTT programme evaluation, the Theory of Change (ToC) is a tool used to describe the chain of causation from the investment to its ultimate impacts:

A ToC for the programme was produced in the early stage evaluation. This was revised by DCMS to better reflect the expected success measures of the programme and inform the measures used in the benefits realisation process. In this evaluation, we have further developed the ToC significantly through workshops with DCMS staff and consideration of economic theories of how the benefits of innovation are transmitted into the wider economy; this has given us a better understanding of what the ultimate impacts of the programme are likely to be, and the intermediate signs of progress towards those ultimate impacts that are observable at this interim stage.

The ToC summarised Key Performance Indicators (KPIs). Some of the KPIs align with targets set out in the programmes' business case. For example, targets include:

- 60% of projects deemed to have demonstrated a significant positive movement towards a sustainable demand/supply certainty and/or new viable business models
- 50% of programme participants will have engaged in further 5G related activities beyond funded projects
- Every £1 invested in projects has been associated with 20p of additional 5G related investments

The 5GTT programme ToC and the evaluation are framed around seven impact dimensions (transmission channels). Some of these impact dimensions outline the expected outcomes and impacts on the programme beneficiaries, while others outline the expected impact on a wider group of stakeholders. The ToC assumes that, through the development of a diverse set of use cases and applications, the programme will contribute to tackling information asymmetry (that is, an imbalance between parties such as firms, networks installers and suppliers of equipment of knowledge about relevant factors and details) that has inhibited earlier investment in or adoption of 5G.

There are linkages between the impact dimensions and positive outcomes and impacts on programme beneficiaries that need to be realised to unlock benefits of the programme to wider stakeholders. Following-on from successful project outputs, the ToC assumes that the programme results in:

- collaboration, knowledge sharing and project partners overcoming adoption barriers;
- the effective use of capital; and
- investment in R&D.

These outcomes (the first three of the seven impact dimensions) are assumed to enable the **development of a diverse set of use 5G cases and applications,** which is a core ambition of the programme. The development of these use cases and applications is expected to unlock a range of further benefits and impact on the programme beneficiary group.

Looking at the impact on the wider stakeholder group, the ToC assumes that establishing the conditions for 5G deployment in the wider economy will help **drive efficiency and productivity**. This is driven by:

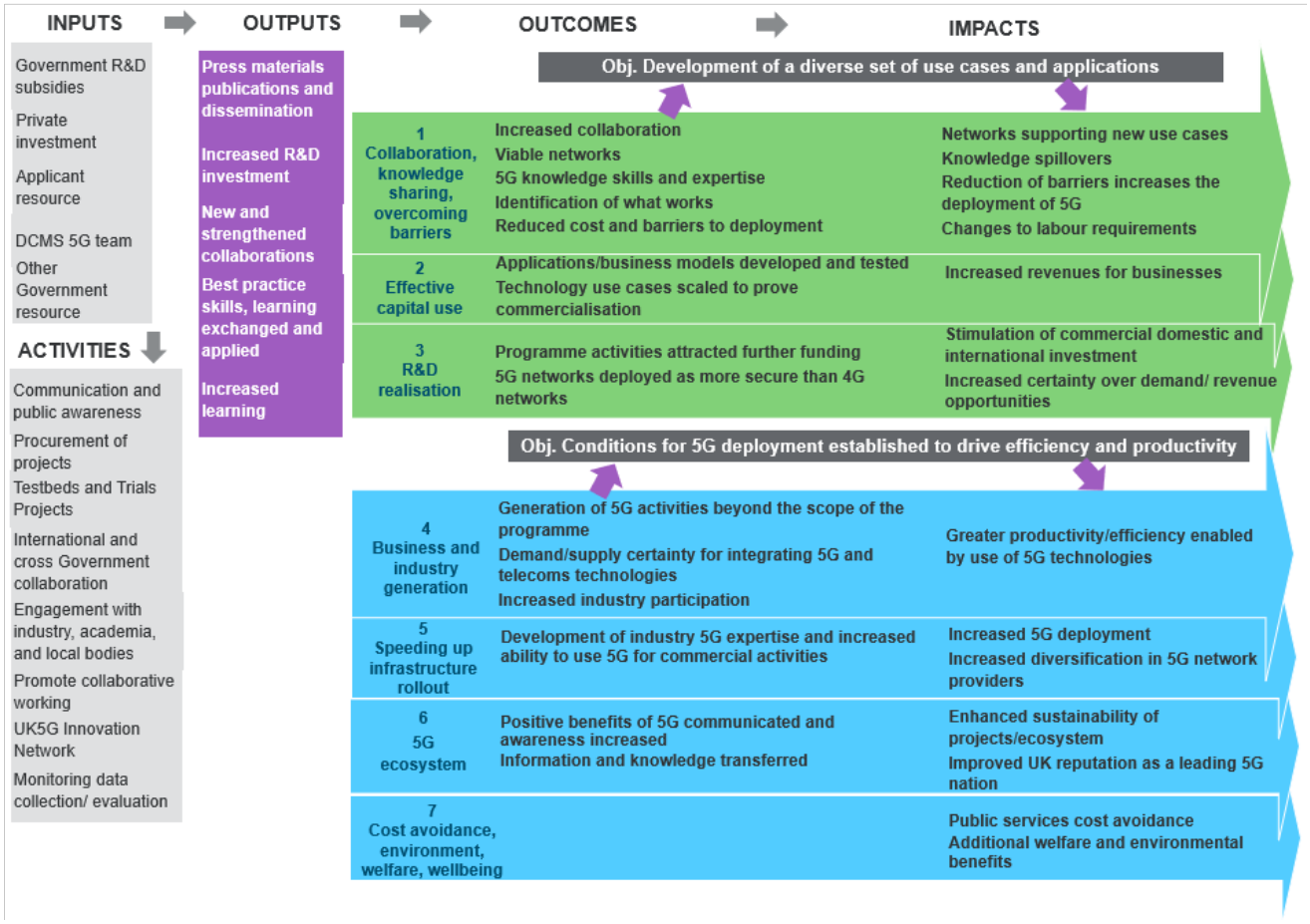
- generation of further business activity around 5G;
- development of industry expertise and platforms for commercialisation; and
- transfer of awareness and knowledge.

This in turn is assumed to have positive impacts on the remaining four impact dimensions:

4. further business generation;
5. further infrastructure roll-out;
6. the creation of a 5G ecosystem; and
7. other benefits such as cost-avoidance.

The Theory of Change is intended to be comprehensive and facilitate capturing a wide range of programme benefits. The interview programme also asked project partners about unintended consequences, however, at a programme level, we have not found outcomes and impacts that fall outside this framework.

Figure 1: Programme Theory of Change / logic model



The seven transmission dimensions are discussed in more detail below.

1. Collaboration, knowledge sharing, overcoming barriers

5GTT has funded collaborative projects that have required different types of stakeholders (academia, private sector, and government, etc) to work together towards common objectives. A positive interaction between stakeholders in the ecosystem is expected to be useful to identify what works, to identify issues along the 5G supply chain, and to allow stakeholders to work together to overcome these and other technical or practical adoption challenges for specific sectors.

This collaboration, and the overall programme activities, have the potential to result in 5G knowledge, skills and expertise. Sharing knowledge can result in reduced costs and barriers for the project partners to deploy 5G technology, for example, if project partners are given better insight into 'what works', what technological options are available, and/or how to into tackle regulatory barriers.

Network building, including by means of stakeholders at events such as the Birmingham showcase event, is expected to help build an ecosystem or network of firms and individuals who have knowledge of 5G technologies, and build awareness of 5G. This in turn improves 5G knowledge diffusion. Over time, the programme could see the networks supporting new business use cases, knowledge spillovers, increased deployment of 5G across programme beneficiaries, and possibly changes to labour requirements as a reflection of human capital needs.

2. Effective capital use

The testing and initial deployment of 5G will provide programme beneficiaries with further lessons on how to effectively use capital, e.g. 5G technology in combination with infrastructure, or the more effective use of 5G itself. The development and testing of business models, applications and use cases will enable project partners to effectively apply 5G technology in their own line of business. The programme ToC assumes that such effective and efficient application of capital can result in increased revenues and productivity (e.g. when companies adopt more efficient practices). This assumption will need to be evidenced as part of the final evaluation.

Examples of this from wider literature include:

- 5G-enabled factories can see up to 20-30% in overall productivity gains, from improvements in assembly time, predictive and preventative maintenance to extend asset life, and defect detection.[24]
- Two-way communication energy grids using smart sensors and meters can save households billions of dollars and drive down energy use.[25]

3. R&D realisation

The programme investment in 5G is aimed at developing and fostering an environment where additional R&D is likely to occur. Project partners, in particular from industry, may use their initial successes to push their business case. Smaller businesses may acquire investment from third parties, including from international investors. Additional R&D increases the probability of further technological advancements and perceived benefits. Moreover, increased certainty over demand will help lower risk to investors.

The ToC also assumes that 5G networks can be more secure than 4G networks, and awareness of such benefits, will drive demand for deployment by investors, business, and other consumers.

This evaluation builds on evidence of additional investment sourced, as a result of positive project outcomes, and barriers to further investment. Some investment will be displaced from other RD&I initiatives, and this is not controlled for as part of this evaluation.

4. Business and industry generation

The ToC expects the development of new businesses and business capacity around 5G or supported by 5G as businesses develop and demonstrate their networks and use cases. In parallel, increased demand and supply certainty for integrating 5G and telecoms technology is expected to create some of the fundamental conditions for further economic benefit. The accelerated deployment of 5G technologies, and increased knowledge around them, increases the likelihood that businesses will adopt productivity boosting technologies and innovations which rely on 5G systems, which has potential to further improve productivity and efficiency, and generate economic growth, which supports new industries and businesses. Data from Ofcom shows that demand for 5G-ready handsets, and private networks and connectivity for 5G enabled IoT devices is growing.[26] The need to diversify the telecoms supply chain and exclusion of high risk vendors also creates opportunities for UK-based businesses to develop to meet the demand.[27]

[24] Accenture "The Impact of 5G on the European Economy," February 2021
[2525] Ibid.
[26] Ofcom "Connected Nation 2022 United Kingdom Report", December 2022
[27] DCMS "5G Supply Chain Diversification Strategy", November 2020

5. Speeding up infrastructure rollout

Infrastructure rollout increases the capacity for productivity benefits to occur by easing constraints such as around spectrum, supply chains for radio equipment, and planning regulations. This is a capacity-productivity relationship, and the increased ability for wider stakeholders to use 5G for commercial activities is very much needed for the programme to result in large benefit gains. Over time, the programme is expected to contribute to increased 5G deployment by wider stakeholders and diversification of 5G network providers.

This is not just about having the technology. For infrastructure rollout to speed up it is essential to have the skills and expertise in the community.

6. 5G ecosystem

Some of the benefits of the 5G ecosystem are expected to be shared through other channels of the 5G network with wider stakeholders. This creation of an ecosystem with knowledge and ideas on the deployment of 5G is expected to ultimately have a positive effect on the reputation of the UK as a leader in 5G technologies. Ultimately, the programme is supporting market diversification and the success of new (home grown) market entrants could also expand to international markets. The role of international programmes can also help foster such learnings. Furthermore, this ecosystem will further help the development of firms in the UK that depend on 5G, through the shared resources and shared external economies they can take advantage of. If the programme supports the ecosystem, there are benefits that will spill over to firms in this manner.

Building an effective 5G ecosystem in the UK and encouraging organisations to participate in it and collaborate with each other, helps firms to overcome technical and practical adoption challenges (speeding up technology adoption) and spread skills and knowledge into the UK economy (spurring further R&D and improving productivity and efficiency).

7. Cost-avoidance, environment, welfare and wellbeing

If the programme is successful, innovation in the UK telecommunications market is expected to result in additional spill over benefits over time. The programme has tested opportunities in a range of sectors and geographies and when this test bed activity demonstrates opportunity the programme is expected to inspire others.

- Increased knowledge of 5G is expected to contribute to a more **secure and resilient 5G environment** through development and sharing of standards and best practice.[28] This can lead to fewer breaches, improved safeguarding of data, and in particular intellectual property.[29] More resilient 5G deployment can also reduce the likelihood and/or severity of losses in connectivity/downtime, which protects the sectors that rely on 5G[30] and their contribution to the UK economy for example, information and communications; manufacturing; and transport[31]. This also applies to the public sector and third sector.
- The ToC also anticipates that there is scope for increased adoption of 5G to result in **environmental benefits**. The 5GTT business case (2021) includes a reference to 60% of the 5GTT projects having at least one benefit that contributes to reducing emissions. Direct effects referenced include:
  - In agriculture, decreases in fertiliser use because of 5G improved crop analysis leading to lower costs and reduced environmental impact.
  - Reduced manufacturing wastage with help of 5G tracking and sensor data.
  - Reduced commuter emissions when remote working expands the options of those working from home, due to 5G higher bandwidth providing faster telecommunications infrastructure (see AMC2 and 5G festival case studies).
- There could also be additional **welfare gains** to society as the development of private 5G networks leads to additional bandwidth being available for consumers to enjoy at reduced cost.

[28] https://www.gsma.com/security/5g-cybersecurity-knowledge-base/
[29] https://www.gsma.com/security/securing-the-5g-era/
[30] https://www.thalesgroup.com/en/worldwide-digital-identity-and-security/mobile/magazine/5g-vs-4g-whats-difference
[31] Accenture "The Impact of 5G on the European Economy," February 2021

3.2 Assumptions for the ToC – how activities lead to ultimate impacts

There are external factors that influence the success of the projects and the feed through to the wider economy. The Theory of Change assumes a progression over time, from outputs to outcomes and impacts, and this causal chain is influenced by external conditions. Some external conditions may have caused delays or inhibited progress, and the evaluation considers:

- The effect of the supply of key infrastructure components, to understand if supply chain disruption impacted projects.
- The effect of the Covid-19 pandemic, to understand the degree to which this has created project delays etc.
- The effect of EU Exit, to understand the degree of administrative burden

The Theory of Change assumes that the 5GTT projects and the 5G network are successful demonstrators and thereby have the potential to stimulate wider business activity and the take-up of 5G technology. The evaluation will:

- Gauge the demand for 5G technology within the wider sector.
- Assess the degree to which public concerns or misinformation over 5G are likely to influence wider adoption of 5G technology.

4. PROCESS EVALUATION

4.1 Summary

This chapter sets out findings against the two process evaluation questions.

- How effective and efficient has the delivery of the 5GTT programme been?
- How could the delivery of the programme be improved?

The key process evaluation builds on an examination of the programme's various activities and processes. This has involved a programme of interviews with successful and unsuccessful applicants for 5GTT funding, DCMS staff, and external stakeholders and programme monitoring information.

Areas of focus of the assessment of the effectiveness and efficiency of the delivery of the 5GTT Programme are as follows:

Table 8: Summary of 5GTT programme delivery

	Key findings and assessment
The competitions and diversity	The rollout of the programme remained experimental throughout. Each of the competitions targeted a slightly different group of potential applicants and the programme managed to secure diversity in types of stakeholders involved and use cases
Marketing and implementation	The calls were designed to meet sectoral demand and diversify the portfolio. Response rate was good in most cases, allowing DCMS to select a diverse range of projects. The application process was considered effective by a majority of applicants and DCMS officials
Application	There were few negative remarks on the application process. Some found that application windows were sometimes narrow
Project initiation	Signing and setting up grant funding agreements led to delays for several projects.
Project teams working together	Most interviewees were positive about how the consortiums worked together
Financials and management	The programme underspent against its allocated budget by 30%. As there was a high level of applications and many unfunded projects, there may have been space for DCMS to be less "risk averse" (in Phase 1) and award funding to more projects. The grant claiming process was sometimes slow, which was a particular problem for resource-constrained small firms.
Change requests and extensions	Time and resources were put into processing claim requests as these were tied to payments. The change request process was felt to be applied inconsistently and was sometimes slow.
DCMS Evaluation and Monitoring through the benefits realisation process	The benefits realisation process was challenging for DCMS to run but worked well when projects were supported by DCMS to identify indicators. 29% of projects said in interviews that they found the process burdensome and/or complicated.
DCMS support and relationships	DCMS project support was effective. The majority of projects saw DCMS as being very helpful in supporting their projects, especially the input from the Technical Design Authorities. Internally, DCMS staff thought that they worked well as a team, although there were some reports of a lack of continuity in DCMS staff managing individual projects.

Data and limitations
Most of the evidence in this chapter has been drawn from qualitative interviews with project delivery partners, unsuccessful applicants, DCMS staff and wider stakeholders. A limitation of this approach is that it relies on self-reporting of the effectiveness of processes, challenges faced and reasons for any delays or failures, which are not always completely objective. To mitigate this, we have reviewed process documentation; considered evidence from those involved in designing and delivering processes, and the funding applicants and project delivery partners who need to use and respond to those processes in the field. We have also used data from BRs and programme finance monitoring where available.

On the whole, we find no major areas of disagreement between groups of stakeholders. Because several project beneficiaries are still involved with DCMS any critique provided may be nuanced. Key evidence of programme challenges are evidenced based finance and monitoring data.

The programme underspent, was resource intensive to run, and we find problems with the grant funding agreement and its relationship to financial processes and grant claiming

4.2 Process evaluation: effectiveness, efficiency, and improvements to delivery

4.2.1 Overview of the competitions

There were six competitions. The competitions and successful projects are set out in the table below. The competitions were launched within a relatively short timeframe and **the rollout of the programme remained experimental throughout**. Each of the competitions targeted a slightly different group of potential applicants. There were learnings from Phase 1 that informed programme continuity. For example, in learning from Phase 1, some other competitions were more oriented to work with smaller organisations.

Table 9: Competitions and successful projects[32]

Competition	Duration of application window	Competition dates	Number of funded projects	Funded projects
Phase 1	8 weeks	23 October-13 December 2017	6	5GRIT; AutoAir; Liverpool 5G; Rural First; Smart Tourism; Worcestershire 5G
Urban Connected Communities (UCC)	5 weeks	8 May – 12 June 2018	6	WM5G (Applications Accelerator; Infrastructure Accelerator; Healthcare; Manufacturing; Transport Use Cases and Transport Road Sensors)
Industrial	12 weeks	18 July – 10 October 2019	2*	5GEM; 5G Encode
Rural Connected Communities (RCC)	8 weeks	27 August – 25 October 2019	7	Connected Forest; MANY; MONeH; New Thinking; Rural Dorset; Wales Unlocked; West Mercia
Create 1	4 weeks	6 April – 1 June 2020	6	5G CAL; 5G Edge XR; 5G Festival; 5G Factory of the Future (FoF); Liverpool 5G Create; Smart Junctions 5G
Create 2	12 weeks	6 April – 27 July 2020	9	5G AMC2; Connected Cowes; Eden Universe; Green Planet 5G; Live and Wild; 5G Logistics; MK:5G; 5G Ports; VISTA

**Excluding work of the Digital Catapult*

The **Phase 1** competition aimed to fund projects in a diverse range of sectors and the selected projects covered manufacturing; tourism; healthcare and deploying 5G in rural areas. Projects were offered between £2m and £5m

[32] This does not include the three university test networks or the international project (5GRN) or UK5G.

funding for these projects.[33] There was a call for views from local authorities and industry about how to develop and target the programme and results of this came in during the assessment phase.

The first full business case identified the need to create a smart city testbed, operating across verticals to solve public sector challenges and views from local authorities and industry supported this. Based on that, around £24 million was allocated for **Urban Connected Communities Competition (UCC)**. DCMS specifically wanted a place-led proposal for a smart city testbed of significant scale, so they set a requirement for areas with a minimum population of 500,000, to promote working across local authority areas. Unlike the other competitions, the applicants for UCC did not need to have a fully formed delivery consortium in place as they would develop and select projects for themselves.[34] Applications received were mostly from Combined Authorities (groups of local authorities who already work together). DCMS selected West Midlands Combined Authority as the successful bid. WMCA then set up WM5G to run the different UCC projects. The available budget was not made clear to bidders. The original ambition was to spend £50 million on this but this was reduced later in the competition process by the DCMS Senior Responsible Officer. This may have limited the scope of what was possible, but the decision was primarily taken to reduce risk of spending a quarter of the total 5GTT programme budget on one project. The decision not to proceed with the Trans-Pennine Initiative influenced this decision as well as changes to the timetable of the project moving it across financial years.[35]

The **Industrial Competition** was aimed at private sector led consortiums (including at least one SME) to explore industrial use cases around manufacturing and logistics. The Competition aimed to provide £3m-£4m for 4 to 6 manufacturing projects and £5-10 million for 2 to 3 logistics projects.[36] Digital Catapult were appointed to work across projects to help with sector development for this competition. DCMS aimed to co-ordinate this competition with the BEIS Made Smarter Competition but this was delayed, which led to some delays in launching this competition.

The competition for **Rural Connected Communities** (RCC) expected projects to trial innovative use cases to build the business case for investment in rural communities, and explore and demonstrate benefits of 5G in a rural setting. DCMS set up a collaboration platform and held a Competition Briefing Event in September 2019 to provide further guidance about the type of projects they wanted to fund. This competition aimed to provide £2m-£5m funding each around 10 projects.[37]

There were two waves of **Create** competitions, which aimed to attract more applications from areas where there had not been much interest previously (Creative, Media, Tourism and Events). Given low levels of interest in the Industrial competitions (only four applications were received leading to two funded projects), this Competition also funded some industrial projects. The lower limit of funding for the Create competition was lower and projects could apply for between £250,000 and £5 million of funding.[38] These competitions were launched at the same time. Create 1 was given an 8 week application window and was for more delivery projects who were able to get going sooner. The application window for Create 2 was 16 weeks. This was for projects that needed more work to develop a consortium and submit proposals.

4.2.2 Diversity of consortiums and use cases

5GTT involved stakeholders from the private sector, the public sector and from academia. In total 34 interviewees out of 79, (43%) including DCMS staff, project participants unfunded projects and wider ecosystem stakeholders thought the programme had been **successful in targeting the development of a diverse range of use cases**.

The programme was successful in **funding organisations operating in a range of sectors**. Table 10 summarises the projects by sector.

While the RCC and UCC projects were more targeted on deploying networks in challenging environments, some of the projects included use cases about specific sectors. For example, West Mercia, had a focus on health, Wales Unlocked and Connected Forest had use cases to support tourism at heritage properties. Similarly, some of the

[33] Phase 1 Competition Guidance
[34] Urban Connected Communities Competition Guidance
[35] ICF "WM5G Project and UCC Programme: Fact finding study", 23 April 2021
[36] Industrial Competition Guidance
[37] RCC Competition Guidance
[38] Create Competition Guidance

Create projects fit into more than one box; Eden tested their AR use cases in care homes, Connected Cowes was mostly around developing a live viewing experience for the Cowes Week Regatta but also developed an education use case. Representatives from six projects said they had aimed to deploy open RAN technologies.

24 of the 37 projects were business led, of which 17 were led by SMEs (turnover less than £50 million and FTE less than 250) and 7 were led by large businesses (Turnover greater than £50 million and FTE greater than 250).

Table 10: Number of projects by competition and sector use cases[39]

	Phase 1	Industrial	UCC	RCC	Create	Total
Network Deployment	5GRIT; Rural First; (University Test Networks)		WM5G Applications & Infrastructure Accelerators	All (7)		16
Agriculture	5GRIT; Rural First			Wales Unlocked; MONeH, Rural Dorset		5
Industry		5GEM Encode				2
Manufacturing and Construction	Worcestershire 5G		WM5G Manufacturing		AMC2 FoF	4
Creative, Media, Sports and Tourism	Smart Tourism			Connected Forest; Wales Unlocked; Rural Dorset; MANY	Edge-XR; 5G Festival; Connected Cowes; Eden Universe; Green Planet; Live & Wild, VISTA	12
Transport and Logistics	AutoAir		WM5G Transport Use Cases		Smart Junctions; 5G Logistics; 5G Ports; MK5G; 5G CAL	7
Health, Social Care & Public Services	Liverpool 5G		WM5G Health	West Mercia 5G; New Thinking; MANY; Rural Dorset	Liverpool 5G Create; Eden Universe	8

4.2.3 Competitions – design, marketing, and implementation

Applicants and DCMS officials thought the competition was overall efficient and effective in getting the right number and type of applications. Competitions and guidance were published on gov.uk and UK5G[40] and set out the full process of the competition for applicants including the scoring criteria and weighting for each selection question. Interest in the programme grew over time and the Create 2 competition received nearly five times as many applications as Create 1. A summary of overall application scoring is provided below.

[39] Projects have multiple use cases and some use cases carried over into multiple sectors, especially on the Rural Projects

[40] E.g. 5G Create Application Guidance

Table 11: Applications and scoring, 5GTT programme competitions

Competition	Target number of projects	Total applications received	Successfully funded projects	% funded
Phase 1	No target	21	6	28.57%
UCC	1	18	1	6.25%
RCC	10	12	7	58.33%
Industrial	6 to 9	4	2	50.00%
Create 1	No target	13	6	46.15%
Create 2	No target	63	9	14.29%

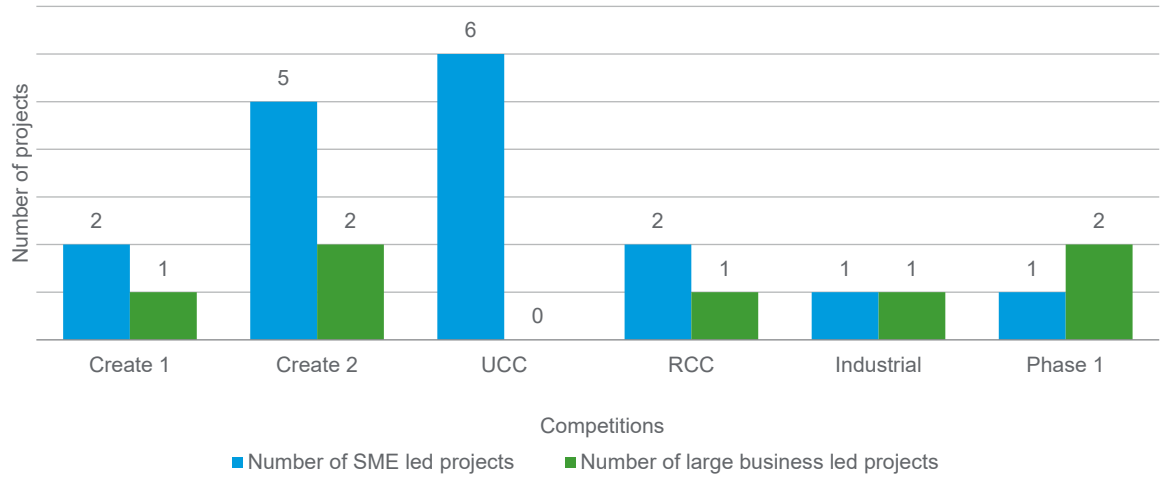
The Industrial Competition received four bids and two were funded (5GEM and Encode). While £30 million was set aside for these projects, only £6m was spent. As stated above, DCMS worked with Digital Catapult on this competition[41].

The RCC competition also received a low number of applications for the number of projects the 5GTT programme sought to fund. In total there were 12 applications received and only 7 selected.

There were nearly five times as many applications for Create 2 than there were for Create 1, though the difference in minimum scores for these two competitions is quite small (3%). The ratio of funded projects to applications received is between 1:2 and 1:4 for all competitions except Create 2, where it was 1:7. Given the budget shortfall this could have been an opportunity to fund additional projects.

Some of the applications were better set up and more familiar with the process of seeking funding from government, so there was a lot of variation in the quality of the bids submitted. For example, larger private sector organisations and academia generally were generally familiar with Innovate/UKRI grant processes. Smaller organisations had less experience of this. However, as shown in the figure below, consortiums were led by both SMEs and large businesses.

Figure 2: Make-up of business led project leads



Source: Project BRs and RSM analysis of data from Orbis

[41] Digital Catapult were already involved in BEIS Made Smarter and DCMS wanted to co-ordinate 5GTT activities with this programme, and it was an area where there was little experience in the 5GTT programme team. A grant was agreed with Digital Catapult in January 2019 to undertake a feasibility study to identify if and what a competition in this area would add value to the programme; and to support ecosystem building during the delivery of projects. Digital Catapult engaged with around 75 organisations, mostly in the private sector. The Feasibility Study noted that there should be ample demand for this type of competition, and that they would benefit from close working with the Made Smarter initiative to raise the profile of 5G in manufacturing.

DCMS ran two rounds of the 5G Create competitions. These were open to applications from all different sectors (see Table 9), but the competition did target creative sectors and applications were made from organisations in media, events and leisure but also construction and logistics. DCMS used both direct approaches and pre-market engagement to attract interest. This combined strategy will have helped increase response rates to calls.

In total 49 interviewees[42] provided information about how they found out about the programme and about half of these had been approached by other interested parties looking to build a consortium. A small number (4 interviewees) were generally aware of the 5GTT programme through their work.

The number of successful applicants that heard of the programme through open events, mailing lists of funding opportunities and platforms such as networking events is relatively small, but such efforts would have helped reach a broader target group. Funding lists and events may have been proportionately helpful in marketing the programme to smaller organisations that are sometimes less familiar with the process of applying for government funding and need more support and guidance on the application process.

Strathclyde University, AQL and the Digital Catapult helped spread information about the programme. Organisations such as Make UK, Tech UK, the Knowledge Transfer Network and other catapults could also have helped broaden the reach.

Table 12: How participants found out about the 5GTT programme

	Approached by Govt	Event	Funding opportunity list	Generally aware through work	Approached by other consortium members	Total
Funded projects (covering 21 projects)	5	4	5	3	17	34
Wider Ecosystem/ Involved in more than one project	3	0	1	1	3	8
Unfunded	1	1	1	0	4	7
Total	9	5	7	4	24	49

Source: Interviews with project participants

Funding lists and events were helpful in marketing the programme, especially for smaller organisations. These may also be less familiar with the process of applying for government funding and need more support and guidance on the application process to ensure a good range of quality applications from this group.

4.2.4 Competitions – application processes

DCMS run a two-stage application process including a written application and an interview stage:

- Table 9 shows the time window for the written application only. We have no information on the overall length of the application process, but stakeholders interviewed have not commented negatively on the duration.
- DCMS staff was responsible for project selection. Similarly, we received no negative comments on the assessment/scoring process overall.
- Five applicants commented on the information and guidance materials provided to applicants. Three said they found these helpful and comprehensive. Two unfunded firms thought the materials could have been better. These were both smaller, newer firms who did not have very much experience of applying for funding from DCMS. One of these was successfully awarded funding in a subsequent programme where they had more support from a larger consortium member.

[42] Please note that not all interviewees answered all interview questions. The target sample has been largely consistent the actual samples vary question by question.

In total 35 interviewees (including a mix of funded projects, unfunded applicants and DCMS staff) provided views on the overall effectiveness and efficiency of the application process. Of these, nearly half (17) thought the application process was effective and efficient. Some compared it to other innovation grant applications (e.g. from UKRI or EU Horizons) and thought it was either easier or about the same. Those who reported difficulties highlighted the following:

Table 13: Reasons for difficulty with applications by interviewee type

	Funded projects	Unfunded applicants	DCMS Staff
They were asked for too much detail	5	2	1
Pulling together a lot of information from different sources and presenting it in the required format was challenging	2	1	
Consortium building issues (identifying partners or partner roles within consortiums)	1	3	1
Competition timescales were too short (around 6 weeks)	1	1	

Source: Nvivo analysis

Three DCMS officials involved in the application process provided feedback on it. They thought it generally worked well and allowed them to select the best range of projects possible. One DCMS officer thought that too much detail was asked for and that this could have disincentivised some potential applicants, especially from larger organisations as awards were relatively small by their standards. Applicants who felt they were being asked for too much detail were a mix of smaller and larger organisations.

Unfunded applicants were asked about feedback they received from DCMS and seven interviewees provided information about this. Five said they received brief, written feedback on why their project was unsuccessful. One was only told that their application was ineligible but it was not explained to them why. Overall, these interviewees requested more detailed information on what could be done to improve their applications would have been welcome. DCMS officials reported that unsuccessful applicants had the right to request feedback and that this was often given to them over the phone to the main contact for the application – the interviewees we spoke to may not have been aware of this or may have forgotten about it by the time they were interviewed.

DCMS and applicant interviewees were asked about the application process. In total 10 had suggestions for how it could be improved:

- One DCMS interviewee thought the use of a bid management portal would have helped in terms of managing the mailbox for applications and having an audit trail on the bid management process. Another officer said this was considered but rejected.
- Three DCMS interviewees said they were not sure if the interview phase of the application process worked and they would consider dropping this in future competitions. They felt it was fairer and marking was more consistent with written applications. Other DCMS staff thought the interview made the selection fairer as some organisations were able to employ a good bid writer and the bid assessors wanted to ensure organisations were able to deliver what they were proposing. At least one applicant (from an overseas firm in a successfully funded consortium) appreciated the interview stage as an opportunity for a conversation. The initial study for the UCC highlighted that the two leading proposals had the same score prior to interviews and the interview stage was useful to help differentiate the strengths and weaknesses of these bids. Overall, the average difference in the pre and post interview scores varied significantly across different competitions, ranging from 0.5 (Create 2) to 16.3 (UCC).
- Two interviewees (one non-lead interview in a funded project consortium and one non-funded project) said it would have been more helpful to split the work into a short listing phase to at least check eligibility and to then have a second phase with more guidance on that stage of the application process. Overall DCMS report very few applications were rejected on eligibility grounds.

- One interviewee who had mentioned timing as a difficulty suggested making application windows longer and not announcing competitions at certain times of year, e.g. August when people are more likely to be away on holiday. Application windows had varied from 4 to 12 weeks and DCMS staff concurred that short windows can result in fewer or lower quality bids.

4.2.5 Setting up projects

The consortiums and DCMS signed Grant Funding Agreements (GFA) for each successful project following the announcement of successful applications. **Signing and setting up grant funding agreements led to delays for several projects.**

The template GFA was published at the application stage as part of the guidance materials. In the Create 2 competition applicants were told to review the GFA in advance of bidding and not apply if they did not agree to the terms set out. This was because some successful applicants in the previous competitions had challenged the GFA after being awarded funding leading to delays. Some delays in signing and agreeing GFAs were quite substantial - up to five months. As work could not begin until GFAs were signed, this led to overall project delays.

"It's a complicated process… but you have to get a [grant] right, but it was cutting into dedicated project time. [Project delivery partners] are assuming from day one they can start working on their project, not that they have to throw resources at setting up the contract for three months…There must be ways of making that more efficient." (DCMS Staff)

Three project interviewees reported some delays from sorting out IP arrangements within their consortium. These were representatives of smaller companies in consortiums with very large multinational companies with a lot of legal representatives. DCMS staff also noted many of the legal challenges they faced were from larger organisations with big legal departments.

A particular area of conflict around GFAs was the inclusion of cash profile forecasts and linked payment to milestones. This was a source of frustration for both projects and DCMS:

"The grants are paid in arrears on deliverables, that is why we make them set out what they set out to achieve by a certain point. They prove they have achieved that and we pay them. To some extent that's all we've got in terms of power over them is the ability to withhold payment until they do what they said they were going to do. Obviously, it's not intended to get into something as confrontational as that. If they start off with this understanding it gets stuff off in the right way." (DCMS Staff)

"Cash flow profiles are quite challenging mainly because of the government processes behind the scenes. So challenging that even the column width for example is locked down so you cannot see the values. Innovate UK seem to have this process in place" (Funded project)

Stakeholders also experienced other issues with the GFAs and, some evidence suggests that **DCMS may not have been always resourceful in identifying solutions to issues with terms and conditions that** were problematic to applicants.

One of the funded project interviewees commented that DCMS did not have a history of running innovation grants and the way the projects were set up with milestones and deliverables was more appropriate for public sector procurement processes than innovation projects, where more freedom was needed.

A senior DCMS officer explained that the GFA had been designed with the aim of 'having some levers and control over the project' but that the process perhaps ended up being too rigid. They had tried to change the process, but there were still some changes needed:

"We've eased off a lot from learnings and put less pressure on the recipients of money to define too early what they are going to do with the money. Having a more rolling approach to setting up projects has helped to make the GFA process less onerous."

Some suggested improvements by DCMS staff and applicants for the set-up phase of the programme are set out below.

- DCMS are keen to avoid too many legal discussions at the set-up stage and should consider approaches to communicate clearly to applicants around how much they are willing to negotiate on these. DCMS staff

suggested that being up front about offering limited scope for discussion, e.g. a single round of markup which the project could either accept, reject or counter, would help in the set-up phase. The Create 2 competition instructed consortiums to look at the grant agreement before applying and not enter into an agreement if they did not like it, and staff thought this was a good idea.

- Having more experienced DCMS project managers involved at the GFA stage. A number of DCMS interviewees highlighted that some of their staff were relatively new to the team or the DCMS project management brief at the start of the programme, as a result of which some projects did not begin as quickly as they might have.
- Re-designing processes by either approaching the Cabinet Office Grants Management Function Centre of Excellence to see if they had some templates or frameworks for setting up projects (contracts, IP agreements etc) that could be provided to projects at the start of the programme, or looking at Innovate UK grant agreements to see how they managed innovation projects. These learnings could be channelled into a better setting up and monitoring approach. The above comment about the fixed column widths in the cash profile sheet is thought to be an oversight – this suggests there may also be some need to QA the usability of some of the forms used to capture project information to ensure they work as planned.
- Greater engagement with potential projects as part of project design could help to better understand the problems associated with the structure of disbursements and the nature of progress on these projects.

4.2.6 Project teams working together

On average consortiums had 9 members, but this varied by competition:

Table 14: Consortium size by competition

Competition*	Average Number of Consortium Members	Range of consortium members
Phase 1	15	9-30
RCC	8	5-18
Industrial	8	8
Create	7	3-13

Source: Benefit Realisation Sheets
**WM5G projects not included because of inconsistencies in BR sheet presentation*

There was a wide range of consortium sizes and overall projects felt they had the right size and mix of members to deliver project outputs.

Around two thirds of the interviewees were positive about how the consortiums worked together. DCMS also remarked how the projects worked well together and how this was one of the large successes of the programme as they helped to bring people together who otherwise might not have, stimulating innovation across numerous sectors and industries. One interviewee noted that at the end of the project the consortium effectively operated as just one organisation showing the synergy which was generated as a result of the programme.

- One smaller consortium noted how they had very effective communication and collaboration and that the size of the consortium contributed to this.
- Larger projects also had positive comments about how the number of organisations involved meant that learnings could be shared across those involved. Whilst large projects overall worked well, there were some comments about how having a significant number of organisations could create inefficiencies. We have not found evidence that inefficiencies impeded projects.

Some interviewees spoke positively about how the consortium helped to share expertise especially around technical elements where firms might have had less knowledge in these areas. While most projects were successful some took a while to get familiar with different ways of working with each other. Even where

disagreements inevitably occurred, interviewees noted that these were dealt with in a dynamic and responsive manner.

As mentioned in the previous chapter, there were some disagreements between network installers and equipment suppliers, but the latter were not typically consortium members. Subsequent programmes did directly fund more suppliers and this may help future collaboration.

The majority of the projects noted that their consortium members remained consistent during the project duration. Factors which caused changes in some cases included the directive to not have Huawei as a named supplier. Covid also meant that some consortium members effectively withdrew (e.g. Center Parcs in Connected Forest). One interviewee indicated that due to a major restructuring of their organisation Research and Development plans were scrapped with the planned consortium member having to pull out at the beginning of the project. Changes usually happened in the early stages of projects, – meaning that there were not significant impacts on project planning.

4.2.7 Financial processes and overall management

The previous chapter provides commentary on the budget and expenditure for the 5GTT programme over time. As well as the six competitions, the programme funded the three University Test Networks, UK5G Innovation Network and other projects such as the Trans-Pennine rail project and 5G Rail Next (5GRN) project with Korea.

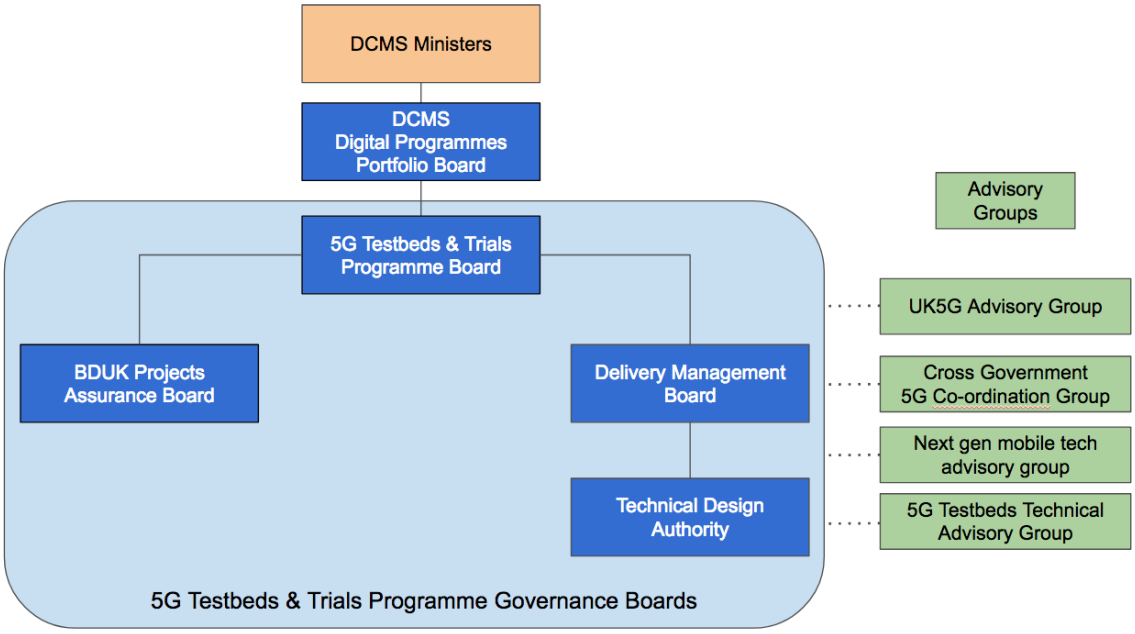
The overall programme budget was £199m. The programme's total expenditure was £140.1m, so there was an underspend of 30%. DCMS reported that there were challenges with Treasury making a timely commitment to the 2021/2022 which may have influenced rollout of the programme in that year. DCMS also said there were restrictions to move budget between financial years. Most applications requested smaller amounts of funding than DCMS had expected. Delays in some competitions being launched, the technological readiness especially earlier in the project and external barriers (specifically COVID) also had an impact on budgeting.

The sequencing of competitions and competition design could also have impacted the underspend. DCMS running costs were £18.9m[43]. DCMS estimate around 60 people worked in their team over the course of the project, which started in 2017/18 and most projects[44] finished in 2022. This included the Technical Design Authorities (TDA), project managers; portfolio managers; finance; and benefits realisation teams.

Two project interviewees thought DCMS had assigned higher priority to monitoring than supporting their project (these were both from Phase 1 projects). This was a reflection of their expectations of how innovation funders typically behave. These were both interviewees with previous experience of UKRI funding. Another representative from DCMS reported that the project manager and TDA ratio is much higher than in UKRI or Innovate UK funded projects. This ratio may have been even larger for Phase 1 projects which had additional staff supporting main project managers.

[43] Chapter 7 on value for money presents some comparisons with other programmes.
[44] Factory of the Future was the last project to close and finished mid-March 2023

Figure 3: 5GTT governance arrangements



Source: 5GTT Programme Business Case update v3.0

There were instances where project leads and DCMS staff thought the overall process for paying claims to projects was slow. Seven interviews highlighted this as particularly challenging for smaller firms involved in consortiums. Three other project interviews said that financial processes were quite cumbersome to manage. DCMS staff also report projects were sometimes slow to submit claims and change requests, or provide information when it was requested and this also contributed to delays in payment. DCMS are not able to provide details of how long payments took to process or how long it took for change requests to be actioned, but are aware these could be improved and the processing times need better tracking.

4.2.8 Change requests and extensions

With the exception of the Trans Pennine train project, all funded 5GTT projects completed successfully. It was noted that this project to install a 5G network for this train route was not going to deliver a good return on investment.

However, all projects put in change requests, and many were re-scoped through change requests. For example, some of the use cases were re-scoped because of the readiness of some of the technologies used. Live and Wild wanted to test a mobile 5G mast in a range of challenging locations for film making and had identified a range of events to run their tests at. Some of these were cancelled due to COVID, so the trials were rescheduled for a later date, in some cases at other events.

Senior DCMS officials also thought some projects needed re-scoping as the applications were overly optimistic about what they could achieve. This caused some delays at the set up stage, and with grant drawdown during projects, as the incremental funding was contingent on meeting milestones set out in the GFAs. This also led to a lot of change requests – too many in the view of some interviewees:

"There were a lot of deliverables attached to each milestone…This created challenges from a paperwork perspective. The change requests also presented challenges. It meant there were no guarantees and that you ended up working towards a target which could very likely shift."

Overall it seems to us that **substantial time and resources was put into making the changes requests and DCMS staff processing these**. One of the DCMS interviewees said that there was a conflict between allowing projects to be flexible to change scope so that they could innovate and explore new avenues, and maintaining control over what the projects were supposed to produce.

DCMS commented that the DCMS PMO may have been under resourced and should have been able to centrally track progress. This responsibility had been allocated to the finance team.

The table below summarises DCMS funding for projects, extensions and numbers of change requests.

Table 15: Project funding, Extensions and Change Requests

Project	Competition	Total DCMS funding awarded	Extension granted?	Length of Extension (months)	Number of Change Requests
5GRIT	Phase 1	£2,700,887	✓	6	6
5G Rural First	Phase 1	£5,212,367	×	0	4
AutoAir	Phase 1	£5,549,237	×	12	2
Smart Tourism	Phase 1	£5,167,305	×	0	5
Worcestershire 5G	Phase 1	£5,575,513	✓	No info	2
Liverpool 5G	Phase 1	£3,669,242	✓	11	14
5GRN	n/a	£1,132,000	×	0	4
Connected Forest	RCC	£4,460,573	×	0	4
5G CAL	Create 1	£4,848,709	✓	3	6
5G Wales Unlocked	RCC	£2,956,312	×	0	6
Live & Wild	Create 2	£1,224,833	×	0	6
MK:5G	Create 2	£4,700,000	×	0	6
West Mercia Rural 5G	RCC	£2,748,061	✓	3	6
5G Festival	Create 1	£2,187,712	×	0	7
5G New Thinking	RCC	£5,000,000	×*	0	7
5G Edge-XR	Create 1	£2,558,000	×	0	8
5G Logistics	Create 2	£4,267,906	✓	3	8
Connected Cowes	Create 2	£1,654,092	×	0	9
5GEM	Industrial	£2,026,032	×	0	10
Green Planet	Create 2	£2,232,953	✓	3	10
Liverpool 5G Create	Create 1	£4,302,596	✓	6	10**
MONeH	RCC	£3,350,000	✓	0	10
5G FoF	Create 1	£4,793,162	✓	7	11
5G AMC2	Create 2	£844,740	✓	6	11
5G Encode	Industrial	£4,002,291	✓	0	12
Eden Universe	Create 2	£3,321,334	×	0	12
MANY	RCC	£4,431,677	✓	3	12
Smart Junctions	Create 1	£1,160,783	✓	4	13

VISTA	Create 2	£2,047,594	×	0	15
5G Ports	Create 2	£3,405,777	✓	0	16
5G Rural Dorset	RCC	£4,581,196	✓	3[45]	23
WM5G	UCC	Approx. £21.5m	✓		55***
Total			**✓=17**		**330**

*Source: BR sheets, information about change requests provided by DCMS, February 2023*Interviewees viewed the entire New Thinking project as an extension of the Phase 1 Rural First project.*
***included one change request with four parts.*
****summarises all change requests across six projects, on average this means there were around 10 change requests per project.*

There were nearly 300 change requests across all Phase 2 projects, with Rural Dorset having the most (WM5G change requests are presented in aggregate across six projects). It also meant projects often had to submit multiple change requests when the overall scope of projects substantially changed.

Project representatives (5) also found that they submitted a lot of change requests. Respondents found that the change request process could be improved. The main difficulties with this were:

- It was overall a very cumbersome process for which projects had to provide a lot of detail and DCMS were seen as being too rigid about the format they wanted information provided in (eight interviews);
- The change request process is the same for moving a delivery date into the next quarter and significantly re-scoping milestones (three interviewees). More flexibility/proportionality is needed for small versus larger requests;
- Processing change requests took too long (five interviews) which was especially frustrating for smaller companies. Interviewees reported they could take up to six weeks to action and on average took around 3 to 4 weeks; and
- DCMS officials were not always clear and consistent about when a change request was required and who needed to be involved to agree it (three interviews)

As shown in the table, funding for projects was extended in some cases, typically for three to six months. The reasons for this were typically related to delays due to COVID and delays to the supply of radio equipment for setting up networks. Extensions generally did not have implications on the overall budgets.

Change requests and grant claims
Change requests were assessed by DCMS staff. There is a link between the Grant Funding Agreement process and the financial process for claiming grant funding during projects: the milestones set out in the GFA are used to trigger grant payments, and project participants need to provide evidence that the milestones have been hit. This was built in as DCMS wanted to ensure that public money was being spent responsibly, however senior Department staff did acknowledge that **relying on the original project plan caused problems if a project needed to change course or was disrupted by an external event**. This link seems to have caused difficulties because of the need for many change requests. The 5GTT projects will have embedded an element of risk because these were set out to be ambitious. The 5GTT projects will have embedded an element of risk because these were set out to be ambitious. At least two DCMS officials commented that maybe a higher failure rate should have been expected for innovation projects.

"Projects have to evidence use cases and we have to agree it... If GFA cash flow profile assumptions are off, the entire project plan is off, which means you're forever in change control. You're being reactive rather than proactive... If things like Covid and regulation change come up you could be more proactive in handling it than being on the back foot" (DCMS interview)

"At the start of our project we had to set out a number of benefits from our use cases. We can't get some of the use cases to work and DCMS are saying 'because you haven't made this work you need to do a change request to

[45] One use case was extended for 6 months

change the scope of the project' which isn't great. We trialled 5G for this process, it didn't work – that's a useful outcome." (Project interview)

4.2.9 Benefits realisation

"Benefits realisation (BR) is the practice of ensuring that benefits are derived from outputs and outcomes"[46]. It is used by DCMS and other government departments to oversee how time and resources are invested. Projects were required to provide information about the benefits realised through their use cases and deployment.

Data was collected on investment, Technology Readiness Levels, test bed and use case activities and outcomes, knowledge dissemination activity, and lessons learned, and all of these areas seem relevant to us to monitor (and data has been summarised in this report). The BR template includes a combination of more open questions (for example for the knowledge dissemination section) and more structured format (for example around use case monitoring). Projects differ in determining their unit of reporting, with some providing a very detailed breakdown of testbeds and use cases, and other providing a high-level summary. Projects were also asked to self-define targets against metrics, with some having provided a rather long list. By self-defining the targets, progress monitoring is bespoke but not benchmarked, making it difficult to interpret the data provided. Our view is that the granularity of reporting could be revisited to minimise burden and help arrive at greater consistency in the approach to reporting. This could help minimise gaps in future reporting.

Overall, while projects mostly understood the value of the BR process and lessons learned, many of them did not find it easy. Overall about 10 out of 37 had positive comments about the BR process. The template for providing BR information was re-designed for later projects and DCMS staff interviewed thought this was positive but further improvements were still needed to streamline this.

"It helped us to stay focused on deliverables and not go too far off on other things"

"The BR document was not the easiest one to complete but we found it was very useful helpful for us to also keep a track of where the project goes…if you want to find a way to map out and explain how a project and its results can be exploited and what kind of benefit you're going to have, you need to have a measurable way to describe it…It's always very difficult to try and make sense of this. But it's absolutely necessary to try and make sense."

"Working with DCMS colleagues, they were very helpful, encouraging, supportive and complimentary. If we were not delivering they were straightforward enough to say and on the other hand if we were delivering they were quick to congratulate and appreciate."

(Funded projects)

Other projects reported that they found it burdensome (nine projects), complicated (three projects) and saw it as a box ticking exercise rather than a process that added value (four projects).

Projects and DCMS staff suggested the main issues and areas for improvement were

- Some projects said that the BR process was something that was introduced as an expected output part way through the project rather than something they would be expected to do at the start, or built into the GFA. Six DCMS interviews acknowledged this was a problem, particularly in earlier projects. Five projects highlighted this as a problem, including three Phase 1 projects. DCMS reported this had improved in later competitions, but other projects who said the BR process was not explained well at the start were from Create competitions, which suggests some further work is required to ensure this consistently explained at the beginning of projects.
- Six projects said the template for providing the information could be improved. A lot of information was requested in a spreadsheet with locked formatting which worked well for monitoring numerical data but less so for more narrative information. DCMS say they experimented with receiving data in a more narrative format as part of one of the Phase 1 projects, but this approach did not adequately capture the data they were interested in. As noted above, DCMS staff reported the BR monitoring spreadsheets had improved for subsequent competitions. Mostly this involved slimming down the BR reporting spreadsheets and making them easier to edit.

[46] https://www.apm.org.uk/resources/what-is-project-management/what-is-benefits-management-and-project-success/

A main challenge was disagreement between projects and DCMS over what to measure, and this was complicated by the diversity in projects. Projects **struggled to identify suitable baseline indicators** to measure improvement against and indicators that could be accurately measured with the project lifetime. Project participants reported that DCMS were interested in quantitative, monetiseable benefits. The technological readiness of the equipment being tested also made this hard. This is a difficult area to overcome considering the scope of the projects.

While projects mostly understood the value of the BR process and lessons learned, many of them did not find it easy. The template for providing BR information has been re-designed for later projects and DCMS staff interviewed thought this was positive but further improvements were still needed to streamline this.

4.2.10 DCMS support and relationships

The majority of projects (23 out of 37) were very positive about the level of support they received from DCMS:

"They have been amazing. The project had so many issues but we always felt supported. I have personally never been with a funding body that I thought were on my side. Most look to catch you out and get their money back but DCMS's focus was on how to get the project going."

"Brilliant, our main project manager and technical consultant were really supportive. They wanted the project to succeed so didn't put barriers in the way."

Participants especially valued the input from the Technical Design Authorities (TDAs), and overall had good relationships with other DCMS staff.

Resourcing

The main area for improvement around DCMS staff was around consistency. Some projects had a lot of turnover of DCMS project managers. One project reported they had 5 project managers for an 18 month project. Information handover did not always work well when there was a change in personnel.

Senior DCMS staff also noted key challenges around resourcing. As noted above there was a lot of turnover. It was difficult to find and keep good people with the right level and mix of skills:

"Stability is important. When you're changing TDA's or BR leads, that has an effect. One project had three project managers in a year, when I came on board they were hoping I could stay, they don't like constant changing PMs. When we go on leave it is very difficult to put another project manager on as cover. It's very tough in workload and being able to grasp what is going on."

"We have project management trying to interface with what is usually a very seasoned project manager. A lot of how we work with projects depends on that link. If it is too out of balance they can't strike up the sort of relationship that I would like to see between us and projects"

There was a lot of expertise available in the team, though sometimes DCMS officials indicated it was hard to know who was the right person to talk to. Some responsibilities were also not clear, for example there was some confusion about how many people needed to review things like change requests before they could be signed off.

Internal working

DCMS staff involved in delivering the 5G programme felt they worked well on the whole. Two reported that they could work better with the wider department and promote the programme better internally, especially to policy colleagues. One person felt there was not enough communication between people doing different roles both within the delivery team and more widely. This was at least in part due to more remote working in response to COVID, which requires more effort to communicate. There were also some internal challenges at times – in particular between the benefits monitoring side and delivery. One officer described the relationship with the TDAs as a "critical friend", able to provide useful information on the technical aspects of the project, but also that they might be a bit too close to some projects.

Ideas for improving internal working included:

- Selling the programme better within the wider Department, in order to work better with policy colleagues and have a better flow of information and knowledge within the department so that people are aware of the programme and it is more linked into other work on diversification.

- Streamlining and clarifying some processes e.g. around paying claims to make them happen more quickly (i.e. identifying who needs to sign off what).
- Being better at working remotely and not working in silos, therefore overcoming information and other barriers between team members, as well as improving individual performance of staff when remote working is necessary

5. IMPACT EVALUATION - BENEFITS TO PROGRAMME PARTICIPANTS

5.1 Summary

This chapter presents the immediate outputs of the funded projects, and the benefits to programme participants which arise from these. The key evaluation questions are those from the "bottom-up" impact evaluation workstream: the key findings are set out below, and the rest of the chapter presents the evidence underlying our conclusions. Evidence in this chapter has been drawn from project monitoring information and qualitative interviews with project delivery partners, unsuccessful applicants, DCMS staff and wider stakeholders. We also surveyed successful and unsuccessful project applicant firms and have collected data from a relatively small sample.

How far were the projects able to deliver on what they set out to achieve?
The projects have been successful in delivering: only one funded project (the Trans Pennine train project) was stopped, and all other projects reached closure. Aside from this, projects have deployed networks to test use cases and demonstrated some of the benefits of 5G technologies for businesses, typically around lower latency and higher bandwidth, allowing for quicker data transfer and the connection of a greater range and number of IoT devices. On average, the starting Technology Readiness Level of use cases was 4.2 and the average improvement was 1.7. Overall, this is a strong result, achieved in spite of a range of factors outside the programme's control including the COVID pandemic and technological readiness of kit and supply chain issues.

What have been key benefits to programme participants?

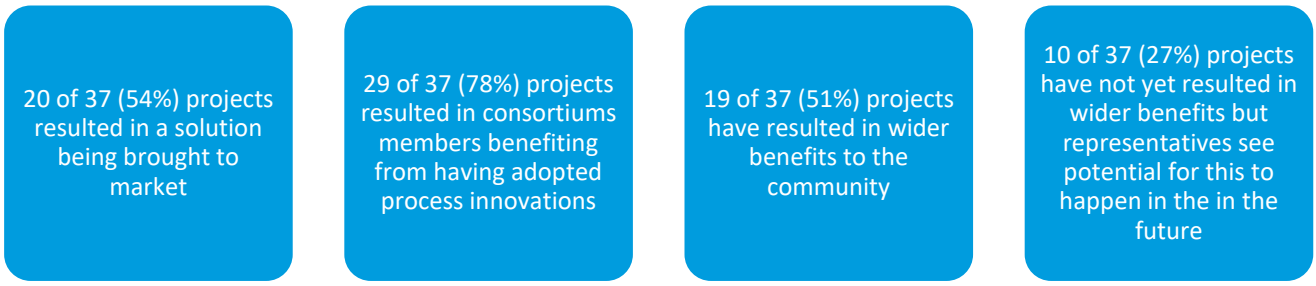
- The programme has resulted in new collaborations across organisations that may not have otherwise been inclined to work together and strengthened previously existing collaborations. The programme resulted in inter-project collaboration and the sharing of learnings across the wider UK5G network. Around two thirds of funded firms had signed up to the UK5G network.
- Private sector project participants spoke positively about benefits of knowledge gains, 5G industry expertise, and applied lessons learned to overcome challenges encountered.
- Projects are known to have deployed 107 networks, of which 70 are known to be still in use.
- Many interviewees having spoken about the creation of new roles and jobs.

Addressing barriers to 5G deployment:

- The programme has been effective in overcoming barriers to 5G deployment.

Was the value of 5G demonstrated through use cases?
The programme has demonstrated the viability of 5G technologies across a wider range of use cases across a range of industries and geographies. The varied use cases and processes developed show that there is potential for 5G to benefit private and public sector developments and urban and rural communities. There were however mixed responses on whether project use cases could have been carried out on previous generation networks. Rural projects, and projects with use cases requiring low latency, reported that 5G was required, and 5G was viewed as an efficiency upgrade to 4G in general. However, some other interviewees believed that use cases could have been developed on 4G. These learnings are also valuable to the wider community.

Projects have resulted in 86 consortium members implementing new processes and/or bringing new solutions to market. These can then improve productivity or efficiency in the wider economy if adopted. Monitoring and interview data also evidence that:



To what extent can we attribute these results to the 5GTT programme?
To a great extent. Almost all the funded participants were clear that the projects they carried out would either not have occurred, or would not have been developed to the same extent, were it not for the 5GTT programme. The importance of 5GTT was confirmed by all the unfunded participants (private sector participants) we spoke to in interviews, many of whom reported that they were not able to carry out their plans to anywhere near the same extent without the funding.

33 of 36 (92%) private sector survey respondents find that in the absence of the 5GTT funding these results would not have been achieved to the same extent or within similar timeframe and evidence from the interviewees supports this[47].

- 16 out of 36 (44%) survey respondents noted that either the activities would not have been implemented
- 17 out of 36 (47%) of respondents noting time to implementation would have been longer

Data and limitations
Response rates from the survey were relatively low and only a proportion of private sector participants were interviewed. Evidence gathered is subject to non-response bias. Self-reported data of barriers to success and reasons for any failings are not always completely objective and thereby the data is also subject to positivity or negativity bias. This is a particular issue with assessment of attribution to 5G, as there may be a bias for recipients of funding to rate it as essential for delivery if they suspect that further funding may be offered. However, the high attributability of benefits was confirmed by the unsuccessful applicants interviewed and by most of the unsuccessful applicants that were surveyed. They reported that their planned R&D would not have gone ahead without the funding. Moreover, the evidence collected from the surveys and interviews corroborates prior evidence that private sector participants have different routes to benefits and impact. The project monitoring information gives a more comprehensive insight into what proportion of projects have delivered impact and where we may expect to see further impact.

5.2 Results of the 5GTT programme projects

5.2.1 Staff involved and new jobs created

The table below summarises estimates of FTE staff in the private and public sectors and the number of university departments involved by project for the 5GTT projects. It indicates that across 37 projects just over 1,300 people were involved from the private sector, i.e., there were around 37 people per project, and around 212 newly recruited people in the private sector worked on 5GTT projects. 101 stakeholders from the public sector were involved and 65 university departments. In total, 23 universities and 15 local authorities were involved (some universities were involved in more than one project/consortium).

Analysis of interviews and benefits realisation monitoring spreadsheets show clear differences in the size of the projects and the number of people involved in these projects. Interviewees noted projects ranged from around 40 people overall to one respondent stating that several hundred were involved in a project over its duration. While a lot of people may have been lightly involved in these projects, for the most part there was a core of around 4-10

[47] Of the 36 funded respondents, only 1 claimed that funding had no impact on the speed or scope of the project. Likewise, only 2 of unfunded projects claimed to have completed their original 5G plans. This implies an additionality rate of between 78% - 97%.

people who were key to the day to day running of the projects. These key members were very active regarding project delivery and were able to adapt to scenarios which were often new for many of the individuals involved.

Table 16: People employed in 5GTT projects

	Private sector staff allocated to project	Private sector staff allocated to project that are newly recruited	Public sector	Private and public sector total	Universities – number of departments involved
5G AMC2	32.5	5	0	32.5	0
5G CAL	38.5	1	2	40.5	2
5G Connected Forest	20	3	1	21	5
5G Edge-XR	24	7	0	24	1
5G Festival	59	3	0	59	0
5G Logistics	33	6.5	7	40	2
5G New Thinking	37.75	8	5.85	43.6	3
5GEM	49	0	0	49	1
5GRN	5	2	0	5	1
Connected Cowes	22	9	0	22	0
Eden Universe	66	24	0	66	0
Encode	29.5	6	0	29.5	4
Factory of the Future	56	3	0	56	2
Green Planet	48	9	23	71	0
Live and Wild	8		0	8	0
Liverpool 5G Create	37	11	13.1	50.1	3
MANY	30	3	6	36	3
MK:5G	46	0	3	49	0
MONeH	5	1	0	5	0
Ports	45	3	0	45	1
Rural Dorset	33	4	5	38	2
Smart Junctions 5G	26	7	0	26	6
VISTA	32	1	0	32	0
Wales Unlocked	10	3	0	10	1
West Mercia	22	1	3.45	25.45	2
WM5G Road Sensors	38		6	44	3
WM5G App Accelerator	12.5	6	0	12.5	0
WM5G Health	22	4	1	23	0
WM5G IA	16	1	0.6	16.6	1

	Private sector staff allocated to project	Private sector staff allocated to project that are newly recruited	Public sector	Private and public sector total	Universities – number of departments involved
WM5G MTC	0	0	0	0	0
WM5G Transport use cases	122	6	0	122	2
5G Rural First	96.95	21.9	4	100.95	11
5G Smart Tourism	121.5	23	13	134.5	2
Worcestershire 5G	13	None reported	None reported	13	None reported
Liverpool 5G Testbed	44.5	14	6	50.5	2
AutoAir	16	None reported	None reported	16	1
5GRIT	48.5	16	1	49.5	4
Total programme estimate	**1365.2**	**212.4**	**101**	**1466.2**	**65**
Average	**37**	**5.7**	**2.7**	**39.6**	**1.8**

Source BR, supplemented by interviews. Note: Grey cells highlight areas where the BR sheet is incomplete or might be counting all personnel involved in the project rather than FTE equivalents.

New jobs created and resourcing

Responses from 30 interviewees suggests that organisations varied in the approach to resourcing.

- About three quarters of the respondents made mentions of how the project led to the creation of new roles. There was variation in the number of new roles created, with some organisations just hiring one or two new people to help with the project but other examples of spectacular employment growth. One interviewee noted that their organisation had grown from 30 to 75 people as a result of the project and that many of the new staff had been hired to work on the programme. What is crucial as well is that these roles lasted after the project completion to help continue the ongoing system development programme.
- Around a quarter of the responses indicated that no new jobs were created for the project and that existing employees were repurposed into different roles to help deliver the project.

The project monitoring information suggests that the smaller firms are committing a larger proportion of their resources to the project they are involved in. Some interviewees noted that at times it did feel as though larger firms within the consortium were not always fully engaged in the project activities to the same degree as the smaller firms. The number of new roles which were created specifically for this project also varied across the firms interviewed. Around 50% of those we interviewed from private sector funded firms, responded that no new individuals were hired to work on the programme but that employees were simply repurposed away from their day jobs to work on the 5G project.

In view of these results, job creation could feature in the Theory of Change. However, we have not looked at possible displacement of new staff and this is something that could be considered as part of the final evaluation.

Staffing issues

Staffing issues were discussed by around 20 project delivery partners, with most noting that whilst there were some staffing challenges, particularly at an early stage of the project, these receded as time progressed. Interviewees did note how the availability of relevant skills was an issue and that there were also tight time pressures for project delivery. One interviewee noted that their firm may have underestimated the amount of support required to manage the network due to their level of complexity and the fact that understanding of this may not have been in place at the inception of the project. The interviewees noted that as many of the use cases were at very early stages of their

conceptual journey, challenges to get the right expertise were present with people often "donning multiple hats" to keep the project running. Even for organisations that did not have an expertise issue, these experienced capacity challenges, in addition to having to maintain the running of their 5G project, comments from participants across 4 projects highlighted that they also had to still carry out their day jobs. As noted at the outset though, these problems did reduce in scale over time as individuals got more knowledgeable around the workings of 5G especially with respect to their specific use cases.

Interviewees were positive about the range of skills covered within their project consortiums. These ranged from key project management functions to the specific expertise required to be able to develop and implement the networks and use cases. This was consistent across different types of projects (e.g. urban/rural, by sector, standalone/non-standalone).

Seven project interviewees specifically spoke about labour requirements for 5G research and development, noting that a variety of skills were needed. Interviewees remarked that the teams compiled were dynamic and had a range of people with different skills from 5G specialists to infrastructure engineers and specific industry experts. One DCMS officer we interviewed was aware of a project that did not have sufficient 5G expertise at the start of the project, but they were able to recruit the people they needed.

Recruitment challenges
31 funded project leads were asked about recruitment challenges but most did not engage with this question. The four that provided a response found that identifying individuals with the correct skills was very difficult. In addition to this difficulty, interviewees noted that they were often trying to attract people from industries where they were well paid. It was often not immediately clear to potential employees that the programme offered an exciting opportunity, and individuals often had to be convinced of this. Eight of the respondents to our question about barriers to deploying 5G in the UK also mentioned skills, especially around hi-tech manufacturing and telecoms (this includes projects, wider ecosystem members and DCMS staff).

Where project staff are currently working (if they have moved)
We asked interviewees if they knew where their former colleagues and project contributors had moved on to and only six were able to provide information. We were told that some staff had moved onto new roles within the (wider) organisation and other employees had moved into new roles that had been created within the consortium.

The low response could be indicative of a lack of staff turnover, lack of knowledge on former staffs' career developments, as well as wariness to disclose information.

5.2.2 Increased collaboration

Collaboration within consortiums
One of the main successes of the programme was how it encouraged collaboration across organisations that may not have otherwise been inclined to work together. Consortium members were positive about how DCMS helped to facilitate this support and how varied these members were. The interviewees noted overall that their consortium had a good blend of various types of organisations.

Across 20 interviews with funded project leads, there was acknowledgement that the programme helped promote collaboration across the ecosystem more widely through the creation of consortiums to carry out projects.

Efforts to promote programme collaboration meant that a small number of participants felt forced to engage but the majority noted that they would never have participated so fully or had the links they do now were it not for the programme.

> AQL (a network vendor) worked on five projects in a range of different sectors including broadcast media, manufacturing and rural connectivity. By collaborating in these different consortiums, they benefited from working with people with sector specific skills and were able to learn about sector/environment specific challenges for 5G. They would not have been able to set up these specific testbeds working alone.

Finding new consortium partners through 5GTT
One of the key success stories of the programme was in how it helped identify new collaboration opportunities. A majority of the interviewees were very positive about how the programme succeeded in a number of areas from

opening up connections across industry, to introducing them to new innovative ways of working. In many cases, respondents noted that the project helped them to enter industries that they would not have ever thought they could operate in previously. The project along with networking groups like UK5G helped to bring these interested parties together.

All the consortium members were working with organisations that they had not worked with previously. Thereby, the programme has helped to bring together organisations in new working dynamics. The baseline evaluation had identified issues around forming collaboration agreements, but these have not been mentioned again.

Most consortiums included some members who had worked together previously. Interviewees commented that these prior personal relationships were useful within the 5G projects. Where consortium members had worked together previously their project had given them a chance to strengthen existing relationships. Some examples of how relationships were strengthened were provided:

- Four respondents said this helped to deepen professional ties and establish trust
- Three respondents from smaller firms said that partnering with large international firms helped them to expand their profile

Plans for future collaboration with consortium partners
36 of the 51 funded project interviewees said that they had some plans for future collaboration after the programme with only a very small minority stating they had no plans at all. Many reported having plans to develop continuations of their 5G applications, or having undertaken steps to carry this out. Members within these project groups have put together a range of events and have regular communications to further their professional relationships. Interviewees said that these relationships would not have been in place had it not been for the creation of the 5G programme. Even amongst interviewees who remarked they had no plans for future collaboration, there were still comments that though efforts to continue the project use cases may have stalled, they were still in communication with their collaborators and noted in these instances how they were still exploring ways of working together again in the future.

Comments from 27 of the private sector partners indicated that they are looking to further develop the use cases beyond the project timelines and in at least two cases (WM5G and 5GEncode), this work was undertaken under continued partnership by the entire consortium. In most instances though, the full consortium has not continued to work together on future collaborations. More prevalent were instances where select firms within a consortium chose to continue working on the use cases which were developed during the project. Whilst the entire consortium might not have been involved, respondents did note that the project helped to introduce their firms to previously unconsidered potential partners.

DCMS support for collaboration
Interviewees remarked that DCMS helped to encourage communication and collaboration across a range of stakeholders from small business owners to local councils and universities and across different regions of the country.

As key facilitators they helped bring consortium members together and bring them to networks such as UK5G and connect projects to each other. Collaboration activities were an aim of the programme and the number of events held to promote this were appreciated by interviewees. One respondent went so far as to say they were not sure what more DCMS could have done. Whilst some efforts were more successful than others, there was little doubt that significant effort was employed by DCMS to encourage collaboration both between projects in their project management capacity but also across the wider 5G ecosystem.

Increased collaboration within the ecosystem
At least 24 of 36 (67%) funded applicants surveyed signed up to the UK5G network. Five of the 36 respondents suggested that they had not done so and seven were unsure. Private sector interviewees, in particular representatives from smaller firms, spoke positively about the network and noted that the initiative had helped bring together individuals working at the cutting edge of these 5G applications. There is evidence from both the surveys administered and interviews of the 5GTT programme private sector participants of how they engaged with others interested in learning from programme beneficiaries. Interviewees spoke about benefits from inter-project collaboration and the sharing of learnings (what technologies were being applied elsewhere, how others had solved

problems) across different projects. Interviewees also spoke about having realised connections in other sectors that they did not usually engage with and that this enabled expertise to be shared more widely.

A few private sector interviewees found that the UK5G network was well intentioned and helped raise awareness but was ultimately not a significant help to them. Suggestions were made for the network to:

- Focus on connecting firms working in similar industries, instead of operating as a general 5G forum
- Widen the reach to the general public, given that the network only involved those active in the 5GTT programme or those with a prior interest in 5G technologies.

Widening the reach of the network beyond those with knowledge and expertise around 5G should enable sharing learnings with others, helping make the programme more impactful. Moreover, one survey respondent commented that this would allow connecting 5G activities to other initiatives/technological solutions that together, could deliver solutions to real-world problems.

5.2.3 Information and knowledge sharing

29 of the 79 (37%) interviewees were very positive about how the programme helped to share knowledge and encourage collaboration across the wider ecosystem. Interviewees reported that collaboration was encouraged between the consortium members but also more widely through events facilitated by DCMS/UK5G such as the 5G showcase. These allowed them to engage with members of other projects who were encountering similar issues or operating within similar industries, which fostered relationships across industry and exposed project participants to new ways that 5G could lead to benefits. Stakeholders said this element of shared learning was valuable. Interviewees noted that they would have liked to spend more time learning not just from similar projects but also from projects who were using 5G technologies in very different ways to them.

Tools for information and knowledge sharing
48 out of 79 (61%) interviewees commented on the range of methods utilised to share project information. Examples included making final reports made publicly available to provide an overview and summary of the use cases and objectives achieved as a result of the programme. DCMS also encouraged dissemination of knowledge through a number of activities such as hosting workshops and putting together events where members could come together to share project developments. As noted throughout this chapter, the formation of the UK5G Innovation network was also a key outlet for learnings to be shared not just amongst project partners but across the consortium more widely.

Social media initiatives were also undertaken by a range of project members e.g. posting on social media, making videos for YouTube and publishing on their websites to spread awareness. This was in addition to the regular newsletters and articles written by a range of stakeholders from DCMS to UK5G to individual project members to ensure that there was regular information on how 5G technologies could be applied.

DCMS had aimed for the citation impact factor of publications/reports about 5G on GOV.UK and UK5G.ORG increases by 1 annually to 5 in June 2022 (an author h-index is used), from a baseline of 3 in FY19/20. This target was reached by June 2022.

More information on the extensive dissemination and knowledge sharing approaches utilised by each individual project can be found within the Sustainability report and within our Case Study Annex.

Effectiveness of information sharing as a result of 5GTT
Views on the effectiveness of information sharing was mixed but across over 50 interviews, nearly 60% were positive that the effectiveness in sharing information was enhanced as a result of the 5GTT programme.

Interviewees reported that without contacting other projects, they would not have been as effective at sharing information and would have learned considerably less themselves. Interviewees said the events and conferences held helped them to learn more about how 5G technologies could be used within their fields. One interviewee noted that especially with private organisations, putting emphasis on sharing knowledge is not an aspect which would normally be promoted.

There were some less positive responses on how effective the knowledge sharing efforts were. Some interviewees felt that the emphasis placed on consortium members to share knowledge was often overburdensome and in many

cases the use cases would only be relevant to very niche industry operators. For consortium members who engaged it proved fruitful but for some it felt a bit too much like a box ticking exercise. Others thought that despite discussion within the 5G programme, issues were still not being talked about in the mainstream. Within DCMS there were some comments that whilst there was a lot of effort into encouraging learnings to be shared, the information was very disparate and hard to aggregate in a manner which would be easy to understand by a wider audience.

Creation and maintenance of UK5G

One of the key elements which DCMS looked to emphasise to all stakeholders in the 5GTT programme was the potential impact of the UK5G Innovation Network. The network was set up to be a key centre where learnings from 5GTT project participants could be shared along with being a forum where organisations interested in the capabilities of 5G could come together.

Across 47 respondents over 75% of the responses were positive about the impact of the UK5G. They praised how the network helped to spread knowledge by putting together a number of events and helping to generate wider coverage and exposure about individual projects. The emphasis on the role of the network to promote collaboration was recognised by project participants and on the whole, it was received positively. Interviewees also commented on the effectiveness of the marketing and communications effort and remarked how there was a stream of dissemination material produced to raise awareness of the network and of 5G use cases more widely. This spanned from magazines to content generated on their website along with the showcase events organised. Interviewees were also very positive about how the UK5G helped to foster inter project collaboration creating a forum where projects who were working on similar use cases were able to learn from each other and overcome similar problems faced. One interviewee commented that without the development of the UK5G network that knowledge about the capabilities of 5G would not have been spread as widely as they were.

A small number of interviewees had some reservations about the efficacy of the UK5G network. They noted that although a lot of effort went into its establishment, some of the information generated could have been more targeted. There were comments that for individuals and organisations not involved within the 5GTT programme the information being produced would not appear highly relevant. The network could have been improved with some more specific information or to try and reach out to an audience which expanded beyond those who already had a prior interest in 5G capabilities. Even amongst these reservations, the respondents noted that the network had helped to raise awareness, there was just the worry that the network could have developed into an echo chamber of sorts.

Level of engagement with UK5G

Project interviewees were mixed in terms of how engaged they were with the UK5G Innovation network. Lead partners and organisations who were involved in presenting at events were very engaged. Others, including unfunded applicants, were generally aware of the events which had been held. Six interviewees indicated that they had little to no engagement with the network (3 funded project, 2 unfunded project and 1 multi-project/wider ecosystem respondent). Project participants noted that demands placed by the projects they were working on, coupled with the location of certain events, sometimes meant that the only engagement they had was through the newsletters generated and the events produced. Despite the variability of engagement, most of the respondents did at least acknowledge that they had been engaged with the network in some capacity even if it was fleeting.

Improving knowledge of companies in the ecosystem

Almost all the respondents noted that the UK5G innovation network had helped to at least improve the knowledge of the other companies involved within the ecosystem. They noted that the network had not only helped to give them knowledge about what some of the other projects were engaged in but had also helped to introduce network members to other useful contacts. Some interviewees did note that despite the fact that the network did improve knowledge of the other companies in the ecosystem, that it could have done more to help promote collaboration across different industries. In general, the respondents were positive about how the network had helped to increase the knowledge of other organisations with the 5G ecosystem.

Engagement with academia, industry, and public services

The degree of engagement with other types of organisations varied depending on a number of factors. These included the type of use cases being developed, the size and breadth of the project consortium members and who

the projects were led by. The impact of academia depended greatly on who was leading the project. For the test networks led by universities, project members within these projects felt like they had strong connections compared to those where the university institutions were not leads. For those who did have a strong academic presence however, the interviewees did feel that their presence was beneficial in providing additional rigour.

Across industry, the impact was much more consistent. As many of the projects were looking to carry out specific industry applications of 5G, interviewees were more in agreement that the project had helped them to engage with useful industry figures and that the UK5G network had helped to facilitate this. Not only did engagement with industry help project participants to learn from mistakes which might be impacting their own programmes, but it helped to raise the profile of the programme and UK industries to generate wider international interest.

The engagement with public services was very much dependent on the use cases being developed by specific programmes. Fewer than 10 projects commented on this aspect, indicating how for many interviewees this aspect was not a major priority for them. Amongst those who did respond, there was the sense that more was required to link public sector players with the wider UK industry players. Organisations such as the Innovation network helped but it appeared to be more successful in connecting academic and industry players together than in bringing public sector organisations into the fold.

Overall benefits of the programme to private sector participants

33 of 35 (94%) of funded applicants found that the programme has been useful to their business. One survey respondent commented that the programme has been somewhat useful, “it helped progress understanding of 5G, and develop products, but also highlighted that 5G was not essential for market launch of the product”. Another commented that the project “had been a distraction and an unnecessary cost, and that the pandemic had wrecked plans”.

Reflections on the benefits from 5GTT from survey respondents (funded applicants):

- The project enabled us to refine future customer pain points and refocus our solution
- The funding helped us to understand current state and demonstrated to manufacturing equipment and device suppliers that we need them to develop solutions with integrated 5G capability
- It has allowed us to explore new avenues and market opportunities for the company

Interviewees noted that DCMS assisted in facilitating regular meetings across the consortium to ensure that all members were continually kept in the loop of latest developments. DCMS also organised regular workshops and the presentations given at these events were used to share findings, challenges, and learnings. DCMS were noted as having been supportive with promoting collaboration and sharing of skills and knowledge which had been acquired over the course of the projects. DCMS ensured that many programmes had targeted marketing and communication initiatives to try and disseminate what was being discovered to the wider public.

Social media campaigns and regular articles and blogs were used to promote the progression of projects, and this was said to have helped keep consortium members, the wider ecosystem and general public abreast of developments as and when they were occurring. From the interviewees who spoke about knowledge sharing, more than 60% noted how **the programme helped their firms to overcome the problems they faced** within their own projects and gave insight into potential capabilities of 5G technologies. Whilst interviewees conceded that there was always more which could be done with regards to dissemination, most were very positive not only about the actions which they undertook within their own project but also with how DCMS helped to facilitate wider dissemination. It was clear that a lot of effort went into producing materials to help share findings and learnings which occurred during the 5GTT programme.

Whilst as noted previously, these were overwhelmingly positive, one point of potential improvement noted by interviewees is that whilst project members were good at sharing what worked well within their projects, that they were not always as effective in sharing things which did not work so well. The interviewees also noted how they were not sure how widely insights were shared with the wider public and/or with firms who were already knowledgeable about 5G technologies.

5.2.4 Network deployment and use cases

The programme deployed at least 107 networks[48] to test 266 use cases. Projects developed networks and were able to test their use cases on them. DCMS had aimed for 70% of testbed projects to create networks capable of supporting the use cases developed. Internal monitoring suggests that by June 2020 75% of the projects had created such networks and thereby this target is met.

The projects varied as to whether the network deployment or the use cases were the primary benefit. For example, some projects were particularly interested in deploying networks in challenging conditions (e.g. in rural areas with poor existing connectivity).

Across 34 respondents, interviewees had mixed responses on whether their use cases could have been carried out on previous generation networks. In many rural applications, the interviewees said the use cases could not have occurred on previous generation technology. One possible explanation is that "rural 4G" tends to be low-band (to ensure wider signal propagation across sparse areas) and that low-band frequencies offer lower performance. 5G technology, even using low-band spectrum, thereby can offer more suitable performance capability for the rural use cases.

For the projects which had use cases that required low latency, interviewees were also clear that the increased computing capacity of 5G was required to ensure that there was sufficient connectivity and bandwidth to achieve these cases. Interviewees commented on how 5G was an upgrade on 4G helping to carry out activities in a more efficient and less costly manner and that whilst certain applications could be carried out on 4G it would not have been as successful.

However, there were three interviewees who believed that some of their use cases could have been carried out on 4G technology, and this is useful insight. In these interviews, respondents noted that in many cases the networks being deployed provided increased network performance, but the added features of 5G were not necessary for the use cases, which implies that they would have been able to develop and at least test their use cases on previous generation technology, but not necessarily fully deploy at scale.

5.2.5 Funded activities identify/showcase what works

Use cases demonstrated the benefit of low latency and high bandwidth across applications. For example:

- WM5G conducted the UK's first remote ultrasound scan in an ambulance. 5G offered sharper and more reliable imagery than could previously be achieved, allowing the remote monitoring of ultrasound examinations[49]
- Liverpool have developed an Adoption Readiness Level Toolkit for assessing healthcare equipment, which was used to give feedback to help develop a physiotherapy app which was tested in the West Mercia project
- Vodafone have committed to delivering their advanced management system for connected and autonomous vehicles and are deploying specific infrastructure to test this in Milton Keynes as a result of the MK5G project and previous projects on CAVs in the area
- 5G Wales Unlocked deployed sensors to monitor heritage assets and reduce closure times – their heritage partner Cadw would like to deploy this technology in more of their properties and were looking for funding opportunities

As part of the survey to private sector participants, applicants were asked if, since participating in the 5GTT programme, they had changed their thinking on how relevant specific 5G benefits (i.e. speed, lower latency, device capacity, higher security, network reliability) are to their business. There was a mixed set of responses to this question. From the 25 responses gathered on this topic, ten mentioned that the project has not changed their thinking on this with the remaining 15 noting that the 5GTT had led to respondents changing their thinking around how 5G could be used. Each bullet point below indicates a response which one or more survey respondent learned:

[48] The total number of networks deployed by WM5G is not known

[49] University Hospitals Birmingham, BT and WM5G demonstrate UK's first remote ultrasound over a public 5G network

- What the specific requirements for 5G technology are
- That the equipment is not that reliable yet.
- That, for the use case, latency is less important and network reliability is the main benefit
- How latency and speed affect (business) activity
- What potential benefits 5G can bring to our business (…) to support efficiency gains required in the industry
- How to apply it with our core sectors
- That greater security is a need as core network functions become virtualised
- The nuances in different end-user markets that affect the relative value of each of the 5G benefits
- That for 'shopfloor' applications more upload speed is needed but not download speed because this requires a different system.

40% (10 out of 25) of respondents provided comments around the limitations of 5G technology. One respondent noted that the activities involved would have been better left to Mobile Network Operators (possibly because they have more resources) and another commented that their real need was a system "not dependent on decades of legacy tech". A review of monitoring data supports this evidence, with reporting showing that many project partners recognised that further funding was needed to continue progress on the initial use cases developed. Moreover, this sentiment was shared by various private sector interviewees. Interviewees commented that the technology was still not at a developed enough stage where it could be deployed commercially. Even in scenarios where the 5G technology was sufficiently developed, without the wider infrastructure in place, the full viability of the technology cannot be leveraged. Private sector participants find that further investment and research in these technologies is required to stimulate further development and that more focused effort needs to be carried out to ensure that the infrastructure is in place across the UK.

Interviewees were positive that once reservations around funding and investment are addressed, 5G technologies can help their organisations become more efficient and benefit the wider manufacturing and construction sector and other sectors.

5.2.6 Technology Readiness Levels

Technology Readiness Levels (TRL) are a measurement system used to assess the maturity level of technology. TRLs range from 1-9 with TRL 1-2 representing the developed of ideas/concepts, TRL 3 the experimental proof of concept, TRL 4 the demonstration of a proof of concept in real life conditions and TRL 6 the completion of initial trials, and TRL 7-9 the deployment and cases where products are brought to market.[50]

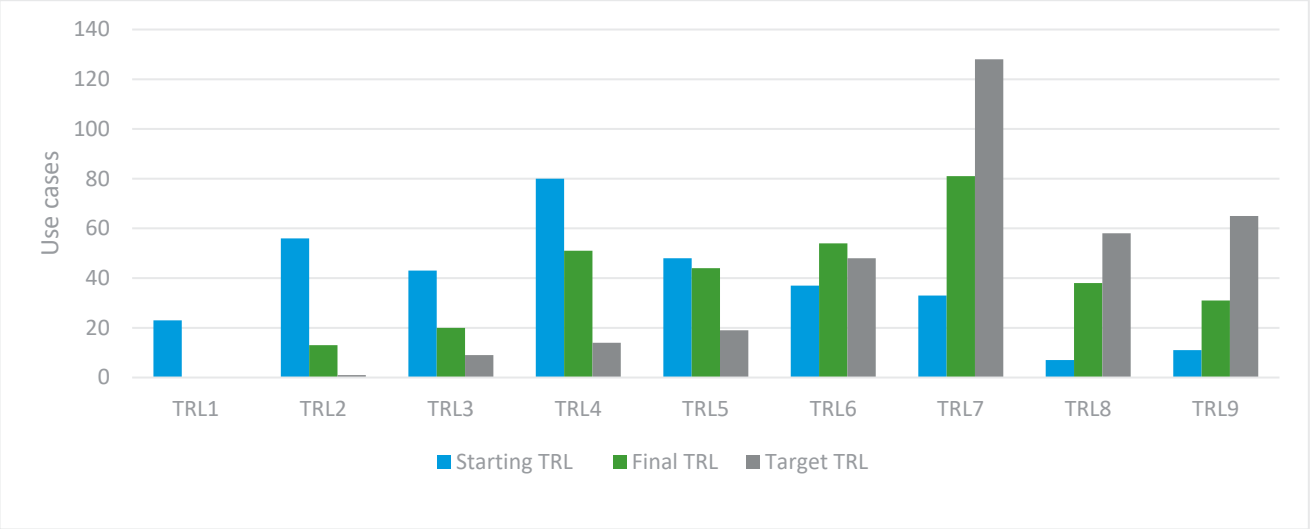
TRL data was collected as part of BRs for 345 use cases and 36 5GTT projects[51]. The figure below compares the progress of 5GTT use cases against original, final and target TRL. The figure shows that the starting TRLs spanned across 1-9 and the final TRL and targets spanned across 2-9. The range of the TRLs of use cases is wide for an innovation programme. By means of comparison, Innovate UK is focussed on supporting innovations that are between TRL 4 and TRL 6[52].

[50] See Microsoft Word - EPSRC-1.docx (ukri.org)

[51] We have no data for one Phase 1 project

[52] Eligibility of technology readiness levels (TRL) – UKRI

Figure 4: Comparison of progress of use cases against original, final and target TRL



Source: Benefit realisation

On average, the starting TRL of use cases was 4.2. This starting TRL aligns to that of the Energy Entrepreneurship Fund project, which on average advanced by 1.9 points at the end of the grant. The average improvement in TRL of the 5GTT programme was 1.7 and the improvement in TRL falls below that of the four comparators listed in the table below. The 5GTT projects may have had a broad(er) set of test cases to trial and ultimately projects did not advance in all areas.

DCMS had set a target for 75% of projects to have made satisfactory progress according to the TRL scale (1-2 points, depending on the starting TRL). This assessment was made by TDAs. By June 2022 95% of completed projects had made satisfactory progress and the DCMS target was met.

Table 17: Comparison of starting TRL and progress

	Average starting TRL	Average increase in TRL	Average final TRL	Average target
5GTT	4.2	1.7	5.9	6.9
Energy Entrepreneurship Fund[53]	4.2	1.9	6.1	-
Hy4Heat[54]	1-3	3.2	4-7	6-9
Advanced Propulsion Centre[55]	4.4	2.3	6.7	7.9*
UK Aerospace Technology Institute grant funding programme[56]	2.6	1.8	4.3	-

**Note final TRL are those recorded at the interview and TRLs for completed projects were reported to be 1.2 levels behind targets. We have assumed the average TRL of completed projects is 6.7.*

The improvement of use cases along the TRL is on average 1.2 levels below target - the average project aimed to reach a TRL of 6.9. Evidence from the comparator programmes show that it is not unusual for project to set ambitious targets. 38% use cases met their target TRL. 78% of use cases improved the TRL. For 5% of the cases, the final TRL was lower than the original TRL. In some cases, this may have been a result of optimism bias. For

[53] Evaluation of the energy entrepreneurs fund (publishing.service.gov.uk).
[54] Evaluation of Hy4Heat final report (publishing.service.gov.uk).
[55] Advanced propulsion centre: interim impact evluation (publishing.service.gov.uk).
56 UK Aerospace Technology Institute (ATI) Grant funding programme: Early Impact Evaluation (publishing.service.gov.uk). Average TRLs based on data in Figure 3.5

three use cases the final TRL was recorded as zero because the use case was not continued. On average, the cases that met targets has a slightly lower starting TRL (4.0 vs 4.3)

At a project level: 23 of 36 (66%) projects had at least one case that met the target TRL and all but one project had use cases that did not meet the target TRL.

Table 18: Summary of TRL change, 5GTT projects

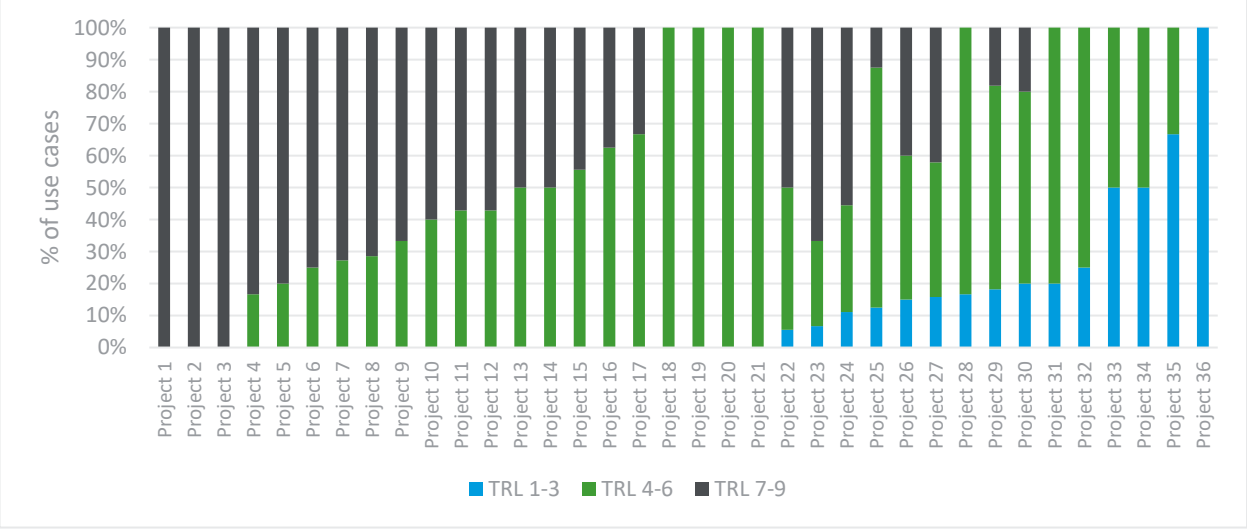
Change in TRL	Number	Percentage
Improvement of 3 or more	93	32%
Improvement of 2 points	56	19%
Improvement of 1 point	45	16%
No change	80	28%
Decrease in TRL	15	5%
Use case/equipment/network meeting TRL target	110	38%

Source: Benefit realisation

The figure below shows that projects focussed on different stages of technological advancement.

- 3 projects resulted in TRL 7-9 (deployment)
- 15 projects resulted in a combination of TRL 4-6 and 7-9 (development and deployment)
- 8 projects resulted in use cases from across the TRL spectrum
- 4 projects resulted in TRL 4-6
- 6 projects resulted in a combination of TRL 1-3 and 4-6 (research and development)
- 1 project resulted in use cases that reached TRL 3 only

Figure 5: Final TRLs of use cases, by project



Source: Benefit realisation

BR data suggests that, in addition to the 11 use cases that were TRL 9 at the project start, 20 other use cases reached TRL 9 at the last BR reporting stage. This includes:

- WM5G - Delivers.ai is designed to autonomously deliver food and grocery from shops to your doorstep, which had started commercial sales in the West Midlands and London at the project start and started commercial deliveries in Istanbul, Madrid and Zurich and completed 2,500 autonomous deliveries with the grocery delivery use case at the end of project reporting stage

- Connected Cowes – Developed new education modules based around 5G-derived content
- 5G Edge-XR – that worked on seven use cases related to the product MixAir and 6 use cases developed from TRL 2 to TRL 9, exceeding the target TRL of 7
- WM5G Transport – where a use case developed a passenger counting system to capture bus occupancy (change from TRL 7 to 9)

5.2.7 Products or services developed, and process improvements adopted

The projects had a wide range of objectives and not all projects looked to bring a product or solution to market. According to project outcome data, 36 of the 37 (97%) projects resulted in a proof of concept being developed, 20 of 37 (54%) brought a new product or service to the market, and 29 of the 37 (78%) projects developed or incorporated process improvements on the back of the programme[57]. These benefits were realised by one or more of the consortium's members.

We have measured the number of products brought to market using data from stakeholder interviews and applicant survey data. Data from projects' sustainability reports and final reports was used to complement this. We were not able to map the solutions developed to the use cases the projects have explored (use cases were identified via BR data). We do know that in some cases a number of use cases contributed to the development of one solution.

Types of solutions developed
Some of the solutions developed are for very specific 'edge' applications and others demonstrate applicability away from dense urban areas. 29 process improvements were adopted (see table below). The case studies and the sustainability report include more information on the solutions developed.

Table 19: Products or services developed by project type

Type of project	Number of projects	Market ready product/ service	Process improvements adopted
Developed 5G technology for very specific 'edge' applications in a particular industry or sector	20	7	16
Developed 5G technology for wider public benefit, including helping to address the issue of poor wider connectivity	11	8	9
Mix of the above	6	5	4
Total	37	20	29

Source: Project BRs & project interviews

Types of process improvements
The process improvements adopted by consortium members were of two types:

- Process improvements that were part of the project's aims. For example, the 5G Connected Automated Logistics (CAL) project aimed to develop efficiency improvements to the manufacturing process by demonstrating a proof of concept for autonomous trucks that could perform timely automated delivery of raw materials.
- Process improvements that were adopted because of the development of 5G use cases. For example, the 5G Connected Cowes project aimed to create an immersive experience for the audience of the Cowes Week yacht racing using real time Virtual Reality (VR) video and 5G technology. As part of this, the consortium developed a

[57] We are not able to map the reported products brought to market with the projects' use cases and present these as a proportion of the total use cases developed as part of the 5GTT programme. This is because sources differ and the data includes self-recall data. More information is in the Sustainability Report included in the Annex.

bespoke camera which could be installed on a racing yacht. This, the consortium claimed, was vital in the development of their use case and had commercial process improvement potential in non-stadium sports events and potentially other industries.

Benefits to the community

18 of the 37 (49%) projects have resulted in wider benefits to the community and for another 17 projects (46%) there is potential for such benefits to be realised in the future. These benefits included putting in place new products and services which would result in a wider choice of higher quality goods for consumers. In addition, many of the benefits focus on environmental improvements and business generation, which would help residents of rural communities to participate in some of the benefits that greater 5G connectivity offers.

Table 20: Overview of project outcomes by type of innovation and wider benefits

	Projects that did not result in process or product/ service innovation	Projects that resulted in process innovation	Projects that resulted in new solutions on the market	Projects that resulted in process innovation and new solutions on the market	Total
Wider benefits – Yes	-	5 (5G Festival, AutoAir, WM5G Application Accelerator, 5G Rural Dorset, 5G MONeH)	3 (Smart Junctions 5G, WM5G Transport Road Sensors, 5G Smart Tourism)	10 (5G Logistics, Liverpool 5G Create, WM5G Infrastructure Accelerator, WM5G Transport Use Cases, Liverpool 5G Testbed, 5G Encode, 5G MANY, 5G West Mercia, WM5G Manufacturing, Worcestershire 5G)	18
Wider benefits – Possibly	1 (5G Rail Next)	9 (5G CAL, 5G Ports, 5G Rural First, 5G-AMC2, 5G Factory of the Future, 5G Edge-XR, Live & Wild, 5GEM, 5G VISTA)	4 (Eden Universe, 5G Wales Unlocked, 5G New Thinking, WM5G Healthcare)	3 (5G Connected Forest, MK:5G, 5GRIT)	17
Wider benefits – No	-	2 (Connected Cowes, 5G Green Planet)	-	-	2
Total	1	16	7	13	37

Source: End of project reporting data, complemented with evidence from surveys and interviews

Consortium members implementing new processes and/or bringing new solutions to market

Projects have resulted in 86 project participants implementing new processes and/or bringing new solutions to market. Data on project participants shows that, 40 have resulted bringing new products/services to the market and, and 38 members have adopted new processes because of taking part in the 5GTT programme. Seven consortiums' members have resulted in both product/service and process innovation. We have identified 51 project participants that are contributing to generate wider benefits and 32 members that could generate wider benefits if they were to invest further in the development of use cases.

We find evidence that projects which resulted in process innovation also furthered the application of 5G technology for wider public benefit, for instance by helping overcome an issue of poor wider connectivity in urban or rural areas. This evaluation shows that wider benefits have been realised via projects that aimed at product/service development (e.g. to improve the commercial capabilities of the industry).

71 of the 86 (82%) are private sector organisations and this includes large organisations such as Siemens, Vodafone, BOSCH, Cisco, and BT, among others. Consortiums members implementing new processes and/or bringing new solutions to market also include other types of organisations such as:

- 3 universities (University of Bristol, Birmingham City University, University of Birmingham);
- 4 members that are parts of the NHS;
- 3 representations from City Councils (Liverpool City Council, North Yorkshire County Council and Dorset Council); and
- A member of the Catapult network (National Composite Centre)

Table 21: Overview of consortiums members, by type of innovation and wider benefits

	Process innovation	New solutions on the market	Process innovation and new solutions on the market	Total
Wider benefits – Yes	17	26	8	51
Wider benefits – Possibly	18	14	-	32
Wider benefits – No	3	-	-	3
Total	38	40	8	86

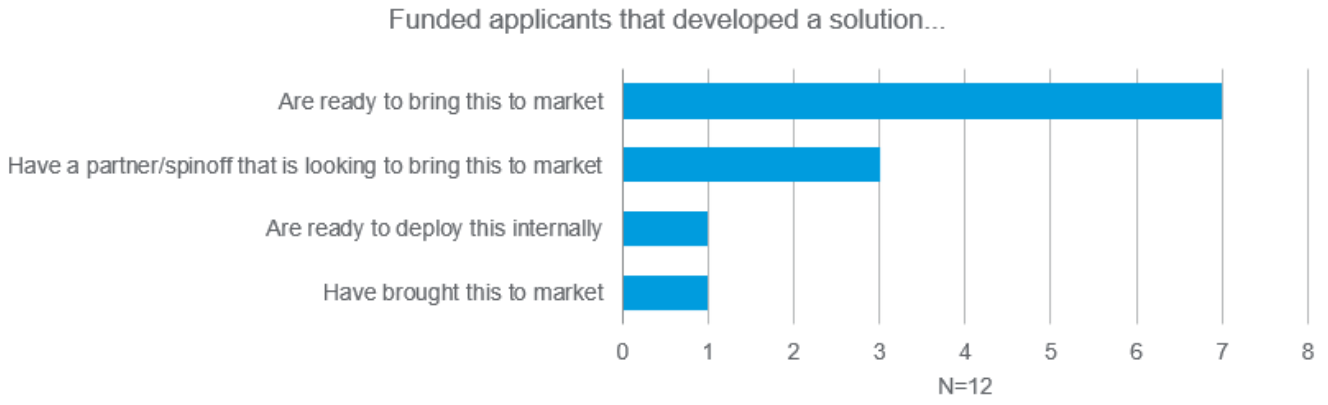
Source: Monitoring information and interviews

Evidence from product and service development from the survey to private sector participants

The evidence presented above comes from monitoring information and interviews. The survey results indicate that a more limited number of private sector participants recognised that they themselves had developed a solution. The difference in numbers could be because the monitoring data has optimism bias or that the survey data is not representative. It could also be that some of the solutions that, at the time of project end reporting, were on the market were pulled.

12 of 36 (33%) of the funded survey respondents reported that the 5GTT project has enabled them to develop a solution that builds on 5G technology. 1 of the 12 funded applicants (from 5GEncode) that responded to the survey has brought the solution developed to market - this company is active in the telecommunications market. One of these firms also reported that the consortium had resulted in a 'Stand Alone' private network.

Figure 6: Survey evidence – funded applicants that developed a solution



Amongst the respondents that did not develop a solution, twelve reported needing additional resources to ensure market readiness (interview data corroborates interest from select firms to push development further). Another four respondents reported needing additional resources to deploy this internally. These projects may have started their 5GTT journey at a more premature stage in terms of technological readiness than those that succeeded in going to market. One respondent from the AMC2 project indicated that they themselves are not developers of a 5G solution but are benefitting from the solutions provided by others.

The remaining 7 of 36 (19%) survey respondents provided the following comments on learnings encountered due to their project involvement:

- The solution that was initially envisaged is not fit for purpose
- 5G equipment costs are too high
- The application could use any network
- The product envisaged is dependent on 5G being available to consumers
- The 5G and 6G technology deployed and trialled is used to develop other operations
- The firm is developing a platform to drive a lower cost point of entry for 5G or 6G O-RAN solutions
- Competition from WIFI and hardwired networks – but running other pilots for feedback

5.2.8 Unexpected outcomes

Interviews asked 31 Phase 2 project consortium members about unexpected outcomes for their projects. We think that many of the unexpected outcomes, summarised below, are integral to a programme such as 5GTT[58].

- Twelve interviewees from ten projects told us that they had not expected to develop good working relationships with other organisations, within their own consortiums and/or within the wider ecosystem.
- Interviewees from six projects reported they had not expected to learn more about deploying and using key aspects of the technology, which had helped to inform the future development of some pieces of equipment.
- A further five interviewees said that they had not expected to be able to create and test enjoyable user experiences, as these had been more positively received than originally hoped.
- Two representatives from the Rural Connected Communities projects said that they had not expected to be able to communicate the positive benefits of 5G to the communities they operated in.

"We had 5G backlash in earlier projects. We had planned for it and had a communication plan and had academics who were interested in community acceptance of new technology. These academics were interested in hearing and understanding the views of 5G sceptics. This time, because we had the resource we could engage and understand the concerns and give them a voice and a sense of being heard. From that we produced a toolkit for local authorities. We shared that with DCMS and it's on the website and we did an event around this toolkit."

"Small businesses are trialling 5G related things in our area, and we have a careers programme inspired by the project."

We asked consortium members about areas where they were less successful than they had originally hoped. The main areas were

- Five projects had less time to run tests, and consequently less data had become available to demonstrate the benefits of the different use cases, due to problems or delays in sourcing equipment
- Five projects were not able to undertake all planned activities because (at the time) equipment was not commercially ready for deployment when they received it and/or required a more complicated installation than anticipated. As part of wider ecosystem interviews, we spoke to at least three smaller suppliers and they all reported technology had improved over the course of the programme.

5.2.9 Addressing barriers to deployment

Overcoming barriers and making it quicker and easier to deploy networks and 5G technologies ensures wider benefits from these technologies are disseminated across a range of industries and consumers respectively. 5G networks have lower latency and higher bandwidth and allow for techniques such as network slicing. Accelerating the deployment of 5G networks facilitates the use of other technologies and applications where large numbers of sensors and devices need to transfer data quickly e.g. for CAVs, industrial applications, or healthcare applications such as transferring high quality live imagery.

DCMS's target was for 67% of projects to generate knowledge that can reduce either deployment time or deployment cost and, for that knowledge to be made available to others. Internal reporting suggests that by

[58] The interviewees were asked if there had been any unintended consequences or unexpected outcomes from their project

January 2022 five of the six Phase 1 projects identified cost reductions. Cost reduction were only a target for 48% of Phase 2 projects and for this Phase this target has not been met.

The table below summarises barriers that the 5GTT programme has helped to address.

Table 22: 5GTT selected examples on progress overcoming barriers

Barrier	5GTT programme barrier busting	Remaining challenges	Wider impacts from addressing this
Cost	A specific aim of the programme was around learning about the conditions under which 5G could be deployed more cost efficiently. For example, the Smart Junctions project achieved a deployable network that was 75% cheaper than a traditional vendor, although it is not yet market ready. This was done using OpenRAN technologies and small cell equipment. (Source: Project Interview) WM5G IA reported a reduction of 3-6 months in time to deploy 5G networks in the West Midlands. (Source: Closure Report)	Cost remains a barrier to deployment (see chapter 5)	Addressing cost barriers would allow other players to enter the market, generating competition and further innovative activity.
Spectrum Licensing	Ofcom made spectrum available through Shared Access Licenses (SAL) and Local Access Licenses (LAL) for 5GTT projects, which allowed for the installation of private networks with less involvement from large MNOs (Source: Ecosystem Interview, Programme Technical Report). MK5G reported that because they had learned about the spectrum licence process and configuration/integration of devices within the network, their follow-on project was attracting significant further investment from the private sector (Source: Project Interview) Six interviewees mentioned that the programme had made good progress • Through freeing up the N77 band	The license application process is cumbersome and iterative. 5G New Thinking developed a toolkit to help guide applicants through this process and save time. This was more successful for SALs than LALs. The spectrum allocated through this process is more suitable for outdoor environments than indoor environments.	Allows for the development of private networks without MNO involvement, challenging business models of larger MNOs and creating opportunities for smaller ones

Barrier	5GTT programme barrier busting	Remaining challenges	Wider impacts from addressing this
	• Through access to shared spectrum licences		
Lack of expertise to deploy private networks by non-MNOs	The programme allowed participants to develop this understanding and expertise. More than 1,000 private sector business employees have been involved in the programme. Knowledge and expertise has been shared through the UK5G ecosystem (Source: BRs – see Sustainability Annex)	The programme finished in 2022 and it will take time for that information and knowledge to be shared more widely within specific verticals who may benefit most (e.g. construction, manufacturing, public services and healthcare. The technology readiness of equipment is still evolving so maintaining momentum around sharing information needs to be maintained. UK5G is still in place and is being re-branded to UKTIN. Other DCMS/DSIT projects (FRANC, Open Networks etc) aim to improve the readiness of equipment.	Potential new opportunities to support businesses deploying networks; develop more 5G ready radio equipment. Greater adoption will also improve the wider economy through the greater facilitation and innovation role that 5G deployment can play across different sectors that rely on telecoms as an input to drive value added activities.
Planning Regulations	These barriers included lack of understanding about the infrastructure required on the local authority side, for example. This had meant that MNOs were able to achieve higher rates of success with planning applications for 5G infrastructure (Project interviews). Projects such as WM5G Infrastructure Accelerator addressed issues around planning permission and legal agreements for deploying 5G infrastructure. This included providing training to local authority staff on the Electronic Communications Code, and standardising engagement processes between LA staff and MNOs (Source: Project Closure Report).	Still likely to experience challenges to applications in some areas although the programme has helped to inform local authority staff about issues and address misinformation about 5G.	Speeding up the deployment of 5G infrastructure and reducing costs to local authorities of potential planning tribunals. WMCA has the highest percentage of 5G coverage when compared to other Combined Authority areas. Monitoring data from the WM5G project suggests that £100k in tribunal cost are incurred when a case is brought by an MNO. An estimated £500k was mitigated.
Technological Readiness of Equipment	The programme helped to improve TRLs of equipment, on average TRLs increased by 1.7 (Source: BRs – see Sustainability Report).	Equipment is still evolving and further DCMS/DSIT programmes are more focused on this aspect.	More reliable 5G networks that are quicker and cheaper to deploy; potential to create new UK-based businesses to supply equipment. These can also

Barrier	5GTT programme barrier busting	Remaining challenges	Wider impacts from addressing this
			drive facilitation of wider economic activity.

Source: Interviews and project reports

5.2.10 External barriers to delivery

There were also a range of issues outside the programme's control that affected delivery. These included the following.

- **The COVID pandemic** (58 interviewees). Many of the projects were ongoing as the pandemic first hit. This meant people were not able to meet in person, networks could not be installed in places like care homes, and planned use case testing (e.g. on public transport or at live events) was cancelled, re-arranged or limited. Only one project (FoF) felt it had no significant impact on their planned activities. A small number of interviewees (from Liverpool 5G Create, West Mercia and WM5G) felt it highlighted opportunities for improving digital connectivity for health and education use cases and, for some of these projects, Covid was one of the justifications for the business case.

We think that, in comparison to the distribution of the pandemic to the wider economy, the impact on the 5GTT programme has been rather limited, because of how this was managed at the programme and project level.

- **Supply issues** with radio equipment (30 interviews). Some components were delayed due to general supply chain issues associated with COVID; some also highlighted an increased administrative burden or higher costs due to EU Exit (28 interviews). The overall technological readiness of some equipment was not as far advanced as some projects expected (25 interviews). Regulations to limit risk from high risk vendors also meant that projects had to source equipment from vendors other than Huawei, which had been the preferred supplier to some (19 interviews). This led to some large MNO stakeholders involved in multiple projects withdrawing from consortiums or significantly scaling back work. Future DSIT programmes aim to further the development of a more diverse range of suppliers of 5G ready radio equipment for use in networks.
- Challenges obtaining **spectrum licences** (17 interviews) or around **planning regulations** (8 interviews).

5.3 Assessing the extent of attribution of benefits to the 5GTT programme

5.3.1 What would have happened anyway?

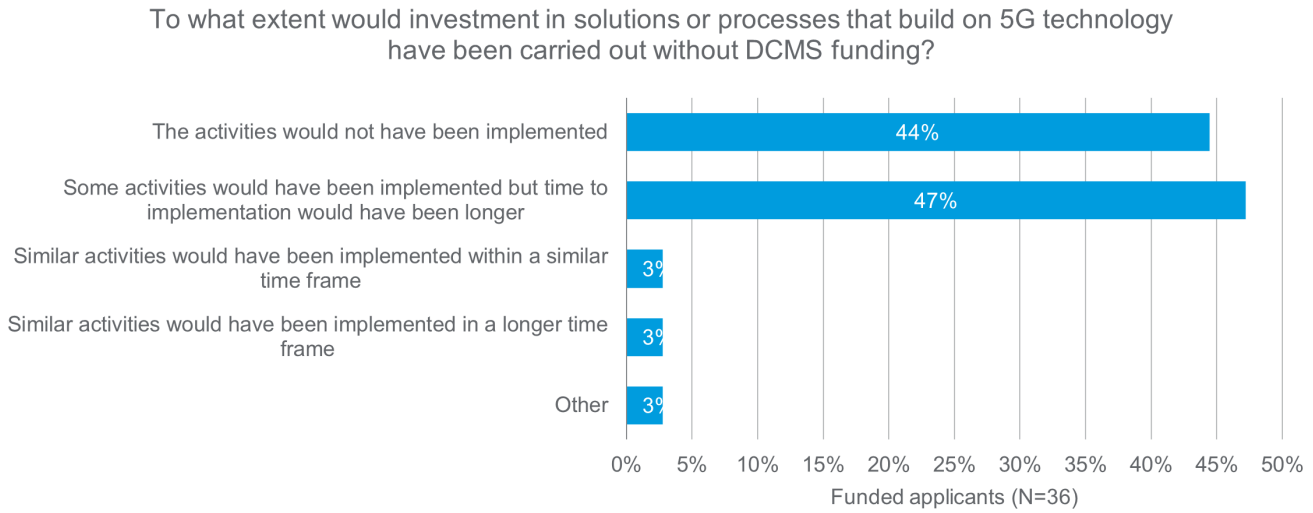
Almost all the project interviewees were clear on the point that the projects they carried out would either not have occurred or would not have been developed to the same extent were it not for the 5GTT programme. This was across over 40 of 79 respondents. Even in circumstances where funded participants noted that the projects being planned could have occurred without DCMS funding, they conceded that they would have had challenges finding funding from alternative sources. In 23 instances where private sector participants noted that they had considered carrying out 5G investments (without funding), nearly 20 noted that their plans would have taken longer to implement and the likelihood that project activities would have been carried out was lower. This evidence is somewhat corroborated by unfunded applicants, and this is discussed further below.

Table 23: Summary of evidence attributing impact to 5GTT

	Interviews	Surveys
Successful applicants	40 of 51 funded project partners interviewed, including 20 of 23 private sector participants attribute results to 5GTT	33 of 36 attribute results to 5GTT
Unsuccessful applicants	13 of 13 made slower or no progress	4 of 9 have not developed a solution, 3 of these lacked resources to do so

Results from the survey of funded applicants suggest that the additionality of the 5GTT programme is high. 33 of 36 (92%) respondents find that either the activities would not have been implemented (16 of 36) or time to implementation would have been longer (17 of 36). Only one respondent indicated that same/similar activities would have been implemented using alternative funding within the same/similar time frame.

Figure 7: Additionality of the 5GTT programme – survey evidence



Source: RSM analysis of responses from the funded applicant survey

It is to be noted that the responses are subject to bias and respondents may over-attribute impact to the 5GTT programme. Data on the journey of unfunded applicants helps validate the success of the programme by providing a counterfactual, even if, in the case of this evaluation, the counterfactual is based on a small sample. The differences between the funded and unfunded applicants help gauge the extent of overall programme impacts and the need for public funding.

- Unfunded firms interviewed noted that they would have been much further along the developmental path had they had received funding from DCMS. With these unfunded firms, respondents noted that in some instances they still had not carried out the planned R&D investment in 5G technologies, or even where this investment had occurred, they believe that they had not progressed at the same speed as they could have with 5G investment. There was only one funded project representative who claimed that the project would have occurred to the same degree whether funding had been present or not, noting that for their product the 5G programme was simply an instrument.
- 2 out of 9 (22%) unfunded survey applicants reported having been able to develop a solution despite being unfunded by the 5GTT programme and one is ready to bring this to market and the other reported having drafted a patent proposal. They had used alternate external funding. Four (44%) of the unfunded applicants reported not having been able to develop a solution and three of these respondents commented that lack of resources had prohibited them to pursue their original project objectives. Three other unfunded applicants commented to have pursued related activities, one via EU funding, and another commented that the interest catalysed by the competition had raised awareness across City stakeholders about the importance of digital connectivity (not just 5G) and led to the establishment of a dedicated Telecoms unit which was reported to have become recognised by industry and other public sector agencies.

Overall, it was very clear from the respondents how crucial the programme was and how in the absence of funding the projects would have not been near the scale that they were.

5.3.2 What did you do more of as a result of 5GTT?

Across the 14 respondents to this question[59], interviewees were positive about the variety of ways that 5G has helped progress across a number of industries. Respondents across construction and healthcare noted that the project had shown participants how cutting-edge technology could be applied. Construction sector interviewees noted how the programme had helped to change the perception around the industry from one of low technological capabilities to one where cutting-edge applications could be used. Within healthcare there were comments that the applications of 5G such as the promotion of remote consultations would not have been implemented.

Those we interviewed as part of the university test networks remarked how the 5G testbed put in place had generated a lot of interest across not just the UK but Europe more widely and had propelled the testbed to the forefront as an industry leader. A response from a large technology operator noted that whilst they would have still developed their own market ready solutions to bring to market, that the project encouraged a lot of time and effort to be devoted to proof-of-concept activities. Other commercial operators echoed this sentiment that the project had indeed helped to accelerate the research initiatives into how 5G could be applied to their ways of operation with others commenting that without the programme they would not have grown as quickly as they did.

Additionally, across rural regions, interviewees noted that the programme helped to shine a light on how 5G could be an attractive proposition to businesses in these locations which would have been much less likely. Interviewees across other sectors such as academia were also very positive about how 5G helped to foster relationships across different types of organisations which had never thought to work together previously.

[59] This was a follow up question to "Without the 5GTT programme would this project have happened anyway?", and was only asked of interviewees who responded "yes" to this question.

6. IMPACT EVALUATION - IMPACT ON PRIVATE SECTOR PARTICIPANTS

6.1 Summary

This chapter provides an overview of the outputs, outcomes, and impacts of the 5GTT programme on private sector participants.

The data sources we used for this section included:

- Monitoring information provided by DCMS on private firm participants including investment stimulation – data was available for 37 projects
- Qualitative interviews held with participant funded firms and unfunded applicant firms – responses were collected from 35 of 211 private sector participants, which includes four firms that were unsuccessful in one of their applications. Another five firms that were unsuccessful in all of their application(s)
- Surveys of funded private firms and unfunded applicant private firms – resulting in partial responses from 36 successful applicants and 13 unsuccessful applicants, which represents 16% and 6% of the population of firms that applied to the programme
- Secondary data from Beauhurst and Orbis for funded and unfunded applicants
- Opinium survey of 500 private sector firms to gain insight on overall private sector sentiment

The evidence collated from the surveys, interviews and secondary data suggests that, overall, private sector participants have benefitted from the 5GTT programme. Employment growth is positive for phase 1 and phase 2 funded firms between 2020 and 2021 but the results are subject to data limitations.

We estimate that between £355.4m and £262.8m follow-on investment was leveraged by consortium members. Based on our conservative estimate, **the leverage ratio for the 5GTT programme is £1.65**.

To go to market, several firms still need further investment (from government or other investors) – 32 of 36 (89%) funded applicants surveyed have identified or are looking for further investment to develop 5G products/solutions and/or conduct further testing. Based on a review of responses (multiple options were possible[60]) 7 of 39 (19%) have identified funding, 12 (33%) have identified some funding and 13 (36%) have not yet identified follow-up funding. Firms recognised the potential benefits that could be generated from 5G technologies, but some find that the market is not at a sufficiently developed stage to allow them to inject that next stage of investment capital. **The value of 5G is perceived as moderate to high by funded firms and is also recognised by firms in the wider economy –** 28 of 35 (80%) respondents (funded applicants) find that having access to 5G technology can provide moderate to high value added to their business. Both funded and unfunded applicants and SMEs in the general population see the benefits of 5G over 4G as potentially relevant to their business.

Data and limitations
The survey and interviews are based on small samples and subject to bias. Evidence from secondary data from Orbis and Beauhurst is not robust because sample sizes are small and there is missing data, and any conclusions derived from this analysis need to be interpreted with caution.

6.2 Overview of firms that benefited from the 5GTT programme

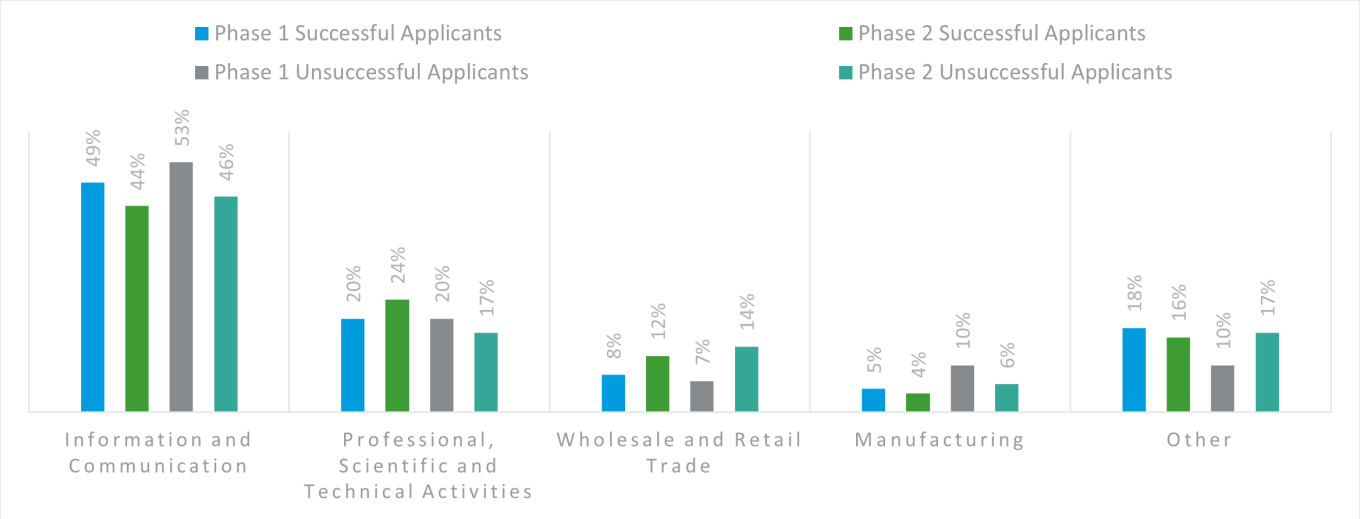
6.2.1 Increased industry participation within the ecosystem

The 5GTT projects involved 211 firms. 48 of these only participated in phase 1, and 141 only participated in phase 2. 22 firms participated in both Phase 1 and phase 2 projects and may have benefited relatively more from the programme. Data from Orbis is used to profile the firms based on turnover, employment, and sector. In our descriptions below, we include the 22 common firms in both the phases to provide a view of each phase more completely.

[60] One respondent selected multiple options.

- **Turnover** - 44% of the phase 1 funded applicants had a turnover of £50m+ (in 2018) and 30% had a turnover between £10m and £50m (74% combined). In phase 2 of the programme, firms with a turnover of £10m+ were also well represented (81%) with 39% of the funded applicants having a turnover between £10m and £50m, and 42% having turnover greater than £50m.
- **Employment** - A comparison of employment data (from 2018) shows that 24% of the Phase 1 and Phase 2 firms are businesses with 250+ employees. 28% vs 40% of Phase 1 and Phase 2 firms employed less than 10 staff. The inclusion of a large proportion of smaller firms in Phase 2 of the programme is likely linked to Phase 2 having allocated smaller grants[61].
- **Sector** - We have classified firms based on their primary sector of operation using UK Standard Industry Classification (SIC) codes[62]. Our analysis shows that the 5GTT programme targeted a range of sectors including agriculture, information and communication and manufacturing industries. A majority of the participant firms belong to 'Information and Communication' sector and 'Professional, Scientific, and Technical activities' sector. This is captured in Figure 8 below. The distribution of business across the sectors is similar across Phase 1 and Phase 2 successful applicants. A notable proportion of businesses (16% - 18%) belong to 'Other' sectors. This group contains firms belonging to 'Arts, Entertainment, and Recreation', 'Administrative and Support Service', 'Real Estate', 'Financial and Insurance' and 'Transportation and Storage' sectors, among others.

Figure 8: Sector breakdown of 5GTT applicants



Source: Projects' monitoring information and RSM analysis using secondary data (Tracker, Orbis, Beauhurst)

Data from Beauhurst from 2003 to 2022 is used to look at the number of grants received and the number of fundraisings of firms that participated in the programme.

- **Fundraising** - Data for 77 of the funded firms suggests that on average 62% (29 of 77) of the firms raised funds between 2010 and 2022. 22% of the total sample raised more than £4m in funding. One of the firms is reported to have raised funds on more than 10 occasions.
- **Grants** - Data for 122 of the funded firms suggests that on average 83% of the firms have received a grant between 2003 and 2022. Thereby, the data suggests that 21 of the firms have *not* received grant funding even though they have taken part in the 5GTT project over this reporting period. In principle this is possible because the 'funded applicant' group also includes 33 firms that received no 5GTT funding despite being part of a funded consortium. The Beauhurst database is relatively comprehensive but working with this also has some limitations and, in some cases, 5GTT grants have not been captured in the Beauhurst data. 36 of 122 (30%) of firms received ten or more grants during 2003-2022, which suggests that a proportion of the firms in the sample have come to rely on grant funding to invest in R&D. 26 of 122 (21%) received more than £4m.

[61] DCMS lowered minimum funding threshold in the guidance - to attract bids from smaller firms
[62] Data was reviewed at the 5 digit level and then grouped for the purpose of presentation.

6.3 Benefits to private sector participants

6.3.1 Funding leveraged

The benefits realisation reporting indicates that many of those involved had used the programme as a springboard to carry out continued investment following the completion of the project. From the benefits realisation where the data was available, 19 of the 37 projects (51%) noted that they had already generated further investment or had been carrying out collaborations which built on the research outputs from the project. We estimate that between £366.4m and £262.8m of total funding was leveraged. Our upper band estimate includes:

- £70.6m in co-funding
- £49.8m recorded as additional spent
- £148m recorded as third party investments (domestic and foreign)
- £97.8m from further collaborations building on 5GTT research and outputs

Our more conservative estimate excludes £54.1m which was recorded as expected by consortiums members at the time of reporting and removes the possibility of double counting. Double counting may have originated because the distinction between co-funding and additional spent is unclear and we suspect that some consortiums partners recorded co-funding as part of the additional spent.[63]

Co-funding data is based on claim information from 2022 data records[64]. Other follow-on investment data is pooled from the latest versions of the BR reports, stakeholder interviews, sustainability reports, and project final reports. This data was collected over the course of the project cycle and as part of interviews conducted in October-December 2023.

41% of the projects indicated explicitly that they had generated third party investment as a result of involvement in the programme. Some project members made large investment. For example, £39.2 million was invested by AutoAir, a member of a Phase 1 project, contributing to the deployment of small cell 5G networks in the UK. The process improvements brought about by the project are being deployed in several locations globally.

The DCMS internal target was for every £1 invested in projects to 'generate' £0.75 additional 5G related investment. This target appears to have been exceeded. Based on our conservative estimate, the leverage ratio for the 5GTT programme is £1.65 and the total funding leveraged is £262.8 million. However, this includes known public funding of £52.96 million. When we exclude the known public funding from our conservative estimate, the total funding leveraged drops to £210 million[65]. In view of the £159 million in cost and the £210 million in further investment, every £1 invested are associated with £1.32 in estimated additional funding.

In consideration of the interview and survey evidence (Chapter 5) we find that this investment was made in view of the testbed and trial results and thereby can be attributed to the programme. Data on unsuccessful applicants shows that those that did not receive 5GTT funding looked for other public support and/or invested at more modest levels. We also know that some project delivery partners are looking for further investment and that such investment would be used to push towards further development of their use cases.

Table 24: Leverage funding and leverage ratios

	£million	Number of projects, including estimations	Number of projects, excluding estimations
Total funding spent	£140.1	-	-
DCMS running cost	£18.9	-	-

[63] Co-funding data is based on claim information records and additional spending on R&D due to the funded project is recorded in BRs and reports.
[64] The exception is data for project UCC which comes from project final reporting.
[65] 54% of known follow-on investment is from public sources. We have no information for 37% of follow on investment but assume that the source of funding would have been more readily provided for public sources.

	£million	Number of projects, including estimations	Number of projects, excluding estimations
Sub total	£159.0		
Co-funding by consortiums members	£70.6	37	37
Additional £ spent on R&D due to the funded project	£49.8	33	32
Third party investment (domestic and foreign)	£148.1	18	16
Follow-on investment from further collaborations building on 5GTT research and outputs	£97.8	16	13
Total funding leveraged Ratio	£366.4 £2.3		
Total funding leveraged - conservative estimate Ratio - conservative estimate	£262.8 £1.65		
Total funding leveraged - conservative estimate, excluding known public funding	£210.0		
Ratio - conservative estimate, excluding known public funding	£1.32		

We have compared the leverage ratio for the 5GTT programme with that of comparator R&D programmes. The comparison is somewhat compromised by differences in the programmes, the timing and approach to evaluation. Nevertheless, the data for three other programmes shows that the additional R&D spending per £1 of public spending ranges from £0.41 for the Advanced Propulsion Centre (APC) to £3.90-£7.64 for the Energy Entrepreneurship Fund. The leverage ratio for the 5GTT programme is lower than that of the APC. This could be, in part, explained by market uncertainties which have made investors reluctant to invest in 5G.

Table 25: Comparison of leverage ratios

	R&D spending leveraged	Public sector expenditure	Estimated leverage ratios – R&D spent per £1 of public sector spending
5GTT	£210.0m – £366m	£159.0m	£1.32 – £2.30
Advanced Propulsion Centre[66]	£80m	£194m	£0.41
Biomedical Catalyst[67]	£248m – £350m	£141m	£1.76 – £2.48
Energy Entrepreneurship Fund[68]	£261m – £513m	£67m	£3.90 – £7.64

The Annex (the Sustainability Report) contains more information from interviews, BRs and project reports about further funding.

[66] Advanced propulsion centre: interim impact evluation (publishing.service.gov.uk).
[67] Normal dot (Rev02 January 2009) (ukri.org)
[68] Evaluation of the energy entrepreneurs fund (publishing.service.gov.uk).

6.3.2 R&D realisation

DCMS support has helped project realise progress, but some evidence shows that the support does not go far enough. We were told by a DCMS Portfolio manager that the programme would probably need another two or three years to move into the adoption phase. We were also told that the speed of progress made at a project level would depend on the approach to support.

32 of 36 (89%) of funded applicants have identified or are looking for further investment to develop 5G products/solutions and/or conduct further testing. 7 of 36 (19%) have identified funding, 12 (33%) have identified some funding and 13 (36%) have not yet identified follow-up funding[69].

Several respondents reflected on the lack of follow-up funding from DCMS to successfully complete 5G Trial projects to bring the solutions/products developed to market and identified this as a missed opportunity. The fact that many firms explored funding options, including from other DCMS funding opportunities, demonstrates appetite to further develop the use cases and solutions worked on during the 5GTT programme.

The types of external funding sources that funded beneficiaries are exploring and/or using are:

- DCMS Future Open 3D Networks Research Challenge (FONRC) programme
- Innovate UK Smart Grant
- Coast to Capital LEP funding - to expand the testbed facilities
- Venture capital funding

The interviewees relayed similar feedback. Some respondents noted that they were in the process of bidding for additional funding or had plans to try and raise additional investment from a number of sources. This included trying to access other governmental department grants, to venture capital initiatives to simply freeing up more resources internally for research and development activities.

The interviewees discussed further investment and funding plans without making specific reference to whether this was towards R&D activities. The investments towards continuing and developing the use cases worked on are clear early signs of the success of the programme. This increased R&D investment is key to ensuring that gains made extend past the programme lifetime and benefit wider industries and society from the outputs of this investment.

Some of the interviewed 5GTT project participants suggested that knowledge around government funding initiatives had led them to receive follow on funding as part of other government programmes such as the Open Networks Programme and FRANC initiatives. The table below shows that 24 of 211 the firms that received funding as part of the 5GTT programme went on to bid and successful win further funding from other DCMS programmes, specifically the Future RAN competition (FRANC) and the Future Open Networks Research Challenge (FONRC). These programmes are open and competitive. These other programmes were in part set up in part to build on the momentum that the 5GTT programme initiated. The relatively high take up of further DCMS funding by firms (11%), is evidence not just of the added awareness of investment opportunities but also of the need for further investment. Some projects have only recently concluded, and we may see some of these projects apply for further DCMS investment in the near future.

Table 26: 5GTT firms receiving follow on DCMS funding

Number of firms involved in 5GTT programme	Number of firms involved in DCMS follow on projects	% of 5GTT firms involved in DCMS follow on projects
211	24	11%

Source: BR sheets and information about FRANC/FONRC projects from UK5G and GOV.UK

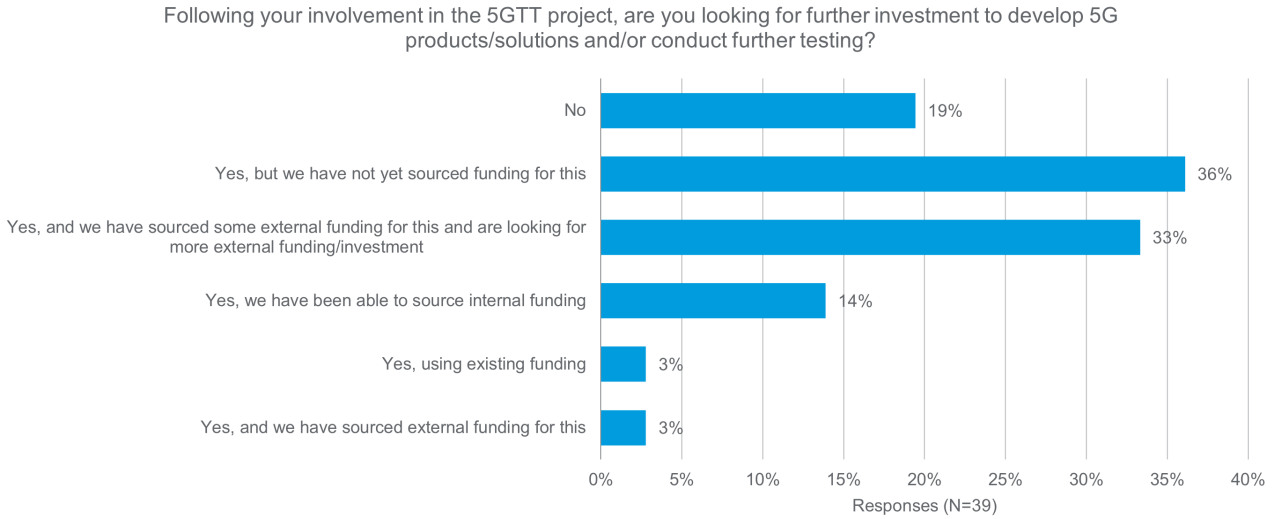
Beneficiaries are also using internal funding to continue to develop the infrastructure and use cases already in place and/or to bridge the gap to market commercialisation, and/or are hoping to source revenues from early customers. Where internal funding was invested, we were told that the projects had served as a sufficient proof of concept for the firms to be encouraged to put in additional financing of their own to fund their future research and

[69] All survey respondents answered this question on investment. Three selected more than one answer to this question.

development initiatives. One firm reported considering private investment in taking a share in the business and having explored a co-funded business model with large sector partners.

Some private sector interviewees indicated that their projects had demonstrated that the technology was not at a sufficiently mature enough stage to encourage them to undertake further investment. These firms did not feel sufficiently incentivised to undertake the risk that additional investment would present.

Figure 9: Further investment – Funded applicants



Source: RSM analysis of responses from the funded applicant survey

Data for 24 funded survey respondents suggests that a total of £20.7m was invested by these businesses in 5G related R&D in the past three years.

- One business invested £10m. This business has been active in deploying 4G and 5G technology for many years, including the first developed 5G core network in the UK and the provisioning of software solutions, support and engagement as part of this.
- Four of the businesses in the sample (16%) have not invested anything.

The survey data shows that the average investment made is £1.2m, which is, on average, 31% of the firms' investment in intangible assets (see table below).

Data on seven unfunded applicants suggests that five have invested in 5G related R&D, this includes one business that invested £20m. This is the above-mentioned unfunded company that was able to carry out their project using funding from an alternate external source and has brought their solution to market.

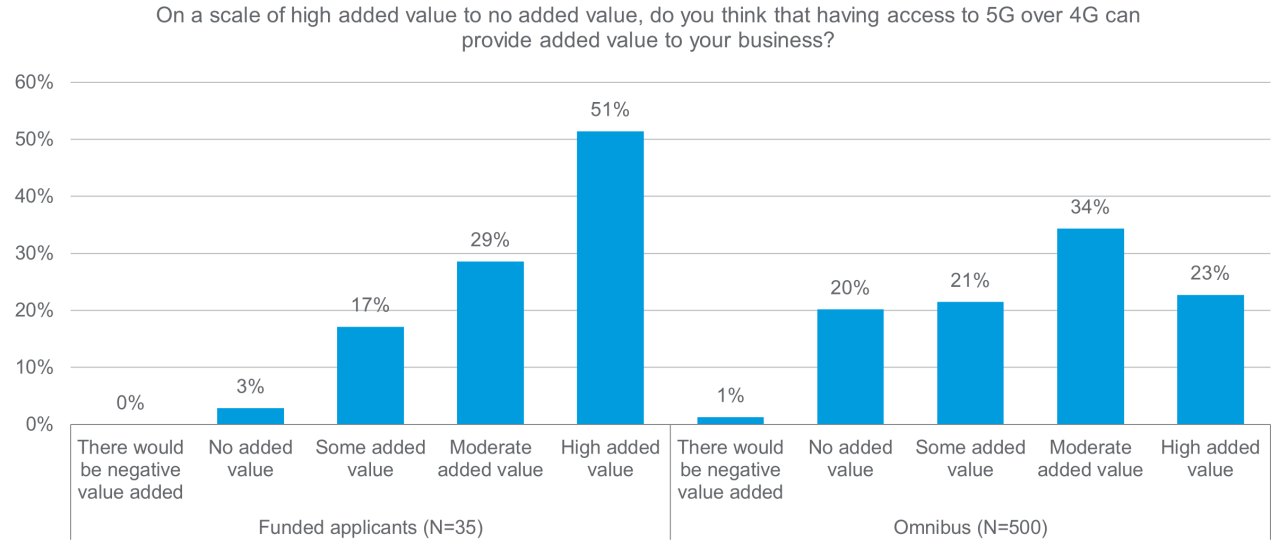
Table 27: Total investment in 5G related R&D in the past three years and investment in 5G as a proportion of investment in intangible assets – Funded applicants

	Total investment in 5G related R&D	Investment as a proportion of intangible assets
Average	£1,152,137	31%
Median	£325,000	20%
Min	£0	0%
Max	£10,000,000	100%
Total	£20,738,458	
N	**24**	**19**

6.3.3 Impact on added value and performance

28 of 35 (80%) of funded applicants feel that having access to 5G technology can provide **moderate to high value added** to their business (note that some of the funded applicants did not provide a response to this question). By comparison, 266 of 500 (57%) of the omnibus respondents are of this opinion. 9 of the 10 unfunded respondents indicate that 5G technology can provide moderate to high value added to their business.

Figure 10: Added value of 5G - Funded applicants and Omnibus survey responses



Source: RSM analysis of responses from the funded applicant survey and the Omnibus survey

The programme Theory of Change assumes that embedding 5G technologies in a firms' products and services can add value and result in an improvement in firms' performance overtime. At the time of evaluation some firms have brought solutions developed as part of the project to market; but it is too early to report on impact performance.

Evidence from interviews shows that there is scope of 5G to provide both efficiency and productivity gains. We asked project interviewees whether their projects were more focused on increasing revenue or profits, or more focused on improving efficiency or productivity

- 20 of 39 interviewees aimed to use 5G technology to increase productivity and efficiency
- 12 of 39 interviewees aimed to use 5G technology to increase revenues/profits
- 7 of 39 interviewees aimed to use 5G technology to increase revenues/profits and to improve efficiency/productivity

Some highlighted that improving efficiency/productivity usually leads to increasing revenues/profits.

The survey aimed to compare past growth rates with expected growth rates to see if the funded applicants have a relatively positive outlook on their economic growth. We find a substantial and positive difference between past growth rates and growth expectations.

The survey data shows that 7 of 20 (35%) funded applicants experienced zero growth in the past three years and the other respondents, 13 (65%), experienced positive growth in income over the past three years. A higher proportion (93%, 14 of 15) of the funded applicants that responded expect positive growth in the next three years. Just over half of the respondents, (55%, 11 of 20) expect that ten percent or more of their 2025 income will be dependent on 5G technologies. 30% (6 of 20 respondents) expect that future income will not be dependent on this. The average percentage of income that is expected to depend on 5G is 29%[70]. Some of the funded respondents did not provide an answer to this question.

[70] Only four unfunded applicants responded to this series of questions and these results are not reported due to the low "n".

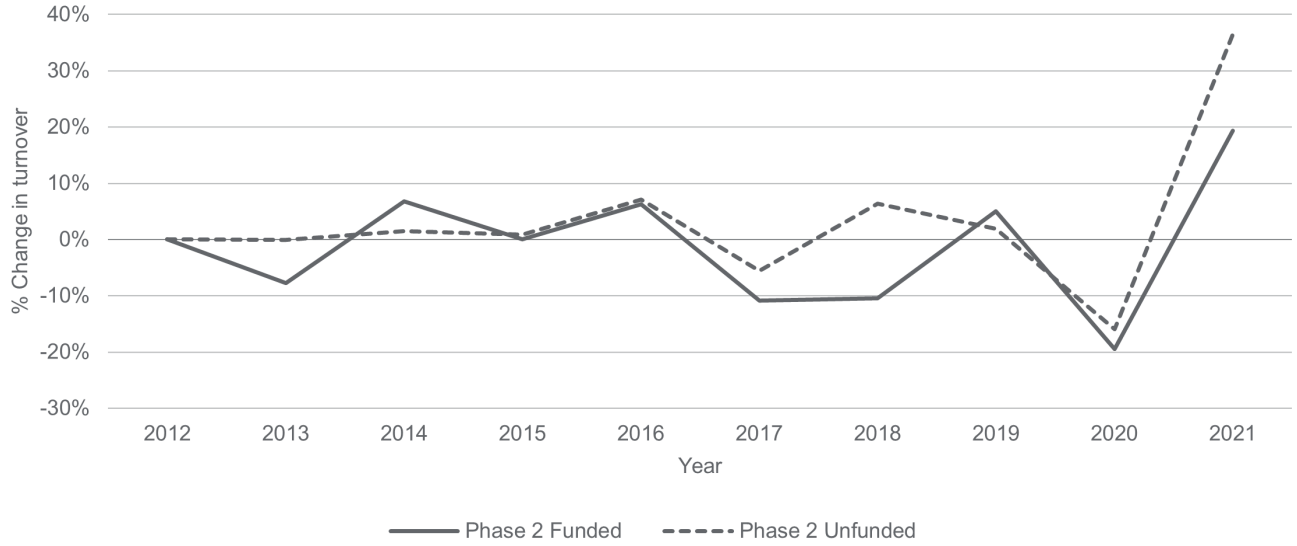
Table 28: Percent growth in income over the past 3 years and expected growth in income in the next 3 years – Funded applicants survey

	Growth in the past 3 years	Expected growth in the next 3 years	Percentage of 2025 income depended on 5G
Average	141%	25%	29%
Median	33%	10%	23%
Min	0%	0%	0%
Max	1000%	100%	75%
N	**20**	**15**	**20**

Figure 11 compares secondary data from Orbis on the year on year growth in average turnovers for funded firms and unfunded firms, for firms that took part in Phase 2. The groups show roughly similar trends in the baseline period up to 2016. Phase 2 funded firms experienced, on average, a negative growth in 2017 (compared to 2016), positive growth in 2019 (compared to 2018), followed by a sharp drop in growth in 2020 (compared to 2019). The data for the unfunded firms mirrors the drop in growth in 2020 (compared to 2019). All groups experienced a strong positive growth in 2021 (compared to 2020), which is the latest year for which we have data.

Having said this, we find that the funded firms show a negative growth in average turnovers while the unfunded firms show a positive growth in average turnovers in 2021, compared to 2016. The difference between the positive year on year growth and the negative growth in average turnovers when compared to 2016, for the funded firms, is likely exacerbated by gaps in the data. Further data limitations are discussed below.

Figure 11: Year on year growth in average turnover



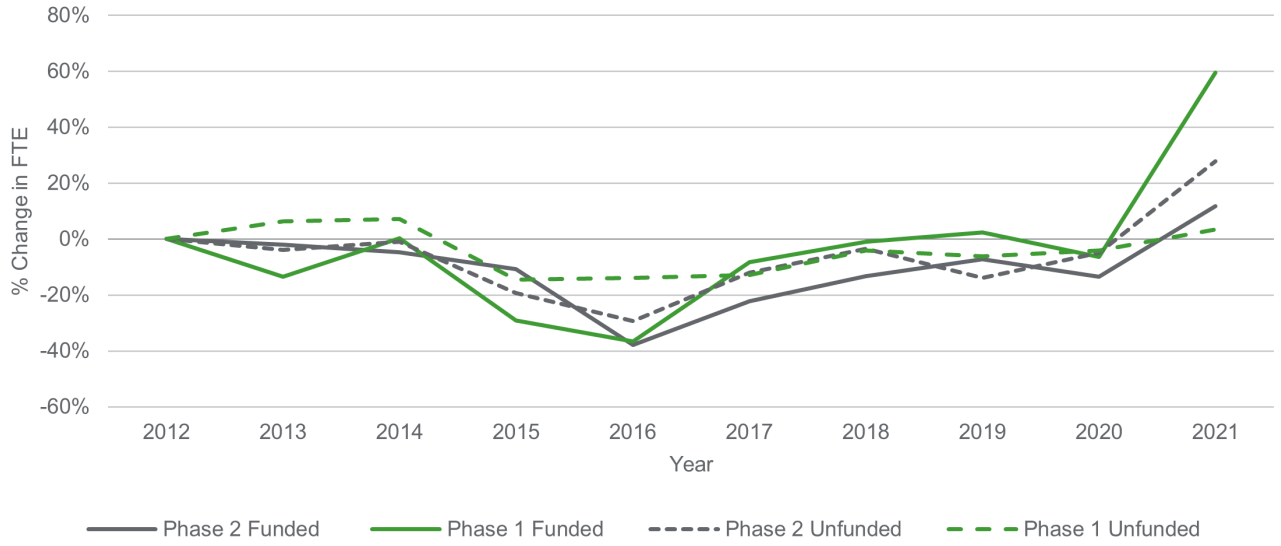
Source: Projects' Monitoring Information and RSM analysis of data from Orbis

Next we compare data on the year on year change in average Full Time Equivalent (FTE) employment for funded firms and unfunded firms, separating between firms that took part in Phase 1 and those that took part in Phase 2. The year on year Phase 1 trendline for the funded firms is similar with that of the unfunded firms from 2017 to 2020. For the Phase 1 funded group, the FTE growth changes from negative 4% in 2020 (compared to 2019) to almost 60% in 2021 (compared to 2020), as the sample drops from 52 to 34. A continuous sample of 11 firms shows negative 3% growth over the two consecutive years.

By means of comparison, the year on year growth of average FTE of unfunded phase 1 applicants is around 3% in 2021 (compared to 2020). The Phase 2 funded and unfunded trendlines follow a similar pattern from 2012 to 2021 and the unfunded group has a higher growth rate by 16-percentage points in 2021 (compared to 2020), which is

the last year for which data is available. Again, the year on year growth spike seems to be caused by variations in data availability. For a continuous sample of 25 firms, year on year growth in average FTE is negative 2% in 2021 (compared to 2020) for Phase 2 unfunded applicants.

Figure 12: Average growth in Full Time Equivalent employment



Source: Projects' Monitoring Information and RSM analysis of data from Orbis

Based on the turnover and FTE data from Orbis it appears challenging to draw conclusions on performance. We are not necessarily expecting to see significant differences between the Phase 2 funded and unfunded groups because time to impact is too short. For both Phase 1 and Phase 2 groups, missing data makes such a comparison problematic. Phase 1 participants may include firms that are relatively more established and ready to benefit from RD&I investment and this could explain why some firms experienced a high growth rate.

There are a few examples of firms that **experienced explosive growth in employment**. One interviewee reported that their firm had grown from a team of 30 to a team of 75 and another spoke about 10 new roles having been created (over the course of the project) and that this would not have happened without 5GTT funding. Over the longer term there is the possibility that these firms could make a disproportionate impact if their development trajectory continues.

The interviewee data also suggests that smaller firms were more likely to benefit from increased job roles created. Project participation led some of these firms to hire 2-5 staff to work on the 5G projects. New roles were created, amongst others, for technical engineers, to work on the infrastructure required. Marketing managers were recruited to help spread awareness about the new applications being developed. Whilst larger firms had more resources available, these firms also had competing priorities which meant that it was often smaller firms who had resources specifically focused on their projects. Both large and small firms had instances where they redirected existing staff to the 5GTT but for smaller firms it was more often the case that these redirected staff could devote more time to the programme.

Table 29: Overview of data availability – Turnover and FTE

		Phase 1 funded	Phase 1 unfunded	Phase 2 funded	Phase 2 unfunded
Population		65	60	141	150
Turnover	2018	25	26	50	53
	2018 onwards	12	19	34	33
	2021	10	19	40	43
FTE	2018	51	45	101	105

2018 onwards	27	35	70	69
2021	34	41	90	92

The final evaluation should look more closely at phase 2 turnover compared to unfunded, especially if more data becomes available. Focus should also be placed on growth outliers.

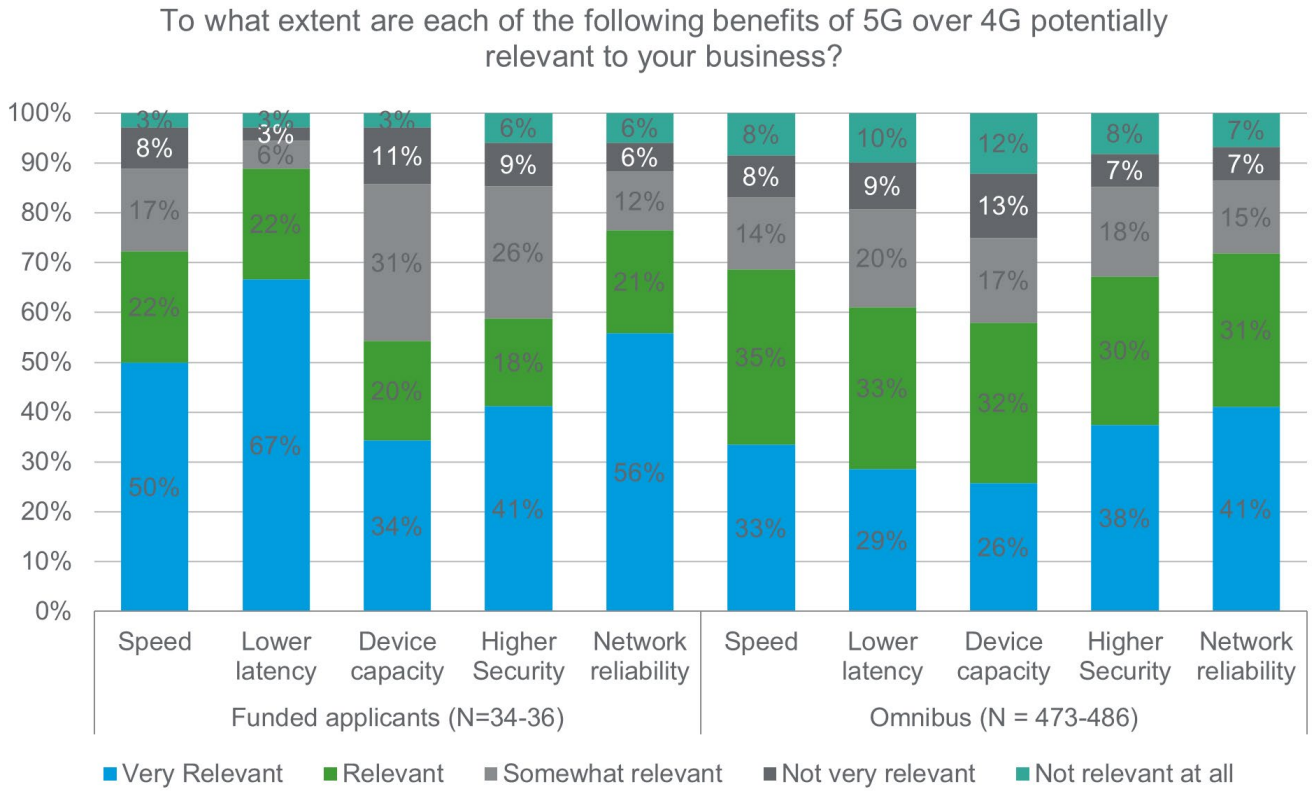
Perceived benefits of 5G compared to 4G

One potential barrier to accelerated deployment of 5G is a lack of awareness or interest in 5G technology amongst businesses which would undermine the market to 5G telecommunication providers and their appetite to invest. The data suggests however that funded and unfunded applicants as well as SMEs in the general population (omnibus survey respondents) see benefits of 5G over 4G as potentially relevant to their business. The data suggests that there is a general market readiness and/or interest to adopt the benefits of 5G by SMEs.

Amongst the funded applicants, only 5 of 34 (15%) or fewer respondents find aspects such as speed, lower latency, device capacity, higher security, network reliability not very relevant or not relevant at all. One interviewee commented that, on some aspects, 4G technology was better than the 5G technology but 5G did offer more reliability.

Amongst the wider population of SMEs surveyed (Omnibus) 25% or fewer respondents find any one of these not very relevant or not relevant at all. There is a substantial difference in the perceived benefits of lower latency between funded applicants and the Omnibus survey respondents, with 24 of 36 (67%) of participants seeing this as relevant, more than twice that, 29%, of the Omnibus survey respondents finding this very relevant. We expect that project participants are more knowledgeable about the specific benefits of 5G and this may explain some of the differences between survey responses. Evidence from both populations surveyed may be subject to optimism bias.

Figure 13: Benefits of 5G over 4G to funded applicants and Omnibus survey responses



Source: RSM analysis of responses from the funded applicant survey and the Omnibus survey

7. IMPACT EVALUATION - WIDER SOCIO-ECONOMIC IMPACTS

7.1 Summary

This chapter presents a first assessment of the benefits to wider society generated because of the 5GTT programme. This is because it will take more time for the wider benefits to diffuse across the wider 5G ecosystem and the overall economy. Overall, the programme has demonstrated some very promising early signs of how it has generated benefit to the wider economy across the areas identified as targets by DCMS.

This chapter builds on programme monitoring information and interview data as well as data from the Omnibus survey to a wider population of SMEs. In reference to the economic transmission channels identified in the programme Theory of Change (see Chapter 2) we find that:

Table 30: Summary of wider socio-economic impacts

Transmission channel	Evidence
Business and industry generation	18 company spinouts[71] were launched
Speeding up infrastructure rollout	At least 70 of the 107 (65%) networks deployed were still in use at the time of reporting. Information was not collected on the status of 28 networks. Data for the (other) 78 networks suggests that 90% of the networks were still in use.
5G ecosystem	Projects were able to enhance their knowledge and skills in deploying networks in a secure and resilient way and share this learning with the ecosystem. Projects have resulted in sustained collaboration: • 76 consortium members are continuing collaboration • 125 consortium members have begun collaborating with other organisations in the ecosystem • 25 projects have collaborated with other projects Increased awareness of 5G is helping increase overall business demand. 53% (265 of 500) of SMEs in the wider population have considered using 5G over 4G. The UK's international position is also seen to have improved as a result of the programme. However, the UK still has some way to go in terms of readiness for (wider) deployment compared with the small number of truly world-leading nations.
Cost avoidance, environment, welfare, wellbeing	Projects considered the environmental impact of their use cases, for example in transport. 5GTT has produced applications to improve health and wellbeing directly, and also to provide enjoyable experiences that people might not otherwise have access to.

Attribution of benefits to the 5GTT programme
We find that attribution is strong:

- Interviewees suggest that, without the programme, nowhere near the same scale of investment or development of 5G use cases would have taken place. This is particularly the case with rural communities and applications where 5G infrastructure investment has been lacking.
- The programme has played a critical role in feeding knowledge and skills into the wider UK telecoms ecosystem (see also Chapter 5). This is key to help establish the conditions for 5G deployment to drive efficiency and productivity, which is one of the two key programme objectives. We were told that UK universities have played key roles in helping to facilitate further advancement of 5G technologies and that 5GTT has made a positive contribution to the reputation of 5G.

[71] A spinout can also be referred to as a spin-off. Spinouts are the result of a company splitting off a section of its business.

7.2 Business and industry generation

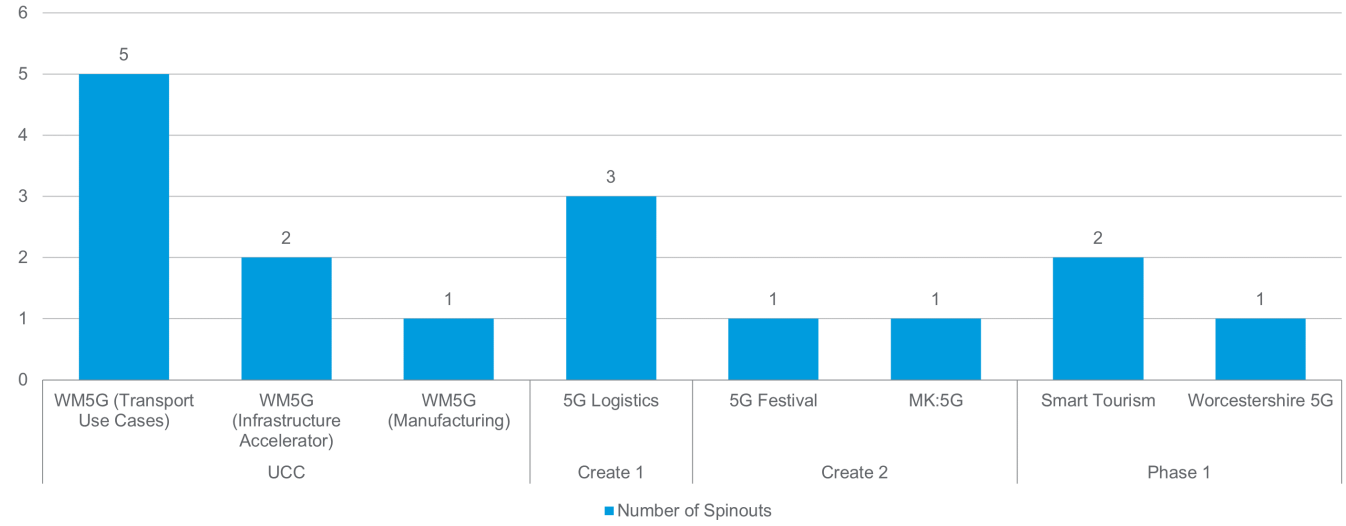
7.2.1 Generation of 5G activities beyond the scope of the programme

A review of monitoring information shows that 18 spinouts were created due to the 5GTT programme.

- Eight of the 18 spinouts were launched as a result of the West Midlands 5G project. For example, one of the five spinouts resulting from the WM5G transport use case project, involved further development of its 'predikt' use case in collaboration with dash cam engaging app developers. Three of the 18 spinouts were launched from the six phase 1 projects. For example, a member of the smart tourism consortium had two joint ventures planned as per the benefits realisation report.

It is worth considering that many of the projects did not look to generate a specific commercial product or service with many instead focusing on the provision of additional connectivity to previously underserved regions and populations. Based on this consideration, it seems fair to us to conclude that the programme has been relatively impactful in this area. Figure 14 below provides an overview of the distribution across the projects and categories.

Figure 14: Number of Spinouts Created by Project and Category



Source: Project Benefit Realisation Documents

One stakeholder commented that, by expanding the development of new technologies, techniques or tools for the telecoms industry, the programme has also expanded the UK technology industry. This may have demonstrated possibilities to generate change and it was said that the programme may have influenced other DCMS programmes like FRANC to become more targeted at developing a new industry in the UK.

7.2.2 Demand and supply certainty

DCMS monitoring information suggests that 75% of projects have demonstrated a significant positive movement towards a sustainable demand/supply certainty and/or new viable business models. The target had been for 60% of projects to demonstrate such improvement and this target was met by June 2022. As part of our analysis in chapter 4, we have considered; new products, services and industries and whether the networks deployed during the programme have been sustained.

Increased commercial certainty about 5G has wider impacts such as more consumer choice around products and services[72] developed and greater productivity and efficiency by existing organisations.[73]

[72] Deloitte Digital Consumer Trends 2020
[73] GSMA Mobile Economy Europe 2022

7.2.3 Increased industry participation

The interviewees noted that there was still a **massive challenge to scale 5G technologies because further technological development is needed.** If scale can be achieved through the support of Government action, amongst others, there will be incentive for further investment and participation from industry players and mobile operators. There is scope to build further on the achievements of the programme:

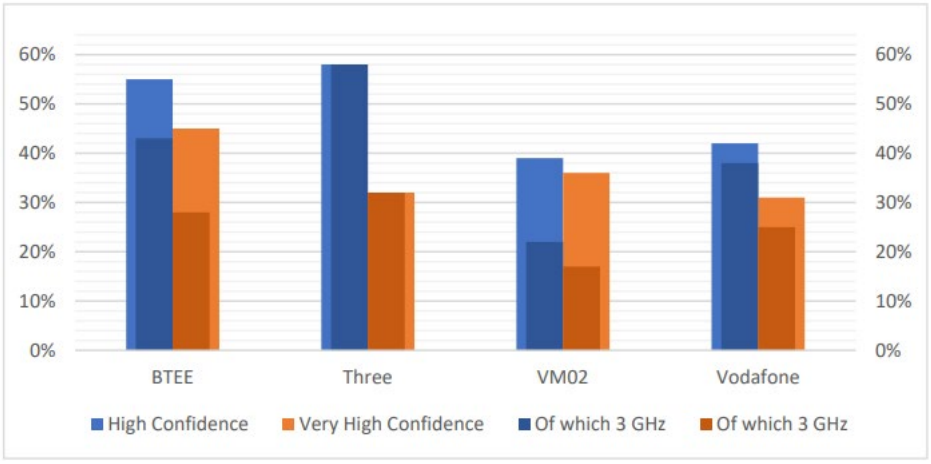
- An analysis of BR data shows that many cases did not reach a high TRL, close to commercialisation.
- Adoption needs to be encouraged industry-wide.

UK Government is pushing for greater involvement of vendors, suppliers, and users as part of the Open Network Research and Development Fund initiatives. Amongst other, the UK Telecoms Lab[74], led by NPL is providing a space for testing and advice.

7.3 Speeding up infrastructure rollout

5G is not rolled out everywhere but in 2023 many consumers can have access to 5G. The Connected Nations 2022 report (Ofcom) evidenced that 5G roll out has rapidly increased. The figure below shows 5G coverage of providers outside of premises, with Three providing the most extensive coverage at 58%. Coverage is reported to be supported by 5G deployments on ca. 12,000 sites, almost double the deployment reported in the 2022 Ofcom report.

Figure 15 MNO 5G coverage outside of UK premises, at High confidence and Very high confidence



Source: Connected Nations 2022 report (Ofcom)

We were told by DCMS that 5GTT may have influenced the early commercial roll out of 5G in the UK. Deployment of 5G across the UK is also assessed by Lifewire[75]

- The provider EE began the rollout of 5G in the UK in 2019 and 5G is now live in over 50% of the UK population. EE plan to cover the UK by 2028.
- Vodafone 5G launched in 2029 in just a handful of locations and has since expanded coverage to over 200 locations
- Virgin Media (in partnership with Vodafone) offers 5G services in the UK since 2021 and coverage is provided in 100 locations

The wider ecosystem survey asked about the extent to which the 5GTT programme and UK5G Innovation Network had increased the rollout of 5G technologies and 46% respondents said that it had improved it to some extent or a large extent. Note that only a small proportion of all network members were surveyed.

[74] UK Telecoms Lab - NPL

[75] Where Is 5G Available in the UK? (Updated for 2023) (lifewire.com), last updates January 2023

Over time, the programme is expected to contribute to increased 5G deployment by wider stakeholders and diversification of 5G network providers. Infrastructure rollout increases the capacity for productivity benefits to occur by easing constraints. This in turn increases the ability for wider stakeholders to use 5G for commercial activities, which is necessary for the programme to result in large benefit gains.

At least 70 of the 107 (65%) networks deployed were still in use at the time of reporting and thereby, were sustained beyond the funded projects. This has allowed for the continued use of the solutions that were developed to run on these networks. Further information on the continuity of these networks can be found within the sustainability report (see Annex).[76]

There are also seven projects with plans to upgrade or improve the networks they installed.

Due to a small number of suppliers, a supply quality issue led to four projects scaling back their planned activities due to a lack of alternatives. These issues were not resolved in the lifetime of the project, but the companies involved have either installed networks, or announced plans to install them, after the projects ended. Seven networks were being shut down or removed.

Overall, this is an excellent demonstration that wider benefits to the economy have continued. The persistence of these networks highlights that the capital adoption and effective capital use transmission channels are being manifested. These transmission channels also feed into the general gain accrued to wider society by the increased productivity unlocked along with new business opportunities which originate because of these 5G networks.

Table 31: 5GTT networks deployed and current network status

	Number of 5G networks deployed	Current network status			
		Still in operation	Shutdown/ dormant	Removed	Unknown*
Number	107	70	7	2	28
%	100%	65%	7%	2%	26%

** Some projects did not provide information about the current network status in reports and the question about current network status was added to the topic guide after some interviews had already taken place.*

7.4 5G ecosystem

7.4.1 Assessment of security standards and best practices of 5G technology

The programme presented an opportunity to investigate and improve security standards for deploying 5G networks. This has links to the external ecosystem, as standards depend on there being a critical mass of users that can benefit from the standardisation. Verification that the standards or best practices offer appropriate security models for 5G networks, improves the ecosystem confidence. Trust in the security and resilience of networks further supports deployment, especially in sectors such as healthcare where data security is important and reduces risk of harm from security breaches.

The programme allowed projects to learn about installing and correctly configuring networks to realise safety and security benefits. Setting this up correctly means that features such as network slicing can be used to differentiate different types of traffic and apply different security levels to them. Five interviewees commented that they were able to see the security benefits of standalone networks, again because they could be configured for specific situations and uses. This provides greater security control.

Eight projects in total said they had a specific focus on security (i.e. had a use case around security or specific things about security that they wanted to learn). Three other project interviewees reported that security had becoming an increasingly important feature over the course of the programme – for example the test networks we interviewed both stated security was not something they considered at the start but it had become an area of focus

[76] Annex, Sustainability Report.

more recently. Security is also being given more prominence in other more recent DCMS programmes e.g. FRANC.

Cyber Security Consultants, the NCC group, produced a security narrative report on the project which covers cyber security aspects of the programme in more depth. The report says that DCMS provided some security guidelines to funded projects and the TDAs were helpful in ensuring the projects had more of an impact on higher levels of security activity than there might have been without them. Overall, the report is positive about the security aspects of the 5GTT programme – DCMS were helpful in providing guidance and support around security to projects and the collaborative aspects of the programme were useful in sharing learning around this. However, security was less important to projects than the overall demonstration of the use cases and larger organisations did not always engage as fully as they could have done. There was also considerable variation around the technical readiness of equipment used, including security features. Recommendations for improvement included:

- Raising the level of expectation on security for future projects;
- Better use of existing security risk assessment tools and agile risk management;
- Providing examples from 5GTT projects around physical security risks for private networks;
- Wider use of third party assurance; and
- More engagement on security with large organisations (especially MNOs).

7.4.2 Enhanced sustainability of the 5G ecosystem

The creation of a 5G ecosystem is crucial in ensuring that external economies of scale can be generated. The improved readiness of 5G technological infrastructure is expected to:

- Lead to lower average costs for firms
- Create agglomeration benefits

Chapter 3 identified at the start of the 5GTT programme the 5G ecosystem in the UK may not have been large enough to absorb the funding from the 5GTT programme, but interviewees from all stakeholder groups reported that overall, the ecosystem has developed considerably. For example, one interviewee noted that the project helped to expand a 5G ecosystem which was in its infancy before.

The table below shows the continuing collaborations and further collaboration opportunities that have arisen as a result of the 5GTT programme, which suggests the ecosystem has developed considerably and there are further collaborative activities planned in the future.:

- 76 consortium members are continuing collaboration
- 125 consortium members have begun collaborating with other organisations in the ecosystem
- 25 projects have collaborated with other projects

DCMS has aimed for 50% of programme participants to have engaged in further 5G related activities beyond funded projects. Data from June 2022 indicates that this target was met, with monitoring data suggesting that 100% has engaged in further 5G related activities.

Table 32: Overview of collaboration activities

Project names	Number of consortium members continuing collaboration	Number of wider collaborations (during and post-project)	Collaborations with other 5GTT projects
5G CAL	All consortium members[77]	7	Connected Forest
5G Edge-XR	3	Potential stakeholders from 3 sectors[78]	Green Planet
5G Festival	3	5	No information

[77] The consortium is seeking further funding for a 'phase 2' of the project
[78] Architecture, Engineering, and Construction

Project names	Number of consortium members continuing collaboration	Number of wider collaborations (during and post-project)	Collaborations with other 5GTT projects
5G Logistics	4	No information	No information
5G Ports	Some consortium members[79]	No information	No information
5G AMC2	3	1	Eden Universe, 5G Logistics
5GEM	No information	4	5G Encode
5G Encode	4	No information	5GEM, 5G FoF
5G Wales Unlocked	All consortium members[80]	No information	No information
Connected Cowes	2	No information	Live & Wild, VISTA
Connected Forest	2	5[81]	VISTA
Eden Universe	4	7[82]	Liverpool 5G, Green Planet 5G, Connected Cowes, 5G Rural Dorset
Green Planet 5G	No information	1	Eden Universe, Edge XR
Live & Wild	3	21[83]	MANY, VISTA
Liverpool 5G Create	All consortium members[84]	2	Eden Project, 5G Rural Dorset
MANY	11	No information	No information
MK:5G	2	No information	WM5G, VISTA
MONeH	1[85]	2	New Thinking
New Thinking	6	5	MONeH
5G Rural Dorset	5	No information	WM5G, New Thinking
Smart Junctions 5G	No information	9	WM5G
VISTA	No information	No information	MK:5G
West Mercia 5G	Some consortium members[86]	No information	MONeH, MANY, 5G Rural Dorset
WM5G (Healthcare)	No information	2	No information
WM5G (Infrastructure Accelerator)	No information	Some business collaboration[87]	No information
WM5G (Transport Road Sensors)	No information	2	No information
5G Rural First	9	14	Liverpool 5G testbed, 5GRIT, AutoAir
5GRIT,	No information	3	5G Rural First

[79] Exact number not specified but the collaboration would likely focus on the further development of the project's 'predictive maintenance' use case
[80] Consortium members have signed a Memorandum of Understanding to continue working together post-project.
[81] Including working groups
[82] Including working groups
[83] All external collaborations were during the projects
[84] Consortium members intend to continue maintaining the network deployed during the project
[85] No information of inter-consortium collaboration but one member is set to join a new project consortium in 2022
[86] Nothing firm, but interview indicate an intention by some consortium partners to stay in touch and they may work together on future projects
[87] New environment was built, called Sitenna. This resulted from business-to-business collaboration. Refer project's BR for further details.

Project names	Number of consortium members continuing collaboration	Number of wider collaborations (during and post-project)	Collaborations with other 5GTT projects
AutoAir	No information	6	5G Rural First, Worcestershire 5G Consortium, 5G Smart Tourism, Liverpool 5G testbed
5G Smart Tourism	No information	3	AutoAir
Worcestershire 5G Consortium	No information	14	Liverpool 5G testbed, AutoAir
Liverpool 5G Testbed	14	12	5G Rural First, Worcestershire 5G Consortium, West Midlands 5G, AutoAir
Summary	76	125	25

Source: BR sheets and Stakeholder Interviews

7.4.3 Demand for 5G

Interviewees from funded and unfunded projects and the wider ecosystem agreed that the UK was still at a relatively early stage of their 5G journey, but demand was growing and there were concerted efforts across the press and programmes such as 5GTT to raise publicity around the benefits of the new technology. Stakeholders noted that demand for 5G varied between businesses and the wider public. We were also told that certain industries had higher demand for 5G and accompanying technology than others. From speaking to consortiums members we find that demand by businesses and consumers is inhibited because:

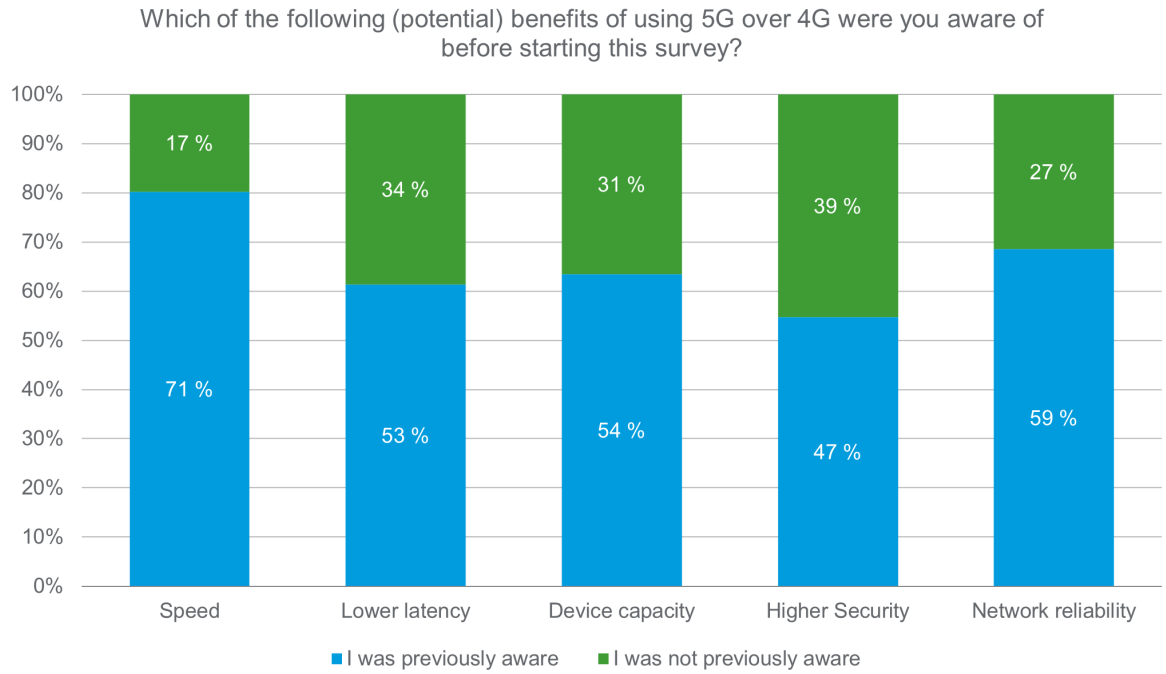
- There are problems with the framing of what 5G is and selling it to the right market: One respondent noted that many individuals just saw 5G as a faster form of 4G. Another commented that even though they were involved in speaking with various individuals across his industry that there was not a clear definition of what a 5G network actually was. For most people 5G was simply something which was deployed in the background without much additional awareness and more needed to be done to inform people about how the technology is helping to improve outcomes. Others thought that 5G in the UK was being used as early-stage marketing for some of the wireless network operators and that the advertising of 5G was not being carried out in a way which helped the wider public to understand the benefits.
- Based on our engagement with high-level stakeholders, we have heard that emphasis is needed on the development of private networks, as this is where the productivity gains are and how businesses can drive innovation, output and growth.
- Much more is needed to rollout 5G more widely to rural locations, due to a lack of market incentives. 5GTT has made a positive contribution by showing what is possible in rural areas (as well as across a diverse range of sectors). Nevertheless, rollout is being prioritised in more populated areas (see section 7.5.2).

Demand by businesses

5GTT consortiums members spoke about the primary need for reliable connectivity, to allow the wider benefits from the network to be used. Increased awareness through the use cases and application of 5G developed in the 5GTT programme was thought to help increase overall business demand.

353 of 500 (71%) respondents to the Omnibus survey of SMEs reported having been aware of the increased speed that 5G technology offers. A majority of respondents also reported having been aware of benefits such as low latency, device capacity and network reliability. Knowledge of the benefits of 5G over 4G such as speed amongst unfunded applicants is higher than the Omnibus survey respondents (all of the ten unfunded applicants that contributed to the survey reported to have been aware). Interestingly, higher security and network reliability ranked relatively higher for the omnibus responses, implying stability of service is a priority.

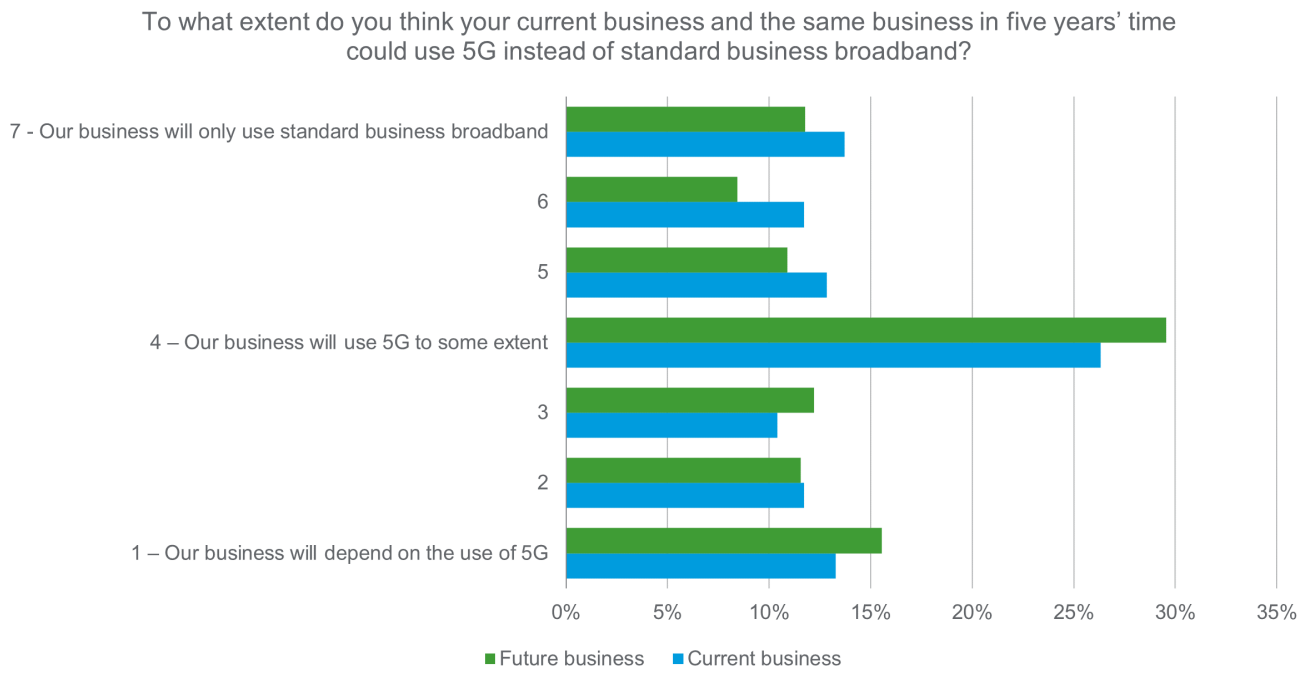
Figure 16: Prior knowledge of benefits of 5G over 4G Omnibus Survey responses



Source: RSM analysis of responses from the Omnibus survey

13% (60 of 452, excluding those that responded 'unsure') of the Omnibus survey respondents suggest that their current business is dependent on 5G technology and 16% (70 of 450) expect that their business will be dependent on the use of 5G technology in the next five years. By contrast, 14% (62 of 452) suggest that their current business only uses standard business broadband and a slightly smaller percentage (53, 12%) expects that this will be the case in five years' time.

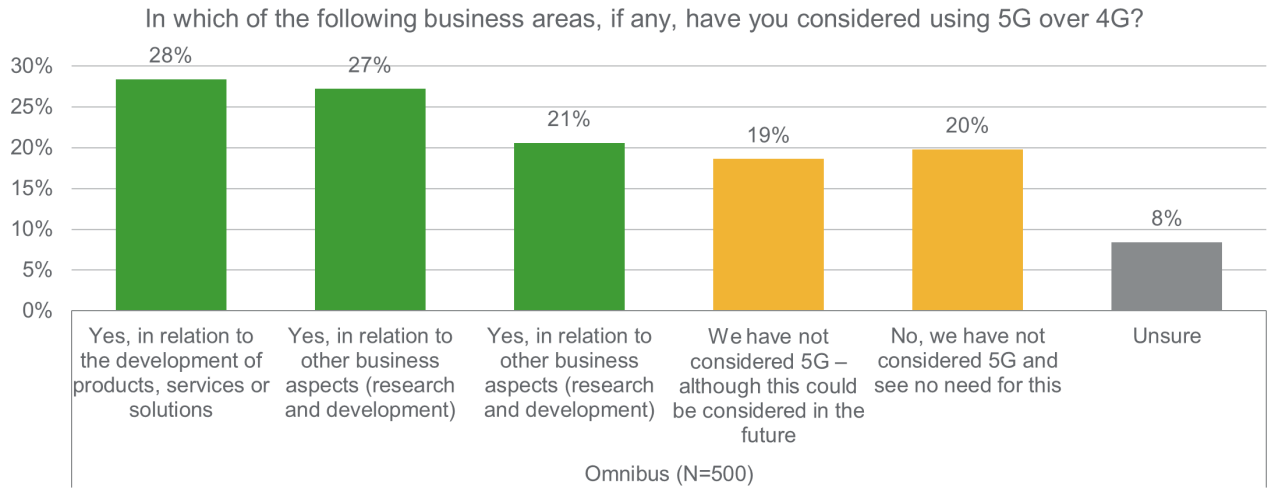
Figure 17: Dependency on 5G technology - Omnibus survey responses (N=500)



Source: RSM analysis of responses from the Omnibus survey

53% (265 of 500) of omnibus survey respondents have considered using 5G over 4G, with some respondents tagging multiple business areas where 5G could be of value (development of solutions – 28%, improvement of internal processes – 27%, other business aspects – 21%). Only 99 of 500 (20%) of Omnibus survey respondents see no need for 5G technology.

Figure 18: Consideration to use 5G over 4G - Omnibus survey responses



Source: RSM analysis of responses from the Omnibus survey

Demand by consumers

Many interviewees (consortiums members) were unsure about the level of 5G demand amongst the wider public, as their use cases had resulted in limited interaction. However, there was the sense that understanding the differences between technology generations was less important to the general public than ensuring good connectivity levels. This finding aligns with that of a poll of 31,600 individuals[88]

- 73% of people are not proactively seeking to upgrade their network but most expect to receive 5G anyway in the future and 5G is being standardised across data plans
- 5G does not drive purchase decisions at the consumer level, with only 9% of those polled ranking 5G as the most important feature of a new smartphone

One interviewee did note that younger people may have more understanding of the nuances of different generation technologies than older individuals. This demand for higher capabilities to access data on mobile devices was an important aspect for consumers and some interviewees did perceive the demand from the public to be higher than for businesses.

Awareness of 5G from the wider public may have become higher today than it was three to four years ago but data from Deloitte (2022), for the UK, shows that 51% of people agree with the statement that they cannot tell the difference between 4G and 5G[89] and the research suggests that this lack of awareness could be a reflection of the lack of interaction of people with mobile operators (which was affected by the pandemic).

7.5 Impact on UK's reputation as a leading 5G nation

7.5.1 UK's reputation as a centre for R&D

The 5GTT programme aimed to improve the UK's reputation on 5G, creating opportunities for investment in developing new 5G technologies in the long term. Interviewees were overwhelmingly positive on this aspect. Interviewees noted that the research side is well advanced with universities playing key roles in helping to facilitate further advancement of 5G technologies.

[88] Deloitte (2022) 5G Mainstream adoption | Deloitte Insights
[89] Deloitte (2022) 5G Mainstream adoption | Deloitte Insights

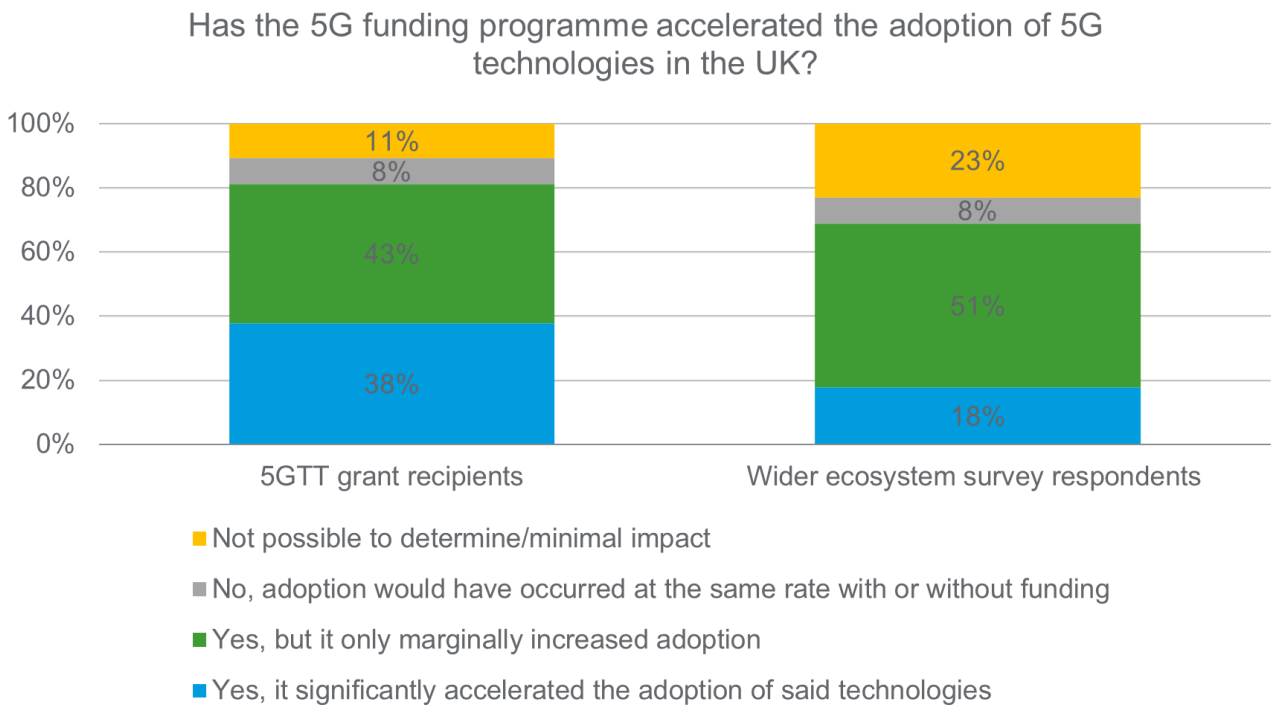
University rankings suggests that five UK based universities are in the top 50 of the world ranking in the field of telecommunications (based on citations)[90]. The Universities are University of Cambridge, University of Edinburgh, University of Southampton, University of Surrey, and Imperial College London[91].

Interviewees noted how the UK was great at developing new applications of 5G and exploring business models to use 5G. Thought leadership aspect was noted as an area where the UK was ahead with one interviewee noting that the 5GTT programme had pushed the UK forward three to four years further than they would have been had the programme not taken place. In particular, the programme helped some stakeholders to attend international conferences and other events. Some comments were made about how the UK was certainly not at the finished stage and that more R&D was needed but that, when it comes to R&D, the UK still seemed to be ahead of the chasing pack.

7.5.2 Deployment levels in the UK

The figure below provides a summary of the perceived impact of 5GTT on accelerating the adoption of 5G. 38% of grant recipients thought that the programme had significantly accelerated adoption vs 18% of those in the wider 5G ecosystem in the UK that responded to the UK5G innovation network survey. 11% of the 5GTT grant recipients and 23% of the wider ecosystem survey respondents thought that programme has had minimal effect on the adoption of 5G in the UK.

Figure 19 Impact of 5GTT on the accelerated adoption of 5G technologies in the UK



Source: UK5G Innovation Network Survey Sep 2022
(Note: N=133)

There is a mixed perception amongst interviewees about the UK as a leading 5G nation when looking at the levels of deployment. 40 of the 79 interviewees were positive about the role DCMS played in improving levels of deployment. One interviewee noted that the UK was in the top 3 in Europe and the top 5 globally regarding deployment. Another noted that the UK was on the leading edge of deployments of 5G and was progressing up the

[90] World's 100+ best Telecommunications universities [Rankings] (edurank.org)
[91] A comparison of changes over time at this level of granularity has been more difficult to source. https://www.topuniversities.com/ provides data for broad subject areas such as electrical, and electronic engineering. These rankings show that the University of Surrey remained at 101 of 151 between 2020 and 2023 and the rank of the University of Cambridge fell from 4 to 5.

global rankings. Some respondents thought the UK was focusing more on urban areas and that more needed to be done to pay attention to rural area deployment, an area which the 5GTT project was looking to address.

Among the commenters with more negative perceptions of the UK's readiness for 5G deployment, many noted that the level of quality of UK 5G networks had a long way to go for them to be comparable with leading nations. The infrastructure was simply not in place and that it would take a long time and a concerted effort for availability of 5G to be present across the UK.

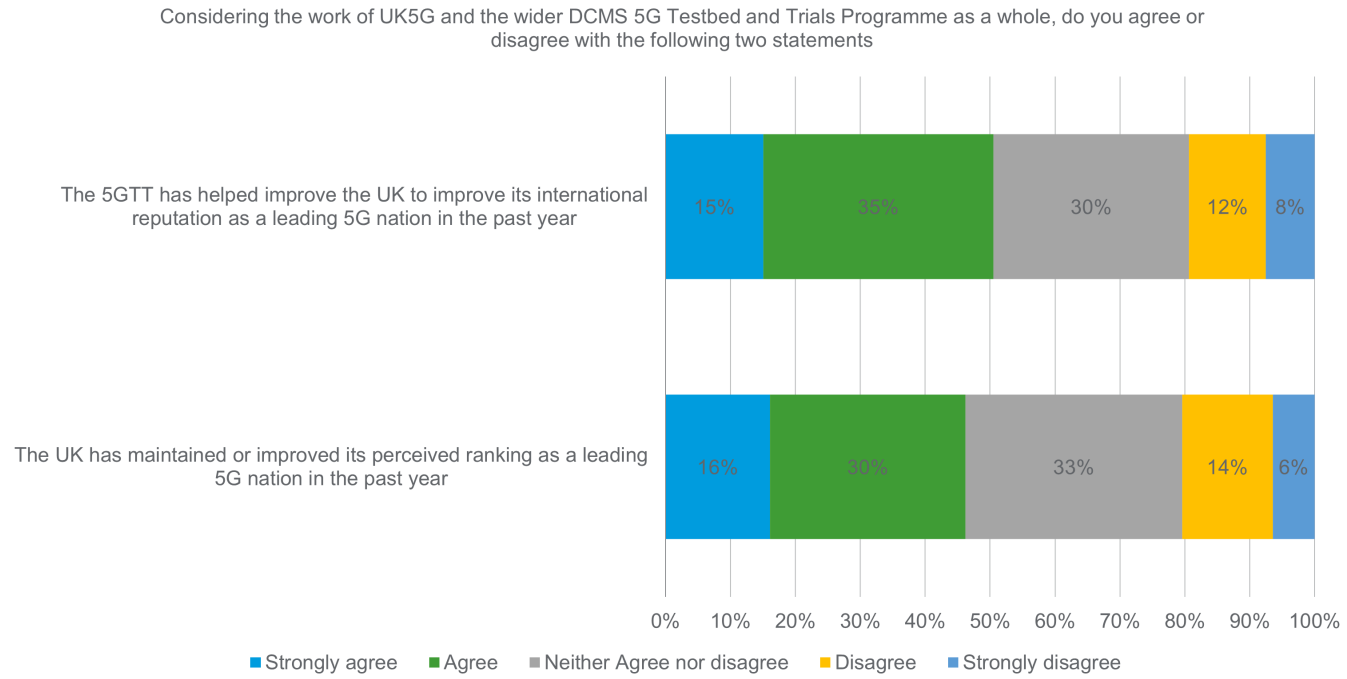
7.5.3 UK reputation as a leading 5G country

There were nearly 30 responses to our interview questions about the reputation of the UK as a leading 5G nation and a mix of opinions emerged:

- Some respondents were unsure of where the UK lay in the global pecking order as much of the focus on 5G through their experiences had been industry specific and they did not have knowledge of what other nations were doing in their respective areas.
- The majority felt the reputation of the UK had improved due to the programme. Events hosted by DCMS and UK5G and the large amount of research in this area carried out by UK academic organisations were effective in improving the UK's reputation internationally.
- Commercial applications of 5G technology were also noted as an element where the UK had been lagging previously and which had subsequently improved. Around a quarter of the respondents went so far as to say that the UK was perceived as an industry leader with regards to 5G. Even respondents who disagreed with this thought the programme had moved things forward and that the desire to be a leading 5G player was apparent.
- Two interviewees thought the UK was strong on thought leadership, but weak on implementation. Another thought work was being conducted in silos and that a coordinated strategy with telecoms providers was needed to create a homogenous network across the country.

The UK5G survey asked about the reputation of the UK on 5G and the results (shown below) indicate that the UK is progressing as a nation at the forefront of developing 5G technologies and that the 5GTT programme has helped to improve this reputation. Just under half (46%) thought that the UK had maintained or improved its ranking as a leading nation over the past year, although 50% said that they thought the 5GTT programme had helped the UK improve its reputation. DCMS set the target for the majority of respondents to agree with the statement that "the UK has maintained or improved its perceived ranking as a leading 5G nation in the past year" and, in view of the evidence, this target has not quite been reached.

Figure 20: Impact of the UK5G network on the UK's international reputation



Source: UK5G Wider Ecosystem Survey September 2022, Note: N=93

Secondary data on UK reputation for 5G

It is hard to identify a consistent metric for the UK's international reputation on 5G but there are several free sources that track how different countries are doing on deployment and other metrics such as upload/download speed.

- Ookla places the UK in its top 15 list for 5G availability (based on number of 5G ready handsets).[92] They also produce a global map which shows around 10,000 commercially available 5G networks deployed in the UK currently. This shows 132,031 commercially available networks around the world which means that around 8% are in the UK. The map also shows several countries where there are currently no commercial 5G deployments. This suggests the UK is among the leading 5G nations.[93]
- Viavi also produces an annual report which tracks how many cities within countries have commercial 5G coverage available and the most recent edition of this places the UK fourth behind China, the USA and South Korea. This is a less useful indicator as it focuses specifically on urban deployment and does not show the proportion of cities covered within each country.[94]
- GSMA also tracks different mobile technologies. The technology mix for Europe in 2022 was 11% 5G, which places the region behind North America and China.[95] Within Europe the UK has the highest proportion of 5G in its mobile technologies mix (7% in 2021, anticipated to increase to 61% in 2025).[96]
- Other sources e.g. Open Signal do not include the UK in their list of top 15 countries for 5G deployment or other network performance metrics that they track.[97]

When these sources are considered together, this suggests the UK is quite high in the current global rankings but countries such as the USA and South Korea are ranked more highly. This is consistent with the opinions of interviewees about which other countries were leading 5G nations.

[92] https://www.ookla.com/articles/state-of-worldwide-5g-2022
[93] https://www.speedtest.net/ookla-5g-map
[94] https://www.viavisolutions.com/en-us/literature/state-5g-deployments-2021-posters-en.pdf
[95] GSMA The Mobile Economy 2023
[96] GSMA The Mobile Economy Europe 2022
[97] https://www.opensignal.com/2022/06/22/benchmarking-the-global-5g-experience-june-2022

7.5.4 Changes in the past 5 years

The UK is investing in the diversification of UK telecommunication supply chains and has set out a strategy to realise this[98]. Investment in the Open Networks Research and Development Fund is a key part of this change. Also, in 2020, the UK Government announced that Huawei will be removed from the UK's 5G networks by the end of 2027[99]

11 interviewees answered our question about how the reputation of the UK had changed in the past five years[100].

- The majority agreed that the profile of the UK had risen in this time. Interviewees noted that the 5GTT programme helped enhance the perception of the UK over this timeframe, and the UK has been more successful on 5G than it was when 3G and 4G technologies were being deployed.
- The emphasis moving from university research to commercial applications was seen as an important next step in taking theoretical applications of 5G and using them to generate real commercial uses. Some interviewees indicated that they did not even know about 5G five years ago, indicating quite how much they had learned over this window of time. The skills acquired over this time and higher levels of awareness provide the basis for the UK to build on progress which has been made.

7.6 Spillover benefits into sectors and areas

The overall programme aims were to increase the deployment of networks and demonstrate use cases for 5G in different business sectors. But there were expectations for further spillovers from this work, including environmental benefits (especially from transport use cases) and other benefits for society, if the programme were rolled out more widely.

7.6.1 Environmental Impacts

The environmental impact of the programme was an element which was considered by DCMS in programme objectives. Within the case studies found in the Annex we detail how many of the projects had use cases which specifically looked to reduce the carbon footprint and reduce the environmental impact of previously utilised processes.

King's College London (KCL) and University of Strathclyde interviewees both highlighted that 5G networks were potentially more energy efficient, depending on how they were configured. KCL reported energy efficiency improvements of 30-40% with some of the radio equipment they had deployed compared to previous network generations. Replacing 3G networks with 5G would remove the need for fans and other energy intensive equipment. Liverpool 5G Create also said that the lessons learned on the early equipment they used fed into the development of next generation kit to make this more efficient.

Across the interviews we conducted with 5GTT stakeholders, there were over 25 responses on how the programme engaged with generating improved environmental outcomes. When summarised, the data suggests that 13 of 37 projects (35%) have had environmental impacts including traffic and travel improvements, travel cost savings from using 5G to allow for more remote working, and improved use of assets or assets maintenance.

- Reduce emissions in transport – The WM5G transport cases had a number of environmentally focused use cases. These ranged from looking to put in place 5G technology to make travel on public transport more attractive to the wider public, to putting in place technology to reduce the number of emissions carried out by transport vehicles. Traffic and travel improvement were also a focus of the project CAL, MK:5G, Smart Junctions, 5G Logistics, Liverpool 5G Create, and Live and Wild. These efforts align with the UK Transport Decarbonisation Plan[101]
- Support for farmers to become more efficient – Interviewees from rural projects noted implications of the use cases for farmers. It was reported that 5G could help farmers reduce the use of fertiliser.

[98] 5G Supply Chain Diversification Strategy - GOV.UK (www.gov.uk)
[99] Huawei to be removed from UK 5G networks by 2027 - GOV.UK (www.gov.uk)
[100] Note that not all interviewees were asked this question.
[101] Transport decarbonisation plan - GOV.UK (www.gov.uk)

- Reduce need for travel – Interviewees representing the projects AMC2, Factory of the Future, Wales Unlocked, and 5G Festival described specific use cases which were designed to reduce the amount of travel needed, which can reduce carbon footprints and could also generate other non-environmental benefits.
- Re-use of existing telecommunications infrastructure – In some instances (Factory of the Future, West Mercia, Edge-XR, MONeH), the use cases were carried out on existing 4G infrastructure which had been upgraded to carry out 5G applications. The re-use of existing infrastructure may help demonstrate less materially intensive avenues for implementing 5G technology .

7.6.2 Wider society impacts

5G technologies have further enabled the development of applications to improve wellbeing as part of wider impacts, but also to provide enjoyable experiences that people might not otherwise have access to and might be willing to pay for.

Data suggests that more than half of the projects (51%) are generating wider societal benefits (see chapter 5 for a more detailed analysis). Amongst the remaining projects who have not realised any wider benefit yet, ten noted that they see the potential for these wider benefits to be realised in the future. The realisation of such benefits can be evidenced as part of a future evaluation. As the programme has only recently concluded, this is a very encouraging early sign of the 5GTT exhibiting the very wider societal benefits that it was designed to cultivate. These wider benefits are designed to increase welfare across regions particularly those who had previously been underserved, improving societal wellbeing overall through new business and service opportunities.

Table 33: Wider Benefits arising from Project

	Total Number of Projects	Wider Benefits	
		Yes	Possibly
Number	37	19	10
%	100%	51%	27%

Source: Benefits Realisation

Examples of projects that directly improved the wellbeing of users include

- Liverpool 5G and West Mercia were both directly focused on using 5G for health and social care use cases (remote visits by health workers to care homes)
- Projects such as Connected Forest, Connected Cowes and Eden Universe, which developed AR and VR experiences which people found enjoyable.

7.6.3 Additional spillovers: adoption in other sectors or contexts

Around two-thirds of the projects focused on developing 5G technology for specific ‘edge’ applications in a particular industry or sector, and some of these applications can be applied more widely. For example, one of the projects developed a camera and mounting device to capture live yacht racing footage because the devices available on the market could not do this. The device they have built is robust and has a long battery life and it has applications beyond yacht-racing (e.g. it has potential uses for the construction industry).

A few 5GTT projects inspired spinoff research testbeds and innovation centres. For example, the 5G Connected Forest project inspired the development of a new innovation centre in Nottinghamshire which hosts a private 5G network to further research 5G applications and use cases. Apart from this, the project also inspired UK’s first 5G based career programme, focussed on researching how 5G would transform different sectors such as care, education, construction, and hospitality, among others. This careers programme is now being trialled in multiple academic institutions in Nottinghamshire and is focussed on preparing students for the change 5G would bring in their careers across different sectors.

8. VALUE FOR MONEY ASSESSMENT

8.1 Summary

Within this chapter, we set out a Value for Money assessment.

We find that DCMS has been well resourced and was actively involved in running the programme. The full running cost of the 5GTT programme was 13.5% of total funding allocated (£140.1m), which seems high to us when comparing this result with that of other programmes.

Overall, we find that there are significant benefits that are expected to be realised from the 5GTT programme, compared to the relative costs. The projects involved in the 5GTT programme have been successful to varying degrees, ranging from demonstrating proof of concept, to adopting process innovations and bringing products/services to market. All of these illustrate the potential for wider impacts to occur. The full benefits are yet to fully materialise and may take place over many years. This is backed by wider literature which places the impact of 5G on the global economy anywhere between £1.08 trillion[102] and £1.91 trillion[103] and on the UK economy at £43 billion[104] till 2030.

At this interim stage, we see that projects have realised early benefits across several success measures such as the creation of jobs, continued use of network infrastructure and cost avoidance, among others. Future evaluations should seek to monetise the direct benefits and wider benefits to be able to estimate the VfM of the programme comprehensively. Internal work within DSIT has been undertaken on the VfM of individual use cases funded within 5GTT.

In reflection of barriers to deployment, the programme has made the biggest difference to overcome information asymmetries, through the work on the test beds and trials and UK5G.

8.2 Value for Money (VfM) assessment

The VfM assessment undertaken as part of this interim evaluation sources data on costs and benefits from the 5GTT project documents and Monitoring Information (MI) received from DCMS. This includes Benefit Realisation Reports (BRs), Final Reports, and Sustainability Reports. We used interviews and desk research to collect additional data for a sample of 15 projects that are representative of the wider portfolio of 37 5GTT projects. This incorporates the 31 projects that comprised the second phase of the 5GTT programme with the six projects that made up phase one. Consultations with DCMS staff were also held to collect data on the cost of running the programme.

Our approach is robust to the extent that outputs are realised via the funded projects and outcomes and impacts are attributed to the 5GTT programme by the programme beneficiaries. A quasi-experimental approach could not be applied because of data limitations and significant heterogeneity amongst the types and timescales of the funded projects. These are detailed in the next section.

8.2.1 Overview of the previous VfM analysis

The comparison of costs and benefits that we present further in this chapter is a follow-on exercise from an ex-ante Value for Money assessment that was conducted as part of a business case update in September 2020. The previous VfM analysis used Cost Benefit Analysis (CBA) approach[105] and identified twelve benefits in the healthcare, rural, and industrial sectors. Based on programme monitoring information, secondary data, and assumptions, the CBA estimated the net benefit of 5GTT as £2.58 billion[106] from 2021 to 2030, against a

[102] PWC. (2021). 'The Global Economic Impact of 5G: Powering Your Tomorrow'. https://www.pwc.com/gx/en/tmt/5g/global -economic-impact-5g.pdf
[103] IHS Markit & OMDIA. (2020). 'The 5G Economy in a PostCOVID-19 Era: The Role of 5G in a Post-Pandemic World Economy'. November, report prepared for Qualcomm Technologies. www.qualcomm.com
[104] Adoption of 5G technology to add £43bn to UK GDP by 2030- new PwC analysis shows
[105] It focussed on estimating future benefits of six phase 1 projects. The model also considered the future benefits from the ongoing (incomplete) phase 2 projects which constituted 26% of the total benefits calculated. However, benefits from ongoing projects were not attributed to individual use cases and a haircut was applied to them, to account for optimism bias.
[106] 5G Programme findings - GOV.UK (www.gov.uk)

government spend of £160.8 million. This is equivalent to a BCR of 15.8:1[107] and a return of over £15 for a £1 investment. These high-level results have been made public, but the modelling has not been subject to external review.

Value added by 5G to the wider UK and global economies

Although the previous VfM analysis might not provide a reliable estimate of benefits of the 5GTT programme at the present time, its approximation of £2.58 billion is well within the ceiling or at least the magnitude of impact that widespread adoption of 5G and related use cases are expected to have on the UK and global economies. We know this from wider literature in the form of commissioned reports and academic publications.

For example, PWC (2021)[108] estimates that 5G will add £1.08 trillion to the global economy by 2030, another is placed at £1.91 trillion by a report produced for Qualcomm by IHS and OMDIA in 2020[109]. With respect to the UK, analysis commissioned by O2 in 2017[110] suggests that 5G would create an added value of £10 billion by 2026, including improving supply chain efficiencies. A more recent study done by PWC (2021) [111] estimates the extent of 5G value creation in the UK to be £43 billion till 2030. It attributes this mainly to increase in efficiency and productivity gains brought about by increased 5G adoption.

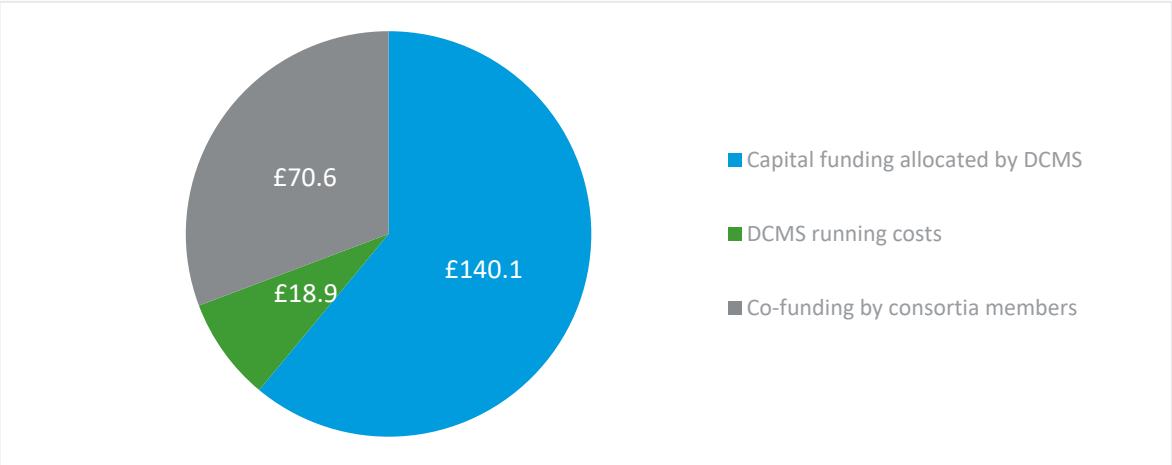
This shows a general positive context for 5G value creation in the UK and the global context in the next 15 years. However, wider literature is sceptical of the value that private MNOs can generate using 5G. A study by Bohlin, et.al. (2022)[112], tells us that it would be difficult for MNOs to generate value using 5G mainly because of the complexity of the new markets created and the cost involved in network deployment. This sentiment is reiterated by Cheng et.al. (2022)[113], which further states that the cost of network deployment to the telecommunications industry is set to increase anywhere between £0.63 billion to £1.19 billion by 2030.

Assessment of costs

The total estimated cost of the programme is £229.6 million throughout its course from 2018 to 2022, which includes £140.1 million allocated across the 5GTT projects, £70.6 million in co-funding by consortiums members[114] (in relation to the 37 funded projects), and £18.9 million resource spending by DCMS running the programme. The running costs make up 13.5% of the total government spend

[107] the sensitivity analysis performed by the model give a lower bound BCR estimate of '6.2:1' and upper bound estimate of '27.7:1'
[108] PWC. (2021). 'The Global Economic Impact of 5G: Powering Your Tomorrow'. https://www.pwc.com/gx/en/tmt/5g/global -economic-impact-5g.pdf
[109] IHS Markit & OMDIA. (2020). 'The 5G Economy in a PostCOVID-19 Era: The Role of 5G in a Post-Pandemic World Economy'. November, report prepared for Qualcomm Technologies. www.qualcomm.com
[110] O2. (2017). 'Press Release: UK 5G infrastructure to outstrip economic benefits of fibre broadband by 2026'. 16 February. https://theonepoint.co.uk/news/post/5g-infrastructure-to-exceed-fibre-broadband
[111] Adoption of 5G technology to add £43bn to UK GDP by 2030- new PwC analysis shows
[112] Techno-Politics-Series-2-Edited-by-Europes-Future-Connected-Policies-and-Challenges-for-5G-and-6G-Networks-Series-Editor-Antonios-Nestoras.pdf (researchgate.net)
[113] 5G network deployment and the associated energy consumption in the UK: A complex systems' exploration - ScienceDirect
[114] This includes co-funding from businesses, academic institutions, and some public bodies.

Figure 21: Breakdown of 5GTT programme costs, £million



Source: DCMS, project documents, Management Information, and RSM analysis

The programme was run by a large team at DCMS with at times around 60 staff contributing to running the programme. By means of comparison:

	Public sector expenditure	Running cost (administrative costs)	**Administrative cost as a proportion of programme spent**
5GTT	£140.1m	£18.9m	13.5%
Cultural Recovery Fund[115]	£1,266.9m	£33.1m	2.6%
Biomedical Catalyst[116]	£141m	-	2.6%

Comparisons are difficult because of the difference in the nature of interventions[117], but the data does suggest that the 13.5% stated for this programme is relatively high.

Initially, the 5GTT programme was resourced with the objective of allocating £199m. The programme has spent 70% of the target budget (£140.1m). If the full budget would have been spent using the same extent of running costs (if this was largely scoped from the outset), the running costs would have amounted to 9.5% of total allocation, which appears to us as more balanced. There are several reasons that can explain the heightened level of expenditure incurred in running the programme, even though the level of resourcing suggests that the programme could have been run more efficiently. These are:

- The amount of time spent on programme and instrument design – 5GTT has been a novel programme and DCMS did not have processes in place from the outset. DCMS has also experimented with a range of instruments and funded a broad range of projects including Rural, Urban, and Industrial projects. The programme also involved stakeholders from the NHS, Local Authorities, and private sector. The project types had different budgets, and some had different eligibility criteria. This may have increased the complexity of marketing and communication of the programme and selection processes.

[115] Evaluation of the Cultural Recovery Fund (publishing.service.gov.uk). The total public funds were reported as £1.3bn including £33.1 in administrative costs.
[116] Normal dot (Rev02 January 2009) (ukri.org)
[117] We have identified two other comparators but the size of the funding that was allocated under these instruments is much larger. First, the cost of running the Research Excellence Framework (REF), the mechanism to allocate resource funding to universities, is estimated as 1% of total allocations. See Technopolis Group » REF Accountability Review: Costs, benefits and burden (technopolis-group.com)
Second, the Job Retention Scheme put in place as a response to the pandemic. The National Audit Office in January 2021 stated that £61 billion had been spent on the scheme up until this point with the estimated administrative costs placed between £2-£3 billion. This places administrative costs at just under 5%. See NAO Annual Report and Accounts 2021-22 - National Audit Office (NAO) corporate information

- The amount of time spent selecting viable projects – DCMS funded 23% of the total applications received for the programme, including UCC (6.25%), RCC (58.33%), Industrial (50%), Create-1 (46.15%), and Create-2 (14.29%) competitions.
- The amount of time spent monitoring funded projects and on Monitoring and Evaluation (M&E) activities – DCMS has invested substantial time and effort in collecting detailed data from all projects/beneficiaries. Interviews with DCMS and wider project stakeholders have revealed that more data has been collected in the context of 5GTT than in several other government funded innovation programmes. This was done to ensure that learnings could be taken from this programme to future programmes.
- The amount of time spent on dissemination activities – Consultations with project stakeholders evidenced that programme staff have spent substantial time in organising and promoting dissemination and collaboration activities such as hosting workshops and putting together events, where members could come together to share project developments.

8.2.2 Assessment of benefits

The benefits of this programme can be distilled as follows:

- **Collaboration and knowledge sharing** was regarded as having been helpful to project participants.
- **Effective capital use -** 36 of the 37 funded projects have developed a proof of concept for use cases which operates on 5G technology. The successes of a few phase 1 projects inspired the consortiums to take their use cases further through follow up projects, that received funding in phase 2. For example, Liverpool 5G Testbed had successfully deployed a working private 5G network in Liverpool in phase 1. This network was extended and improved upon by the Liverpool 5G Create project in phase 2. Several projects have resulted in further development of projects' use cases beyond the projects' scope. For example, the 5G New Thinking project' smart cattle monitoring use case was increased in scope.
- **Solutions to market -** 40 project members from 20 consortiums have brought specific commercially viable products or services to market. 38 project members from 29 consortiums have adopted new processes innovations which can serve to add efficiency to their current operational processes. 8 project members from 13 consortiums show evidence of both having brought products or services to market and having adopted new process innovations.
- **R&D realisation** – our conservative estimate suggests that £263m of funding was leveraged
- **Business and industry generation** - 6 out of the 15 projects included in the case study analysis resulted in the creation of new jobs which were either permanent or where employees moved on to work in similar sectors.
- **Speeding up infrastructure rollout** - The projects cumulatively deployed a total of 107 networks, 70 of these are still in use.

There is **scope for projects to result in additional value if they secure further investment**. Project beneficiaries have commented that lack of funding is impeding further developments.

While some benefits may appear to be narrow and self-contained, it is especially important to consider benefits such as proof of concept, scope for additional follow-on funding and setting up channels of collaboration. As 5G technologies permeate the entire economy, these benefits could have large aggregate impacts, due to benefits that flow systemically through a number of sectors and industries.

Evidence from monitoring information and consultations with projects participants also shows that the programme is generating wider sector benefit:

- 51 members of consortiums from 18 projects are, at least to some extent, currently generating wider sector benefits. For example, the 5G network deployed by the Liverpool 5G project has improved the efficiency of public service provision, which has tremendous potential for welfare gains
- For another 32 members of consortiums from 17 projects, there is scope for wider impacts to be generated if the use cases are developed further

- 3 of the 14 projects presented as case studies provide strong evidence of public costs avoided. For instance, the Liverpool 5G Create project demonstrated a cost saving of £182,000 per annum to NHS and care homes, among other stakeholders to provide Health and Social Care services.

8.2.3 5GTT programme addressing barriers to adoption

Stakeholders interviewed also identified a range of barriers to the deployment of 5G. The table below summarises the number of interviewees who mentioned types of barriers.

Table 34: Interviewees who mentioned specific barriers

Barrier	Number of Interviewees	Percentage of total interviewees (n=79)
Lack of demand	36	46%
Limited variety of equipment available	19	24%
Cost	18	23%
Access to spectrum licences	17	22%
Technological readiness of equipment	13	16%
Insufficient UK manufacturing capacity	12	15%
Misinformation	12	15%
Underlying networks	8	10%
Hi-tech manufacturing skills	8	10%

In the following sections we expand on the evidence collected and summarise the findings in accordance with the three broad market and systems features that were introduced in Chapter 2, drawing on the work of Blind and Niebel (2020):[118] asymmetric information, economies of scale and scope, and infrastructure failures.

- **Asymmetric information –** We were told that demand for 5G was still lacking, possibly because people are not sufficiently aware of how 5G may benefit their business. We were told that there is still misinformation about 5G e.g. linking it to COVID. This led to people making objections to planning applications for 5G infrastructure and in some cases vandalism and threats of violence to installers. Twelve interviews commented on misinformation as a barrier and half said this was a less significant barrier now than it had been earlier in the programme. DCMS compiled a report highlighting good practice in addressing misinformation about health risks from 5G.[119] Ofcom have also done work to address misinformation[120].
- **Economies of scale and scope** – we were told that networks are expensive to install and that the cost cannot always be justified which is why being able to demonstrate stackable use cases is useful. Access to spectrum licences was also referred to as a barrier. Existing large MNOs were said to be more able to obtain licences.
- **Infrastructure failures** – 13 respondents spoke about the lack of technological maturity of the devices, applications and networks. Technological readiness had been undermined partly due to the removal of Huawei equipment from 5G networks and a limited range of equipment available from other suppliers. This includes equipment from large existing suppliers, but also the new UK-based suppliers who needed to increase capacity and quality of their kit. UK based manufacturing for hi-tech electrical equipment is mostly offshored and some interviewees thought there was a skills deficit in this area preventing more radio equipment being produced within the UK. Moreover, around 46% of projects reported having used **non-standalone** networks i.e. built on

[118] Blind and Niebel (2020) 5G roll-out failures addressed by innovation policies in the EU, Technological Forecasting & Social Change 180 (2022) 121673

[119] DCMS "5G Testbeds & Trials: Tackling Health Myths," 11 August 2020

[120] https://www.ofcom.org.uk/news-centre/2020/clearing-up-myths-5g-and-coronavirus

top of existing 4G infrastructure which was difficult to use and in need of substantial upgrade to make best use of the additional functionality of 5G.

The table below provides an assessment by us of the degree to which 5GTT has addressed barriers that the 5GTT programme was aiming to overcome. The programme has made the biggest difference to overcome information asymmetries, through the work on the test beds and trials and UK5G.

Table 35: Overview of barriers and assessment of the contribution of 5GTT

Market and systems failures	Was the barrier overcome?	5GTT contribution	How has 5GTT made a difference?	External influences
Asymmetric information – *Business cases may be pushed by equipment suppliers (and other stakeholders that see value) but MNOs lack certainty*	**Yes, but more limited engagement with the wider public** Stakeholders consulted commented that more progress is needed to disseminate knowledge among the wider public. 51% of people agree with the statement that they cannot tell the difference between 4G and 5G[121]	Substantial	Projects invested in increasing knowledge of the benefits and applications of 5G applications, helping increase technological capacity. 5GTT and UK5G created an ecosystem where knowledge about 5G is shared within the community of members and among businesses. Interviewees noted that resistance to 5G deployment based on perceived health risks or environmental damage was lower than expected but where this was in place the 5GTT helped to reduce this (via dissemination activities such as articles, reports and community events)	Information on 5G is also diffused through other means including via European projects and MNOs
Economies of scale and scope – *High initial investment costs make investing in 5G infrastructure development and deployment risky in an environment where networks, capacity and uptake are uncertain*	**Partially** Private sector stakeholders commented that costs are still a barrier to scaling up. The market has not achieved a diversity in the supply of critical equipment needed for 5G deployment and large network operators and suppliers are still dominant	Moderate	Stakeholders consulted noted that their 5GTT project was successful in involving different types of stakeholders. 5GTT has involved 211 private sector members of consortiums including Cisco, Vodafone, and BT. The programme supported organisations to develop a wider range of use cases and to bring solutions to market. 5GTT leveraged between £359.3m and £263.1m in follow-on investment, but more support was said necessary to unlock further private sector investment	Some unfunded applicants managed to make some progress through other means
Infrastructure failures –	**No** Stakeholders consulted suggest	Small	Interviewees commented that, before 5GTT, large MNOs needed to be shown that there were	Progress is also pushed through other initiatives.

[121] Deloitte (2022) 5G Mainstream adoption | Deloitte Insights

Market and systems failures	Was the barrier overcome?	5GTT contribution	How has 5GTT made a difference?	External influences
For example, MNOs lack incentive to invest in less populated rural areas	that underlying infrastructure still needs to be improved Some MNOs have plans in place for the rollout of 5G. EE aims to offer 5G anywhere in the UK by 2028 and has the ambition to provide 4,500 sq miles of new rural EE coverage paired with additional road, air and space solutions to offer high speed connectivity on the go (2021)[122]		benefits in operating in different locations and industries. 5GTT provided proof of concepts of how 5G could be applied in other industries 5GTT demonstrated the viability of rural applications and networks. The 7 RCC funded projects, 2 of the Phase 1 projects and several of the Create projects had a specific focus on rural deployment and other Phase 1 and Create projects (eg Live and Wild and AMC2) tested 5G technologies in remote locations. 70 of the 107 network infrastructures developed are still in use and could remain legacy	MNOs have made their own investment in infrastructure

Note: Market and systems failures adapted from Blind and Niebel (2020)[123]

These findings are broadly reiterated based on case study evidence. The table below summarises progress against success measures for the case study projects. These are loosely tagged against the barriers presented above. The summary of progress is based on a contribution score to assess how the 5GTT funding contributed to progress against each of these measures. This is a score of 0 to 3, and this mark is quantified more in the table heading. The average contribution score is also shown and the 3 highest (green) and lowest (red) average scores highlighted:

Table 36: Success measures and contribution scores for case studies: Number of firms and average

Contribution claim	0 (no evidence of activity relating to this impact)	1 (evidence of activity but no evidence of contribution/ additionality)	2 (some evidence of contribution/ additionality from activities)	3 (strong evidence of contribution/ additionality)	Average contribution score
Asymmetric information					
Information and knowledge is more readily transferred within the 5G ecosystem	0	0	6	9	2.60
Additional welfare and environmental benefits	0	1	6	8	2.47
Public services cost avoidance	4	3	4	4	1.53
Development of industry 5G expertise and increased ability to use 5G for commercial activities	1	0	6	8	2.4
Economies of scale and scope					

[122] EE to offer 5G solutions across the entire UK, as BT Group unveil new mobile and convergence ambitions

[123] Blind and Niebel (2020) 5G roll-out failures addressed by innovation policies in the EU, Technological Forecasting & Social Change 180 (2022) 121673

Generation of 5G activities beyond the scope of the programme	0	0	2	13	2.87
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	1	2	1	11	2.47
Programme activities have attracted further funding within the area of 5G/5G R&D	0	3	5	7	2.27
Reduction/removal of barriers has accelerated deployment of 5G in the UK	0	2	6	7	2.33
Infrastructure failures					
The reputation of the UK as a leading 5G nation has improved	0	4	10	1	1.80
5G networks are more secure than the 4G networks they replace	2	1	5	7	2.13
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	1	0	7	7	2.33

8.2.4 Comparison of costs and benefits

An overview of the costs and benefits associated with the 5GTT programme is presented in Table 37 below. It is prudent to note that only a few of these are presented in monetary terms as, at this interim stage, we concluded that a full monetisation is not possible. This is mainly due to limitations in the availability and quality of data - including the use of secondary data sources, as well as uncertainties about the future.

The results need to be interpreted with caution because the sample is small and there is significant heterogeneity between projects in terms of objectives, scope, level of success, extent to which activities were disrupted by external factors, among other things.

The total cost of the 5GTT programme has been significant in absolute terms, though this represents only approximately 0.60% of UK Gross Expenditure on R&D (GERD) in 2019[124] (less than 0.01% of UK GDP). Furthermore, this expenditure has taken place over four years from 2018 to 2022, and is non-recurring, so even the figure above is a significant overestimate of actual yearly economic burden. This expenditure has therefore taken up an extremely small relative amount of UK economic activity. As discussed above, the benefits of the programme are significant (albeit unquantified) and are expected to eclipse the costs due to the fact that these will enhance and improve numerous economic sectors representing a significant proportion of UK economic activity.

Table 37: Presentation of costs and benefits of the 5GTT programme (2018 – 2022)

Costs/Benefits	Source	Unit	Programme level estimations
Initial outlays			
Total allocated funding	Project Documents	£	£140.1 million
Co-funding by consortiums members	BRs (37 projects)	£	£70.6 million
DCMS running cost	Project Documents	£	£18.9 million

[124] Gross Expenditure on R&D (GERD): Total - Office for National Statistics (ons.gov.uk)

Total costs			£229.6 million
Benefits			
Average Technology Readiness Level (TRL) increase	BRs (37 projects)	TRL level	1.7
Number of jobs created (number of staff newly recruited by consortiums members on the back of the projects)	BRs (37 projects)	Number of jobs on an FTE basis	212.4
Network infrastructure deployed by 5GTT	Project documents and stakeholder consultations (37 projects)	Number of networks deployed	107
Network infrastructure deployed by 5GTT that are still in use	Project documents and stakeholder consultations (37 projects)	Number of networks still in use	70
Consortium members that brought products/services developed as part of 5GTT to market	Project documents and stakeholder consultations (37 projects)	Number of consortiums members	48
Consortium members that adopted process innovation developed as part of 5GTT to market	Project documents and stakeholder consultations (37 projects)	Number of consortiums members	46
Additional £ investment into R&D due to the funded project	BRs (37 projects)	£	£49.8 million
Third party investment attracted (domestic/foreign)	BRs (37 projects)	£	£148 million
Further investment/ collaborations building on project's research outputs	BRs (37 projects)	£	£97.8 million
Potential reduction in costs of providing public services	Project documents and case studies (37 projects)	Number of projects	11
Number of projects contributing to wider impacts to industries, including welfare and environment	Project documents and stakeholder consultations (37 projects)	Number of projects	18

Source: DCMS, project documents, MI, and RSM analysis

This evaluation has explored the benefits that resulted from the phase 1 and phase 2 project funded as well as from the UK5G. There are other initiatives that were funded as part of the 5GTT programme (see Chapter 2 for an outline and budget of all activities supported) and benefits from that investment is not captured.

The costs and benefits enumerated in Table 32 are not all in monetary terms. However, we judge that the overall amount spent on the programme has the potential to generate returns which are many times larger than the initial

outlay due to the nature of 5G, especially when considering the potential of positive feedback returns[125] associated with technology. We think that the 5GTT programme will contribute positively to the adoption of 5G.

[125] Positive feedback in economics is explained as "The more people adopt a particular technology, the more it improves, and the more incentive there is for further adoption." Sci. Am 26.11.89.Web (adamdell.com). In a market context, positive feedback leads to the rapid and sustained growth of companies through increasing returns, for example, Facebook, Tesla, and SpaceX, among others.

9. IMPLICATIONS FOR A FINAL EVALUATION OF THE 5GTT PROGRAMME

9.1 Summary

There are plans to conduct a final evaluation once 5GTT projects have had more time to generate the intended outcomes and impacts, such as any impact of 5G adoption on revenue growth and additional 5G related investment. In this chapter, we draw out how the results of the current interim evaluation can feed into approaches that could be used in the final evaluation. This is then followed by our recommendations for the final evaluation.

We find that the final evaluation would benefit from a mixed methods approach – Quasi Experimental methods should be re-examined and the approach should include qualitative analysis of stakeholder consultations and case studies. The VFM should consider Cost Consequence Analysis (CCA) and Cost Benefit Analysis (CBA). We think that the Theory of Change developed should continue to frame the final evaluation.

9.2 Applicability of counterfactual analysis to estimate benefits to participating firms

As part of this evaluation, we assessed the option of applying econometric/counterfactual analysis, such as difference in difference analysis, using a combination of primary and secondary data (from Orbis and Beauhurst) to estimate the impact of the 5GTT programme on private sector participants. We considered several possible counterfactual groups including unfunded applicants and a wider group of similar non-applicants.

We concluded that this approach was not viable because of limited data. There are also other limitations including significant heterogeneity among the projects and participants funded by the 5GTT programme in terms of type, sector, and size. We are cautious on whether an econometric approach can be undertaken as part of the final evaluation unless (other) comprehensive data on beneficiaries can be sourced[126], or unless a significant amount of time elapses that would allow one to evaluate impact through KPIs such as turnover and productivity. These may take a number of subsequent years to significantly reflect input benefits provided through schemes such as 5GTT. This will however need to be explored fully as part of that work, including an exploration of novel alternative data sources that may be more impact contemporaneous.

For an econometric/counterfactual analysis a minimum sample of 50 firms is recommended[127]. This is a general rule of thumb and more data is better[128] We also note the following[129]:

- **The sample size of private sector beneficiaries** – 211 firms received support/funding and we would expect the 71 firms that have implemented process innovation and/or launched a solution to market to generate productivity benefits that can be attributed to the 5GTT programme.
- **Secondary data availability** – Out of the 211 firms that received 5GTT funding, we found turnover and employment data from the Orbis database for 188 firms. Calculations of average changes in employment and turnover are sensitive to the firms included/excluded and having continuous data is important. Continuous data (2018-2021) on employment is available for 46% of the sample (97 firms) and on turnover for 22% (46 firms). We assume that by 2027, data for a similar sample will become available through Orbis/Fame for the year 2025.

[126] As part of the exercise conducted, we have focussed on the impact on participants firms. It could be possible to work with a different unit of analysis, for example by exploring the impact on value chains or by using the use/test case as the unit of analysis and focusing the analysis on benefits from learnings of those cases. These are just examples for inspiration. What is important for robust quasi experimental analysis is the availability of a sufficiently large sample and good comparator data. To be able to capture statistically significant differences the expected impact on beneficiary groups needs to be substantial, especially when sample sizes are relatively small.

[127] Understanding Power and Rules of Thumb for Determining Sample Sizes (tqmp.org)

[128] This sample size will not be a large enough to identify smaller differences in performance but a pronounced uptick in employment or turnover can be detected.

[129] There are also some secondary considerations, such as the inclusion of larger firms in the sample. It will be difficult to attribute productivity changes of larger firms to the programme. It is also possible that firms that adopted process innovations may realise productivity gains but the likelihood of these gains to translate into market growth (employment growth and/or revenue growth) may be lower.

- **Response rates to primary data collection** – This data was key for establishing short term impacts that would have been attributable to the programme and the survey launched attempted to obtain information on short term KPIs such as level of investment in 5G related R&D, changes in growth in income levels in the three years before and after receiving funding, and the level of income that would depend on 5G in 2025, among others. The survey of private sector firms resulted in only one response from a firm that launched a solution to market. It will be a challenge for future online and/or telephone surveying to generate a sufficiently large sample from target private sector participants - though secondary data may be more viable in a few years.

In addition to these considerations, note that that counterfactual analysis to estimate benefits to participating firms will not fully capture the wider societal benefits that the projects/firms will have contributed to realise.

9.3 Other methodological options for the final evaluation

For a comprehensive final evaluation of the 5GTT programme, we consider the options outlined in the table below . Both primary and secondary data collection will be relevant. As an alternative to online surveys, a future evaluation would benefit from telephone surveying and/or more unstructured interviews[130]. Primary data collection will be particularly relevant to help attribute any impact on improvements in productivity and/or growth to businesses to the programme and to capture the wider societal benefits.

Table 38: Relevance of data sources to the final evaluation

Data sources used in this evaluation	Relevance for the final evaluation	Risks and limitations
Consultation with staff members in programme design, management, and delivery	Low – less relevant to impact evaluation	N/A
Review of monitoring information (Benefit Realisations documents, final reports) and other project documentation	Low – data has been analysed as part of this evaluation	N/A
Interviews with representative funded project participants	High – relevant to evidence uptake of solutions and continued adoption of process innovations	Low response rates and ability to attribute impact to 5GTT
Follow-up interviews with a selection of project partners	Medium – interviews could ask a more targeted set of questions limiting the need for follow-up	Low response rates and ability to attribute impact to 5GTT
Surveys of funded and unfunded companies	Low – in view of data quality/response rates	Very low response rates. Potential imitation to of data collected; a semi-structured approach would allow asking more bespoke questions
Survey of UK5G Innovation Network members	High – track dissemination of lessons learned from 5GTT	Changes in the nature of the network and challenge with attributing to 5GTT over future funded activities
Survey of SMEs in the wider population (Omnibus)	Medium/high – relevance is dependent on availability of secondary data on the adoption of 5G across sectors, industries, regions	Challenge to attribute change to 5GTT
Review of publicly available company data (Orbis, Beauhurst)	High – relevant to identify high growth firms and draw comparison about performance levels between beneficiaries and non-beneficiaries. Could help identify firms for impact case studies	Econometric counterfactual analysis likely not possible due to limited sample size. Heterogeneity and gaps in the data may impede drawing robust conclusions
Desk research on 5G adoption and other wider literature sources (e.g. from Deloitte)	High – adoption of 5G across sectors, industries, regions. Major players in the 5G telecommunications industry (UK and abroad)	Challenge to attribute change to 5GTT, trend series analysis may not be possible

[130] Please note that in an attempt to boost response rates, some of the survey responses collected as part of the evaluation were completed via a telephone interview.

For a comprehensive final evaluation of the 5GTT programme, we consider the options outlined in the table below as relevant.

Table 39: Methodological options for the final evaluation of the 5GTT programme

	Nature of evaluative work	How this evaluation contributes
Document the role of UKTIN in disseminating any outcomes of the 5GTT programme	UKTIN is now part of the Open Networks Fund and will be subject to evaluation as part of this programme. As part of that evaluative effort and/or as part of a future impact evaluation of 5GTT there is scope to look at the effort and value of future dissemination activities relating to 5GTT use cases and other learnings. Emphasis can be placed on understanding: • What stakeholder groups are targeted as part of knowledge sharing and dissemination activities • What stakeholder groups are benefitting from knowledge sharing and dissemination activities	Future surveys that align with the UK5G network surveys (which were carried out in 2021 and in 2022 as part of this evaluation) allow for a comparison of benefits experienced over time. For such comparison, it will be important to consider differences in implementation of UKTIN and the 5G Network (5GTT).
Targeted follow-up consultation with organisations that have brought products/services to market and/or realised process evaluation	Future evaluation can focus on evidencing which of the products/solutions that went to market have taken off and have a consumer base, to estimate Gross Value Added. It can also look to evidence which process innovations have transformed business and how they have done so.	This evaluation included consultations with 37 private business, eight government bodies, and three academic institutions. Out of these, 15 private business have either brought a product/service to the market or have adopted a process improvement. Among other institutions that aided in the commercialisation of products/services, or the adoption of process improvements, we interviewed two government bodies and one charity. Future evaluations can build on this consultation, amongst other, by applying a more target approach to reach project participants that are likely to have benefited more. DCMS will need to keep a record of the businesses that have benefitted from 5gTT support and from other (future) DCMS funded projects. Ideally, contact information is updated periodically.
Impact case studies	To document the types of societal benefits that projects have realised and estimate impact on welfare and/or environmental benefits, including benefits that are not easily quantifiable such as an increase in rural connectivity or public safety. The case studies could explore in greater detail the unintended consequences of 5GTT at a programme level.	This evaluation has resulted in a Theory of Change that provides evidence of (possible) transmission channels including impact on wider stakeholders. It provides an outline of types of benefits that projects have looked to achieve. This could be expanded to stress test the TCs further for proof of impact, and to quantify and the potentially find evidence of others.
Value for Money assessment	To monetise the benefits that the programme has realised and is expected to realise, in comparison to the cost of running the programme and any additional co-investment. In addition, to compare final VfM estimates with those that had been initially estimated and are included in the programmes' business case. A Cost Benefit analysis can underpin the VfM analysis. A Cost Consequence Analysis can be used to distinguish costs and benefit ratios for different stakeholders.	This evaluation provides a breakdown of the costs of the 5GTT programme. These costs will need to feature in a future VfM assessment, including opportunity costs. The evaluation also identifies types of benefits that have been realised and others that can be anticipated in the future. Future evaluation work should distinguish between benefits accrued and anticipated additional benefits – as well as exploring ways to quantify these benefits (perhaps QE, other quantification and econometrics or targeted desk research). Care must be taken to avoid double counting. Any assumptions made should be documented in a transparent manner and, where possible, should build on primary data (from projects) rather than secondary data.

9.4 Identification of focus areas

The Theory of Change covers seven transmission dimensions. We think that the final evaluation could cover all of these. This will involve asking slightly different questions than those asked as part of this evaluation.

1. Collaboration, knowledge sharing, overcoming barriers – This evaluation has established the nature of collaboration and the extent of collaboration and provided an understanding of the benefit of knowledge sharing to programme participants. We have also outlined barriers and progress made to address these. Future evaluation can look to establish if relationships created under the programme have been maintained, provide renewed understanding of the barriers and understand the legacy effect of the programme to continue tackle these (e.g. cost barriers, regulatory barriers) and the impact on 5G deployment. The evaluation can also look to understand if the programme has had any (continued) impact on labour requirements.

2. Effective capital use – This evaluation has identified successful use cases and firms that have brought new solutions to market and/or realised process innovation. Evidence from consultations showed that the majority of projects found that their use cases would not have been possible on previous generations of network. Where testing showed that they would be possible on previous network generations, in many cases full deployment would require 5G to roll out use cases more widely. Future evaluation should look to establish the impact of commercialisation and process innovation on performance (revenue, growth, productivity). It can also establish which of those solutions that were brought to market generated substantial market penetration.

3. R&D realisation – This evaluation has estimated the amount of follow-on investment generated. It may be difficult for future evaluation to generate more comprehensive data on this, but this could be explored using secondary data, and by testing attribution using a comparator group. It would be important to capture the investment climate and the degree to which the programme has contributed to help increase certainty over demand and revenue opportunities. Early deployments focused on getting networks working and mostly followed best practice for security, but there was potential for further R&D focus around security of 5G networks as the technology allowed for more advanced security techniques than previous network generations.

4. Business and industry generation – This evaluation has identified the creation of spinouts and technological bottlenecks that could lower incentives to invest in 5G and impede wider business and industry generation. Future evaluation should look to establish the degree to which the programme contributed to unlock supply side issues, establish the degree of wider industry participation and impact on productivity, efficiency, jobs and growth.

5. Speeding up infrastructure rollout – This evaluation established the number of networks that were created as part of the programme and those that are still in use. Future evaluation can look to establish if future use has continued and under what remit this has happened/not happened. The evaluation should look to appraise progress made toward the diversification of 5G network providers and landscape and establish the continuation of the programme to help realise diversification.

6. 5G ecosystem – This evaluation has established progress made towards to creation of a 5G ecosystem and the role of UK5G. UKTIN can play a role in further disseminating the knowledge and lessons learned under the 5GTT programme and future evaluation should establish if this has happened. Future evaluation can also benchmark progress made in the UK vs that made in other countries leading in the field. It would be important to be able to attribute any contribution to UKs reputation by establishing links to specific contributions of projects.

7. Cost-avoidance, environment, welfare and wellbeing – This evaluation has provided limited evidence of cost avoidance and welfare and environmental benefits realised through the 5GTT projects. It has established that there is potential for substantial impact, but this has not been monetised. The final evaluation should make a much more grounded assessment of wider impacts. Consultation with firms that have launched solutions to market would be essential to the evidence gathering exercise. There is also scope for the work to, for example, build on the work of UKTIN and the newly established Climate and Environment Working Group.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Summary of programme delivery and outcome and impacts

Programme processes that have been delivered effectively and efficiently are:

- The **funding competition processes**. The calls were designed to meet sectoral demand and diversify the portfolio. They were effectively marketed in all but one competition, and the response rate was good in most cases, allowing DCMS to select a diverse range of projects. The application process was considered effective by DCMS officials and a majority of applicants.
- DCMS **project support**. The majority of projects saw DCMS as being very helpful in supporting their projects, especially the input from the Technical Design Authorities. Internally, DCMS staff thought that they worked well as a team, although there were some reports of a lack of continuity in DCMS staff managing individual projects.
- The **benefits realisation process.** This was challenging for DCMS to run but worked well when projects were supported by DCMS to identify indicators that were beneficial for their own project management. A minority of projects found the process burdensome and/or complicated.

We have identified issues in two areas:

Financial processes, however, caused problems for delivery. The grant claiming process was sometimes time consuming, which was a particular problem for resource-constrained small firms. This was exacerbated by the change request process, which was felt to be applied inconsistently and could be slow. There were nearly 300 change requests across all Phase 2 projects, which added to programme complexity and intensity of tasks. Projects often had to submit multiple change requests and the overall scope of projects substantially changed.

We recommend future programmes allocate more resources to financial processing, if possible, as delays have affected delivery. This additional support would need to be provided on a cost-efficient basis.

We also recommend providing more clarity around the process and workflow for processing change requests within DCMS, and to reformat the structure for submitting these. DCMS could track the processing time for change requests and set targets for completion time.

We recommend reformatting the structure for submitting the information required for change requests to avoid misunderstandings and the need for rework.

To reduce the need for change requests in the first place, we recommend relaxing or rethinking the nature of the link between grant payment and initially agreed milestones, as innovative projects do sometimes change scope in flight and require funding to adapt.

Programme efficiency - The programme running cost is large by comparison with innovation programmes from other Government sources (e.g. UKRI); however, the services provided by the extra resource (project support, technical support, ongoing monitoring and evaluation, and in particular network building and ecosystem development) have contributed to the programme running well and/or are valued by project delivery partners. The programme **underspent** against its allocated budget by 30%. Technological readiness and external barriers (specifically COVID) each had an impact on this. Project beneficiaries also commented negatively on the level of staff turnover of project officials.

We recommend DCMS to consider outsourcing some programme management activities if that could make the programme run more efficiently.

We recommend DCMS to identify mechanism to minimise disruption from staff changes, for example by ensuring effective handovers.

We recommend DCMS to be less conservative when awarding grant funding when budgets are available to do so. In the case of 5GTT there was considerable value in engagement and 36 of 37 projects were successful in developing and testing use cases.

Given the uncertainty of interest from the community, we recommend DCMS to consider launching market engagement events ahead of competitions to gauge the needs and interests from the community and ensure that budgets are well thought out and to help underpin decisions around programme design. This could also help create awareness and provide opportunities for organisations to connect.

10.1.1 Development of a diverse set of use cases and application

The programme has resulted in the development of a diverse set of use cases and demonstrated applicability across sectors and geographic areas.

The programme has successfully led to the development of new products, services and processes with direct commercial benefits to project delivery partners. We think that these have or will contribute directly and more widely to improve productivity or efficiency in the wider economy. Developing products and services to address poor connectivity also helps to overcome a barrier to further deployment of networks (low level of technological maturity).

The immediate benefits accruing to project delivery partners and private sector firms can be **extensively attributed** to the 5GTT programme as 5GTT participants noted their projects would either not have occurred or would not have been developed to the same extent, were it not for the 5GTT programme. Some impacts could however have been realised on earlier generation networks than 5G – although not in rural contexts or low-latency applications. Without the 5GTT projects exploring and reporting this, this may not have been recognised.

5GTT encouraged collaboration across organisations that may not have otherwise been inclined to work together. It also strengthened previously existing collaborations. Data for 37 projects suggests that just over 1,300 people were involved from the private sector (on average 37 people per project), 101 stakeholders from the public sector, and 65 university departments

Private sector participants gained knowledge about overcoming barriers and cost effective deployments. The range of use cases and processes showed the potential of 5G in the private and public sectors, alongside urban and rural communities

107 telecommunication networks were deployed and tested, of which 70 are known to be still in use

Data available for 36 projects suggests that 345 use cases were identified at the project outset. On average, the starting TRL of use cases was 4.2 and the average improvement in TRL of the 5GTT programme was 1.7

20 of 37 (54%) projects resulted in a solution being brought to market. 29 of 37 (78%) projects resulted in consortium members benefiting from having adopted process innovations

The programme resulted in £262.8m in further private and public investment. For every £1 of government funding the programme leveraged £1.65 in further funding, £1.32 when known public funding is not counted. This ratio falls in line with that of other comparator R&D programmes

10.1.2 Establish the conditions under which 5G can be deployed to drive efficiency and productivity

The programme sought to diversify the market and tackle issues around Information and awareness, cost and scale that were prohibitive to smaller players and the lack of readiness of infrastructure and technology. Most progress was made towards tackling information and awareness barriers.

One of the strongest aspects of the programme was ecosystem development, accomplished through DCMS networking activities, the UK5G Innovation Network, and through DCMS's support to create project consortiums and, later, gain further investment. Awareness gained from being *involved* or part of the UK5G network will likely prove crucial to many organisations who had previously not been aware of similar funding opportunities.

Overall, this programme has demonstrated some very promising early signs of how it has generated benefit to the wider economy across the areas identified as targets by DCMS. As many of the projects had only finished in 2022, the wider benefits will take some time to diffuse across the wider 5G ecosystem and the overall economy, and there will be a further time lag before impacts are reflected in the available data.

More effort is needed to tackle the other barriers which will unlock further spill overs. The wider impacts of this include challenging existing MNO business models and creating opportunities for new market entrants. Efficiency savings also arise from regulatory processes (planning, spectrum applications) as well as reductions in unit costs and resource usage. While 5GTT has been effective in this area, work is still ongoing to reduce costs and barriers. DCMS/DSIT have other programmes under way to support deployment and are maintaining the UK5G network (now running as UKTIN, the UK Telecoms Innovation Network) to share knowledge.

The 5GTT programme played an important role in developing the 5G ecosystem within the UK and has thus supported wider impacts through this. We were told by DCMS that 5GTT may have influenced the early commercial roll out of 5G in the UK. Since 2019, more consumers have access to 5G. Survey evidence also suggests that the programme has also had a positive impact on the reputation of the UK as a key player in the sector. However, the UK still has some way to go in terms of readiness for deployment compared with the small number of truly world-leading nations. Global rankings suggest that countries such as the USA and South Korea are ranked higher than the UK.

There have been spillover benefits into sectors and areas not directly related to the 5GTT programme

- Project delivery partners were able to enhance their knowledge and skills in deploying secure and resilient networks and share this learning with the ecosystem more widely.
- Projects considered the environmental impact of their use cases, particularly in transport. Environmental considerations can lead to more efficient and sustainable practices, and reduction of environmental damage increases wellbeing in the wider public.
- 5GTT has produced applications to improve health and wellbeing directly, and also to provide enjoyable experiences that people might not otherwise have access to.

8.1.6 To what extent can the 5GTT programme generate benefits in the future?

Many of the impacts currently seen appear to be at **an early stage, with the full spectrum of large benefits still to be borne out.** These wider spillovers will be pivotal in bringing business generation and connectivity to previously under-served areas. The costs and benefits enumerated in the main report are not all in monetary terms. However, the overall amount spent on the programme has the potential to generate **returns which are many times larger than the initial outlay due to the nature of 5G.**

The development of 5G over previous generation technologies will support the UK economy to adopt further innovation and benefit from that. The improved latency, security and network capacity aspects of 5G over 4G create opportunity for new industry applications.

A Value for Money assessment was conducted as part of a business case update in September 2020. This estimated the net benefit of 5GTT as £2.58 billion from 2021 to 2030, against a government spend of £160.8 million. Our review of wider literature shows that, although the scale of benefits might be smaller, the approximate level of impact as estimated by the previous VfM model (2020) is well within the range of the magnitude of impact that widespread adoption of 5G and related use cases are expected to have on the UK and global economies.

10.2 Implications for future economic evaluation

There are plans to conduct a final evaluation once 5GTT projects have had more time to generate the intended outcomes and impacts, such as any impact of 5G adoption on revenue growth and additional 5G related investment. The final evaluation would benefit from a mixed methods approach including qualitative analysis of stakeholder consultations and case studies in conjunction with quantitative methods such as Cost Consequence Analysis (CCA) and Cost Benefit Analysis (CBA) for a VfM, based on additional years of company data (e.g. from Orbis) and market data. The limitations and challenges encountered during this project will provide key learning to take into a final evaluation. Knowledge about likely challenging response rates, and timing of collaboration tool deployments will be critical to develop the framework to carry out quantitative analysis.

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