INTERIM EVALUATION OF 5G TESTBEDS AND TRIALS PROGRAMME

Annex 3: Case studies

5 June 2023

CONTENTS

1. INTRODUCTION

As part of the 5GTT programme evaluation we prepared 15 case studies of projects that were successfully awarded funding. Case studies were selected to ensure good coverage of different sectors, geographical location types, 5G technologies, project progression, success levels, and region. The case study selection criteria and rationale are covered in detail in Annex 1.

The table below shows the case studies selected and summarises their characteristics. Ultimately, 5G Ports was excluded from the case study sample, due to issues carrying out fieldwork (it coincided with work related to project closure). Following discussions with WM5G, we agreed that the Transport Road Sensors could be treated as one of the Transport Use Cases rather than a standalone project in its own right. These projects are therefore not included in Table 1 below.

Table 1: Summary of case studies selected.

Project name	Sector	Rural/ Urban	Standalone/ Non-standalone/ Mixed	Public/ Private	RAG	Region
5G CAL	Industry	Unknown	S	Private	A/G	NE
5G Connected Forest	Leisure	Rural	Mixed	Private	A/G	EM
5G Festival	Leisure	Unknown	NS	Private	A/G	SE
5G Logistics	Transport	Urban	S	Private	A	SW
5G Wales Unlocked	Infrastructure	Rural	NS	Public	G	Wales
Connected Cowes	Leisure	Rural	NS	Private	A/R	SE
Liverpool 5G Create	Health	Urban	S	Private	A	NW
MK:5G	Leisure	Urban	S	Private	A/R	SE
5G Rail Next	Transport	Urban	S	Private	A/R	
5G New Thinking	Infrastructure	Rural	S	Private	A	UK
West Mercia Rural 5G	Health	Rural	NS	Private	A	WM
WM5G Transport Use Cases	Transport	Urban	Mixed	Public	A	WM
5G AMC2	Industry	Unknown	S	Private	A/R	Scotland
5G Factory of the Future	Industry	Urban	S	Private	A/R	NW
WM5G Infrastructure Accelerator	Infrastructure	Urban	N/A	Public	A	WM

Each case study contains:

- A description of how the project was designed and delivered, including test networks deployed and the use cases tested.
- An assessment of project consortium experiences around collaboration; sharing knowledge with the wider ecosystem and experiences with DCMS process.
- A summary of the project's outputs and measurable impacts.
- An assessment of the additionality and contribution of the project to the wider programme success measures/KPIs, as set out in Annex 1. This is assessed by a **contribution score** of 0-3 where:
  - 0 = no evidence of activity relating to this impact.
  - 1 = evidence of activity, but no evidence of contribution to this impact/additionality of 5G.

- 2 = some evidence of contribution to this impact/additionality of 5G.
- 3 = strong evidence of contribution to this impact/additionality of 5G.

These are based on analysis of monitoring information such as:

- project benefit realisation spreadsheets;
- project final reports;
- project websites (where they exist); and
- interviews conducted with members of the project consortiums.

For each selected project, we interviewed representatives of the lead organisation and other member organisations in the consortium, so that information came from more than one perspective. Some interviews were conducted as a group interview and others were conducted with individuals. There were also some organisations who led or were involved in more than one case study project. Topic guides were tailored to ensure all relevant projects were covered.

2. 5G CAL

2.1 Project Overview

5G Connected Automated Logistics (CAL) was funded as part of the first round of 'Create' projects. It lasted for 15 months, from March 2021 to June 2022, including a three-month extension. The project sought to understand and mitigate innovation challenges in the manufacturing sector, and enhance efficiency. The overall aim of the project was to demonstrate the use of 5G communications as a core component of CAL in manufacturing.

To this end, the project demonstrated a proof-of-concept for 'automated just in time delivery' using retrofitted autonomous 40-tonne yard tractors with remote driver supervision and teleoperation capability to provide timely intervention in the event of the autonomous system experiencing abnormal conditions. The project used a privately deployed 5G network, and was heavily reliant on the ultra-low latency and enhanced speed of 5G to test the switch from automated driving to teleoperation.

The project was conducted between Vantec Logistics centre and Nissan's Sunderland manufacturing plant, where its key experiment was delivering parts from Vantec to Nissan using the automated tractors[1] . Having developed a proof-of-concept, the project hopes to further develop its use cases in the near future and hopes that 5G powered teleoperation would aid in reducing the need for safety drivers in vehicles in CAL trials moving forward.

Table 2: Overall project summary

Project	5G CAL
5GTT Competition	Create Window 1
Sector	Manufacturing and Industry
Location	The Northeast of England, Urban
Timeline	Originally March 2021 to March 2022. Extended by three months to June 2022.
Lead consortium partner	North-East Automotive Alliance (NEAA)
Other consortium partners	StreetDrone Ltd, Connected Places Catapult, Perform Green, Vantec, Nissan Motor Manufacturing UK Ltd, Fergusons Transport Limited, Zenzic-UK Limited, Terberg DTS UK Ltd, Sunderland City Council, Department for Transport, Newcastle University, Coventry University
Type of network/technology deployed	Private, standalone 5G network
Total project costs	£4,412,040
Funding awarded by DCMS for 5GTT	£2,250,776

2.1.1 Progress on success measures

The 5G CAL project has resulted in strong evidence of added value of 5G technology against 5 of the 11 5GTT success measures.

[1] A logistics firm co-located with Nissan Sunderland

Table 3 Summary of impact of 5G CAL

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The project focused on increasing the reputation of the North-East as a hub for CAVL. The proof of concept it developed was the first instance of full end-to-end delivery using an autonomous HGV in the UK. This project has also featured in several press articles which would help UK's reputation as a leader in 5G.	3
Programme activities have attracted further funding within the area of 5G/5G R&D	The project attracted £4 million in third party funding. Consortium members have also applied for further funding to the Centre for Connected and Autonomous Vehicles (C-CAV). One consortium member has successfully garnered venture capital on the back of 5G CAL to further develop its use cases.	3
Reduction/ removal of barriers has accelerated deployment of 5G in the UK	The project deployed a private 5G network to test its use cases. There is little evidence of the project significantly breaking barriers or accelerating 5G deployment in the UK. Interviewees reported that the consortium learnt of the existing barriers to 5G deployment and what would be needed to surpass them.	1
Information and knowledge is more readily transferred within the 5G ecosystem	The project featured in several local and national press articles. Knowledge dissemination activities included presentations, conferences, and webinars which targeted the wider public, individual organisations, other 5GTT projects, and wider DCMS groups such as health and security. These were primarily aimed at increasing the awareness of the project and increasing the level of acceptance of the end user towards CAL.	2
5G networks are more secure than the 4G networks they replace	The security and reliability of the deployed 5G network was paramount. The consortium included 5G experts and cybersecurity specialists to ensure the network deployed met the industry standards to be considered safe and reliable.	3
Additional welfare and environmental benefits	Generating environmental benefits were not of primary concern for the project. However, their use of an electric vehicle in developing their use cases resulted in positive environmental impacts in terms of fuel savings which contributed to their objective of increasing efficiency.	2
Public services cost avoidance	Reducing the costs of public services was not the primary aim of the project. However, the project did aim to increase efficiency by cutting down business operational costs such as labour and fuel, which has indirect impacts on the cost of providing public services. As it currently stands, the project is far from realising these cost avoidance benefits, but it has successfully demonstrated proof-of-concept, which has the potential for huge benefits in the future.	2
Development of industry 5G expertise and increased ability to use 5G for commercial activities	The project did not directly increase the ability of the industry to use commercial 5G. It did generate several high paying jobs in the tech and software development space, which persisted after the end of the project and could be viewed as having some impact in this area.	2

Success measure	Evidence	Contribution Score
Generation of 5G activities beyond the scope of the programme	The consortium has applied for funding from C-CAV. One consortium member has also acquired capital to further the 5G CAL use cases. The consortium also received expressions of interest from several ports including the Port of Felixstowe to collaborate for developing 5G CAL further.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	The 5G CAL use case has not yet been commercialised. However, by demonstrating the proof-of-concept for 'automated just in time delivery,' the project has garnered interest from several institutions to further develop the use case in controlled environments. This the consortium says is the first step towards commercialisation.	1
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The project deployed a robust private 5G network which met the standards considered to be safe and reliable for testing CAVL use cases. The network is still in place and may potentially be used by the consortium to further develop 5G CAL.	3

2.1.2 Project aims and activities

Project objectives include:

- understanding the innovation challenges and improving efficiency in the manufacturing sector using Connected Autonomous Vehicles (CAV) and CAL;
- demonstrating the efficiency gains brought about by 5G in CAL and from reduced fuel costs and added resilience in logistic operations;
- investigating the support needs of the end users to design safe and user-friendly 5G enabled automated vehicles; and
- increasing end user awareness regarding CAV/L and improving adoption.

Through the course of the project, the consortium members used a privately deployed 5G network on Nissan's Sunderland test track and the private road between Vantec's warehouse facilities and Nissan's manufacturing plant to test the following use cases:

- autonomous driving, reversing, and docking software; first on smaller vehicles, followed by 40 tonne HGVs.
- using additional equipment such as eye-tracking glasses to enhance safety during live operation.
- exploring the impact of 5G on the effective transition from autonomous driving to teleoperation of CAV.
- exploring the remote driver's attention and behaviour when interacting with 5G CAL.
- investigating the effect of multitasking on the remote driver's takeover performance and behaviour in 5G CAL.

The project successfully met its aims through deploying a 5G network and testing the use cases outlined above, including demonstrating proof of concept for the 'automated just in time' delivery system.

2.1.3 External factors affecting delivery

As part of our stakeholder consultation, we asked whether external factors had an impact on project delivery. COVID-19 was identified as an ongoing risk for the project's operations in terms of availability of workforce

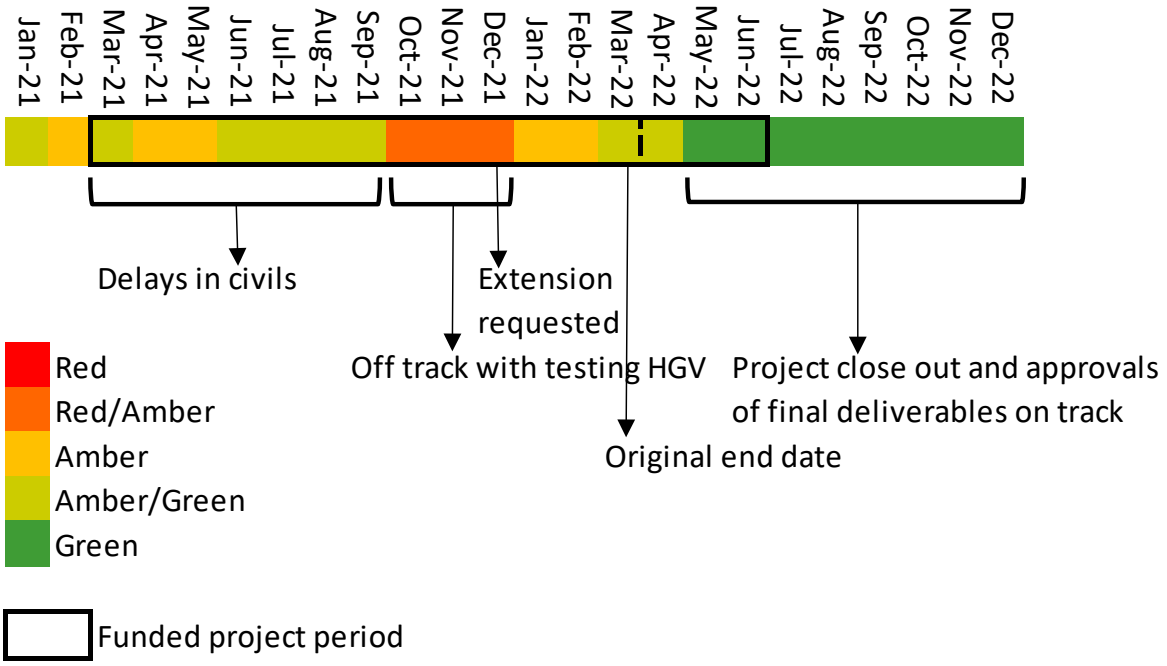
and equipment. While they successfully managed the shortage in workforce, a greater impact was felt due to their inability to source parts such as sensors and lidar equipment from outside the UK. Interviewees felt this was mainly caused by COVID-19, but exacerbated by EU Exit and the global shortage of semiconductors.

The project used Nokia's NDAC system to set up their 5G network, so the impact of trade restrictions with HRVs was minimal, manifesting mainly as price fluctuations. They said that the consortium had to actively manage the project expenditure on 5G infrastructure equipment.

2.1.4 Timeline

As mentioned in Table 2, the project was initially planned to last for a year from March 2021. However, a three-month extension was granted to the project towards the end, which stretched it till June 2022. This was due to external factors cited above. Besides these, interviewees also noted that there is insufficient supply chain capability for connected mobility infrastructure in the UK. They identified this as an opportunity for organisations like the C-CAV to aid in the development of digital supply chains. They said that it was something the project has been supporting by sharing its findings with the Centre.

Figure 1: Project timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

The project had a rocky start due to delays in installation of equipment and obtaining spectrum licences. Delays with equipment testing led to a change request being submitted to extend the project by three months. Following the extension, the project was rated higher, and approvals were delivered on time, within budget.

2.2 Consortium Partners

5G CAL was delivered by a large consortium of 12 members, including businesses, academics, and public entities. It was led by the North East Automotive Alliance.

Table 4: Consortium members, 5G CAL

Organisation	Type	Role/responsibilities on project	Staff allocated to project
North East Automotive Alliance Limited	Private, limited by guarantee, no share capital	Lead Partner – Overall project governance, assurance, and reporting	2
Newcastle University	Academic	Identification and definition of use cases, user engagement, design of trials, data collection and analysis, evaluation, future upscaling, regional/ national beneficiaries, dissemination, and liaison	1 (School of Engineering)
Coventry University	Academic	Cybersecurity assessment of 5G connectivity and remote operation of vehicle control	1 (Institute for Future Transport and Cities)
StreetDrone Ltd	Private Limited Company	Developing CAV technology and operating on-site trials	16
Connected Places Catapult	Private, Limited by guarantee, no share capital, use of 'Limited' exemption	Investigate the commercial opportunities and roadmap for the technology, and establish a cost benefit analysis and investigate the impact for UK PLC	8
Perform Green	Private Limited Company	Provision of technical advisory and assurance, coordination and design of the 5G implementation and for support for integration of the 5G network as well as assurance on information and cyber security and dissemination support.	6
Vantec	Private Limited Company	Logistics Expertise	3
Nissan Motor Manufacturing UK Ltd	Private Limited Company	Trial end user, provision of operational/logistics expertise, land for masts, test track and private road for testing	0.5
Fergusons Transport Limited	Private Limited Company	Logistics Expertise & Engineering	0.5
Zenzic-UK Limited	Private Limited Company	Connected and Automated Mobility Expertise	2
Terberg DTS UK Ltd	Private Limited Company	Vehicle partner	0.5
Sunderland City Council	Public body - Local Government	PMO and City/Regional Coordination	2
Department for Transport	Public body - National Government	Providing wider insight, government policy	

2.2.1 Working with consortium partners

CAL was identified as the next key innovation challenge for Nissan and Vantec's logistics operation. The NEAA led several workshops to identify the CAL opportunity. Partners, including NEAA, Nissan and Vantec, collaborated with Sunderland City Council on their Smart City Programme, identifying CAL as one of the primary use cases.

While many members of the consortium had a history of collaboration, new members such as Coventry University and Perform Green were readily incorporated for their expertise in cybersecurity and setting up 5G networks. Stakeholder consultation revealed that a few non-funded organisations also joined the consortium after the 5GTT funding had been received (they signed the collaboration agreement and supported the project). Once the project was funded there were no changes to the consortium. Interviewees reported that members of the consortium work well together and planned to continue working together to further develop 5G CAL.

2.2.2 Personnel

5G CAL created several new jobs, in sectors ranging from street driving to tech and software development. Interviews report that around 105 people worked on the project as a whole, with 20 to 40 employees engaged in its daily operations. The project also resulted in a significant increase in FTE in the consortium members. For instance, StreetDrone, a member of the consortium, started with a staff of 18 and grew to employ over 35 staff on an FTE basis, nearly doubling in size during the course of the project. Besides StreetDrone, Sunderland Council and NEAA also recruited significantly on the back of the project, with many of the jobs persisting after the completion of the project. Stakeholder consultation revealed that StreetDrone was able to garner additional funding, which has allowed it to create more high value jobs.

2.3 5G Deployment

2.3.1 Approach to deployment

The 5G CAL project used Nokia's NDAC and 77-spectrum to deploy a stand-alone private 5G network at Nissan's Sunderland manufacturing plant. Perform Green, and Coventry University and Newcastle University helped articulate the requirements for setting up a reliable, fast, and secure 5G network. Deploying a private network helped the consortium develop a teleoperation system, which would enable a remote driver to take over control of the vehicle if it came across abnormal conditions.

The network deployed was divided into 49 segments of 50 meters each, covering the starting point (Vantec's Turbine Way facility) to the end of the route (Nissan's manufacturing plant). Testing was carried out at several points in time starting at the baseline. Baseline testing was done to benchmark the metrics for future comparison and to ensure the network was safe and ready for the trials. These tests measured the network's overall latency (<10ms), its reliability (uptime) and the reliability of the "failover" switch from autonomous driving to teleoperation.

Apart from this, throughout the course of the project, and in line with developing the proof of concept for 'automated just in time delivery,' the consortium tested several metrics at each of the 49 network segments, and at the start and end points. These metrics included network latency, network up-link and down-link bandwidth, and the percentage of the route driven manually, teleoperated, and driven automatically, among other metrics. Not all the metrics were tested consistently.

Benefit Realisation Sheets report the networks measured and their progress against target.

- The target for network latency was around 4 milliseconds as ultra-low latency was required to ensure safe operation of the teleoperated delivery vehicles. Whether this target was achieved at the end of the project was not disclosed, but the baseline measurement was less than 10 milliseconds, which meets the standard required to safely carry out tests on autonomous 40-tonne vehicles.

- The project successfully met targets for testing network resilience, e.g., uptime and handover between radio sites.

- The project also measured how much of the route was driven autonomously and how much required remote operator input. The target was for 70% to be driven autonomously and only 30% to require remote operator input. This target was met and exceeded.

2.3.2 Use cases

Six use cases were tested.

1. **Autonomous Driving Software test on mule:** The software was first tested on a smaller vehicle (Nissan eNV200 van). The early assessment and verification testing on a smaller vehicle aided in accelerating software development before moving to 40 tonne HGV.

2. **Autonomous Driving Software test on HGV:** After successful trials with the smaller vehicle, the consortium tested the autonomous software on a Heavy Goods Vehicle (HGV). For enabling successful operation of a 40 tonne HGV without safety driver intervention, the consortium used multiple methods for localisation, path planning, and object detection designed specifically for the logistics environment. There was also a 5G communications link to a remote operator to enable smooth handover and operation when the Automated Driving System is outside of its ODD (Operational Design Domain).

3. **Test on autonomous Zero Emission HGV:** The consortium used a 40 tonne zero emission autonomous logistics (ZEAL) vehicle which meets or exceeds industry standards. Care was taken to make sure that it was capable of operating without human intervention by incorporating a 'fail operational braking system' and specific logic within the onboard ECUs to execute a Minimum Risk Manoeuvre (MRM) should an error occur. This was in addition to allowing a remote operator to take over the vehicle through teleoperation in any fallback situations. The robust 5G private network deployed, was essential in reducing the number of MRM's executed due to the communication between the remote operator, and the vehicle exceeding a fixed latency threshold.

4. **Testing autonomous docking/reversing:** The consortium further tested the autonomous reversing / parking abilities of a 40-tonne truck with an articulated trailer unit. High accuracy software modules were developed for reversing up to the relevant loading door. Apart from this, infrastructure-based cameras were used to communicate over the deployed standalone 5G private network system with a 3.8GHz (N77 band) radio link. This was done as part of a system-based approach to enable the remote operator to oversee safety of the reversing manoeuvre.

5. **Teleoperation:** This involved the remote operation of a terminal tractor (Terberg) including full remote driving of the vehicle as well as execution of discrete commands, for either a pre-determined standard operating procedure or in a fallback situation. This was done by developing a functionally safe remote driving set-up in a static location with redundant communication links over the standalone 5G network system with a 3.8GHz (N77 band) radio link. 5G was essential in maximising bandwidth and reducing latency. While maximising bandwidth enabled the remote operator to see multiple live camera feeds from the vehicle, low latency enabled higher speeds at which it was safe to operate the vehicle.

6. **SASMI (Nissan):** To develop a 'Proof-of-Concept,' it was necessary to understand how 5G technology could support or replace existing communication methods on the shop floor to provide high bandwidth and low latency data as a cost effective solution. To do this, the consortium used AI based sensors for vision, and electrical resistance and infra-red to support cost-effective monitoring. It was found that processing data at the sensor had low latency but was very expensive. Use case was set up to stream data from sensors to Edge or Cloud compute, run the algorithms designed by the project and return the results with low latency.

Key benefits from the use cases that the project measured included:

- Running and equipment maintenance costs for 5G CAL were estimated to be 10% lower than the vehicles currently deployed.
- Operational efficiency and productivity was monitored in terms of number of trips and hours spent idle. Deploying autonomous vehicles was shown to increase operational efficiency.
- Deploying the use case would allow for a reduction in accidents from 33 to 26 incidents compared to the baseline.
- The project also considered technology acceptance – e.g., whether the project led to a reduction in the time to adopt autonomous/teleoperated vehicles, but there was less information available about this at the end of the project.

2.3.3 Safety and security impacts

Interviewees reported that safety and security were considered most vital throughout the course of the project and was built into the network. Trials were carried out in a live manufacturing environment and involved autonomously driven 40 tonne trucks with trailers. The consortium also wanted to raise awareness and the level of acceptance of CAVs which would be adversely impacted by accidents, further leading to lower adoption rates.

This led the consortium to involve organisations specialising in cybersecurity research such as Coventry University. Baseline testing of the deployed 5G network was undertaken to ensure that the network was safe to carry out the experiments; mainly by testing its uptime, failover, and the overall latency. It was ensured that these metrics met the standard target requirements for the network to be considered safe.

2.3.4 Technology Readiness Levels

All six of the use cases record an improvement in their TRLs as a result of the project. End TRLs were largely in line with targets.

Table 5: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
Autonomous Driving Software (Mule)	3	6	6	Yes
Autonomous Driving Software (HGV)	1	7	7	Yes
Autonomous Zero Emission HGV	1	7	7	Yes
Autonomous Docking/Reversing	1	6	6	Yes
Teleoperation	2	7	7	Yes
V2I	1	6	2	No

Source: Benefits Realisation

2.4 Collaboration knowledge sharing and overcoming barriers

2.4.1 Sharing Learning and best practice

5G CAL successfully demonstrated the proof of concept for the ‘automated just in time’ delivery system and achieved the objectives set out for the phase 1 of the project in its project overview (see Figure 2). However, the exploitation report published by the consortium in 2022, suggests that close examination and further development of several use cases is required to achieve full automation. It also suggests that currently, legacy solutions are likely to be cheaper and more readily accepted by the end users. This sentiment is also echoed by the stakeholders interviewed.

Interviewees also revealed that the project has led to the development of best practices from working with project partners and across the wider 5GTT ecosystem. The learnings and best practice have been shared with the DCMS team through the benefit realisation process.

Table 6: Publication and events summary

Dissemination activities	Number of articles/events
Webinars	128
Collaboration calls with other 5GTT projects	11
Presentations and Conferences	17
Press features	20

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website[2], which provides an overview of the project.

2.4.2 Interaction with wider ecosystem

Apart from sharing learnings with DCMS, Table 6 informs us of avenues such collaboration calls, presentations and conferences, and press features that were explored by the project for the wider dissemination of its learnings and knowledge. Through these, the project had significant interactions with

- Individual organisations such as University of Strathclyde, Vivacity, and Weaver labs
- Other 5GTT projects such as 5G Connected Forest;
- Wider DCMS groups such as Skills, Health, and Security;
- Wider accelerators such as Digital Catapult; and
- The general public.

The primary focus of the project was the development of technology rather than specific benefits of its deployment. The consortium have created a video demonstrating the proof-of-concept for 5GCAL.

2.4.3 Business and industry generation

Besides stimulating investment through the consortium members, the project has also resulted in additional third-party investment to the tune of £4 million for the further development of 5G CAL. The stakeholder consultation we undertook not only revealed that members of the consortium were looking for further funding, but also that StreetDrone, a member of the consortium who own the IP to the 5G CAL use cases, have already secured additional funding from Wilko and are looking for further VC funding. The interviewee mentioned that the outputs of the 5G CAL project were at the forefront of this funding.

Apart from the funding, we learnt that StreetDrone are also looking to collaborate with other controlled environments such as cargo and ports, among others, to further the development of 5G CAL.

The table below summarises the funding received from DCMS how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

[2] https://uk5g.org/discover/5G-projects/testbeds-and-trials/5g-cal/

Table 7: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£2,422,000	£2,512,000
Number of partners that received funding / contributed R&D	7	13

Source: Benefits Realisation

2.5 Programme processes and support from DCMS

Interviewees reported a minor communication issue at the start of the project around reporting. DCMS misunderstanding the roles of the consortium members and the overall objectives of 5G CAL was also a reported issue. Once this was resolved interviewees said that the programme was well managed and progressed smoothly. They felt that DCMS had acted as a vital enabler in terms of successfully creating an environment that conducive for the development of a possibly viable commercial 5G use case. They viewed finance as the main barrier to further 5G technology in the UK, and opined that DCMS had weakened the barrier through the 5GTT programme by allowing them to demonstrate the use case and potential return on investment. This they said has the potential for huge benefits in the future.

In terms of processes that could be improved, they cited the bi-weekly updates required by DCMS on each aspect of the project and the high frequency with which DCMS changed its personnel. Besides this, they also cited the overwhelming importance that DCMS and UK5G placed on collaboration activities, which sometimes did not add significant value and came in the way of developing use cases.

2.6 Project Impacts

Table 3 shows strong evidence of impact against 5 of the 11 success measures of the programme:

- the reputation of the UK as a leading 5G nation has improved
- programme activities have attracted further funding within the area of 5G/5G R&D
- 5G networks are more secure than the 4G networks they replace
- generation of 5G activities beyond the scope of the programme
- projects generated viable networks that fulfilled the specifications to support the 5G applications required

2.6.1 Additionality

We asked the lead stakeholder to comment on both the additionality of 5G as a technology and the additionality of the 5GTT programme funding. The interviewee expressed that the 5G CAL project, and specifically the proof of concept for teleoperation, were wholly reliant on 5G. The remote operation of the 40 tonne trucks and the removal of the safety driver needed a fast, reliable, ultra-low latency network, which could not have been provided by 4G or other previous generation networks.

On the additionality of the programme funding, the interviewee opined that the project could not have been accomplished in the absence of the funding received from the 5GTT programme. They said that the programme “had brought forward tech in the UK by years,” enabling the first full end-to-end delivery using autonomous HGVs with reverse parking in the whole world.

It can therefore be said that both 5G as a technology and 5GTT funding have added significant value to the project, its processes, and outputs.

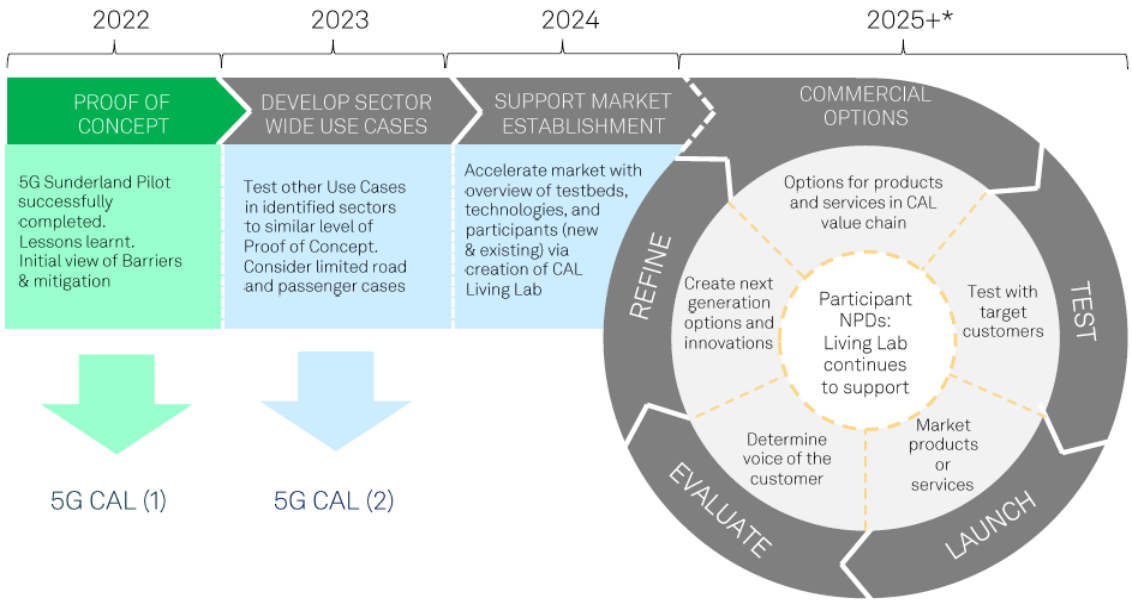
2.6.2 Sustainability

5G CAL was envisioned as a multi-stage project, from proof of concept until commercialisation. Out of this, the first stage of the project has now been accomplished with the help of 5GTT funding. Figure 2 presents the 'process to commercialisation and scale up' as envisaged by the consortium in its 'exploitation plan' published in 2022. Besides this, the project plan published by the consortium in March 2021 also describes it as a multi-phase testbed with its long-term vision being 'To develop a globally unique centre of excellence and testbed for Connected Automotive Logistics (CAL) in the North East'. This shows that there was always an intention to further develop the outputs of the project.

The project received c.£4 million of additional investment from third parties throughout its course. StreetDrone, a member of the project that owns the IP for the use cases, has received further VC funding from Wilko. We have also learnt from stakeholder consultation that the consortium members, along with a few new members, have applied for further government funding from the Centre for Connected and Autonomous Vehicles (C-CAV)[3] to further develop 5G CAL.

Initial knowledge sharing and collaboration efforts as part of the project have garnered the interest of ports in the North-East of England to further develop the use case. Although full commercialisation is still far away, the consortium is putting continued efforts towards further developing and commercialising its outputs in controlled environments.

Figure 2: Process to commercialisation and scale up



Source: 5G CAL Exploitation Plan

[3] https://www.gov.uk/government/organisations/centre-for-connected-and-autonomous-vehicles

3. 5G CONNECTED FOREST

3.1 Overview of the project

The primary aim of the 5G Connected Forest programme was to explore and assess the potential ways in which 5G could be used to protect, promote, and enhance visitor experience in the Sherwood Forest region and Rufford Abbey in Nottinghamshire. In this respect, it set itself apart from several other 5GTT projects that looked to demonstrate specific efficiency gains brought about by specific aspects of 5G connectivity. Its research-oriented nature led the project to deliver unique use cases such as the world's first 5G network in a non-commercial forest setting and 5G enabled visitor attractions. Apart from its own use cases, the 5G Connected Forest programme has also inspired several spinoffs and further research testbeds such as a unique 5G careers programme and a new digital innovation centre in Nottinghamshire, among others, which have the potential to generate significant benefits in the future.

Table 8: Overall project summary – 5G Connected Forest

Project	5G Connected Forest
5GTT Competition	Rural Connected Communities (RCC)
Sector	Leisure/Tourism/Events/Media
Location	Sherwood Forest, Nottinghamshire (NCC)
Timeline	March 2020 to June 2022
Lead consortium partner	Nottinghamshire County Council
Other consortium partners	Netmore IOT Solutions Ltd, Gooii, ISPB, Parkwood Leisure, Stagecoach East Midlands, Harworth Group, Birmingham City University, Nottingham Trent University
Type of network/technology deployed	Private, standalone network
Total project costs	£7,351,790
Funding awarded by DCMS for 5GTT	£4,557,270

3.1.1 Progress on success measures

5G Connected Forest has generated strong evidence of added value for 4 of the 11 5GTT success measures

Table 9 Summary of impacts of Connected Forest

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The project focused on exploring how 5G could be used in a rural setting in Nottinghamshire County. Elements of use cases such as deploying a 5G network in a forest setting and developing the world's first interactive holographic movie were unique and garnered some attention in the press. The project also involved partners who were very new to the UK but had a significant international presence. These activities could be seen as having improved the UK's reputation as a leading 5G nation to some extent.	2

Success measure	Evidence	Contribution Score
Programme activities have attracted further funding within the area of 5G/5G R&D	Although the exact extent of further third-party funding received is not known, we know that the Nottinghamshire Innovation Centre, which was inspired by the programme, received funding from (Getting Building Fund (GBF) for its creation. Stakeholder consultations have revealed that the consortium is actively looking for further funding.	2
Reduction/removal of barriers has accelerated deployment of 5G in the UK	Stakeholders unanimously agree that project activities increased awareness of 5G through its activities and spinoffs. For instance, the project used the Robotic Dogs (Eric and Gizmo) for a range of public engagement events to inspire future generations in the wonders of science and technology. The project deployed two working 5G networks, and is actively working towards increasing awareness through its spinoffs such as 5G Careers.	3
Information and knowledge is more readily transferred within the 5G ecosystem	Consortium members participated in the knowledge sharing activities of the wider 5G ecosystem through presentations and conferences. The project also individually connected with several other 5GTT projects such as Worcestershire, Rural Dorset, and 5GCAL. Nottinghamshire County Council, the lead partner in the consortium, collaborated with UK5G's 5G Skills Working group to develop its 5G careers spinoff. Lastly, the consortium shared its learnings with DCMS through the Benefits Realisation process.	2
5G networks are more secure than the 4G networks they replace	Security was not a specific focus of this project	0
Additional welfare and environmental benefits	The project's Environment Management use cases, especially the Robot Forest Manager, was designed to more efficiently detect forest fire and raise a timely alarm in cases of emergencies. It was successful in detecting a fire in each of the 30 instances where a video or a photo of a fire was shown to it. Although the use case is still in development, it has significant potential for future benefit materialisation.	2
Public services cost avoidance	The Robot Forest Ranger and Robot Forest Manager are designed to increase efficiency in forest management and reduce labour costs by mitigating the need for as many personnel. Although the use cases are far from commercialisation, they do show tremendous potential in cutting the public costs in the environment management industry.	3
Development of industry 5G expertise and increased ability to use 5G for commercial activities	The project employed 6 researchers throughout its course to develop its use cases. Apart from this, one of its spinoffs, 5G careers employed 8 staff on an FTE basis. Although not all of the positions were permanent, and were focused more on the non-tech application of 5G. The 5G Careers spin off project also aimed to engage school students around career opportunities enabled by 5G technologies in different sectors.	2

Success measure	Evidence	Contribution Score
Generation of 5G activities beyond the scope of the programme	The project has inspired a wide range of spinoffs and parallel testbeds in rural Nottinghamshire such as the 5G careers, Nottinghamshire Innovation Centre, and the Swift lab. Although not a part of the project, the members of the spinoffs are working closely with the consortium members to develop 4 new 5G testbeds in Nottinghamshire	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	By increasing awareness, the project's activities have created a demand for better connectivity in rural Nottinghamshire. This is evidenced by the fact that network operators such as CityFibre, ConnectFibre, and TrueFibre are now interested in bringing broadband to Nottinghamshire.	3
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The project deployed two 5G networks, one standalone and one non-standalone. Stakeholder consultations further revealed that the two networks run three types of 5G. Although not all the use cases could be tested using the networks during the course of the project, the networks were designed to fulfil the 5G specific requirements of the project's use cases and are still functional.	2

3.1.2 Project aims and activities

The 5G Connected Forest had several stated aims such as:

- developing a mobile 5G network in a protected forest setting (the Sherwood Forest in Nottinghamshire);
- identifying business models and applications suitable for the commercial development of its use cases;
- boosting 5G related skills development and employment opportunities for residents of Nottinghamshire; and
- encouraging the creation of new tourism business opportunities across Nottinghamshire.

Consultations with stakeholders have revealed that the goals of the 5G Connected Forest programme fall within the wider underlying aim of the Nottinghamshire County Council, who were looking for ways to enhance connectivity in rural Nottinghamshire prior to their involvement in the 5GTT programme. This motivation formed the essence of the use cases of the 5G Connected Forest project which included:

- deploying two 5G networks in the Sherwood Forest, Rufford Country Park, and Rufford Abbey;
- delivering three different 5G-based visitor experiences:
  - An Arrow Through Time – an outdoor based AR experience;
  - Rufford Ghost Walk – an indoor based AR experience;
  - Tag in the Park – a mobile proximity-based outdoor treasure hunt.
- deploying 5G-powered Robot Forest Rangers and Forest Manager drones in the Sherwood Forest.

The project was successful in achieving its aims but some use cases were de-scoped or abandoned due mostly to COVID restrictions impacting the tourism sector.

3.1.3 External factors affecting delivery

5G Connected Forest was significantly impacted by external factors such as COVID-19, EU exit, global supply chain crisis, and trade restrictions with High-Risk Vendors (HRV), among others. One stakeholder reported that the consortium had initially planned on using components from Huawei but had to switch to Nokia or Ericsson due to restrictions to limit risk from HRVs. Another stakeholder stated that six months into the project, the consortium should have had a working 5G network, but instead, they had not started deployment due to severe shortages of equipment in the whole of the UK (see Figure 3). Stakeholders also mentioned that the regulations involved with setting up a 5G network in a protected heritage area worsened the impact of these external factors by creating more delays. This was on top of not being able to visit the site due to COVID-19 restrictions.

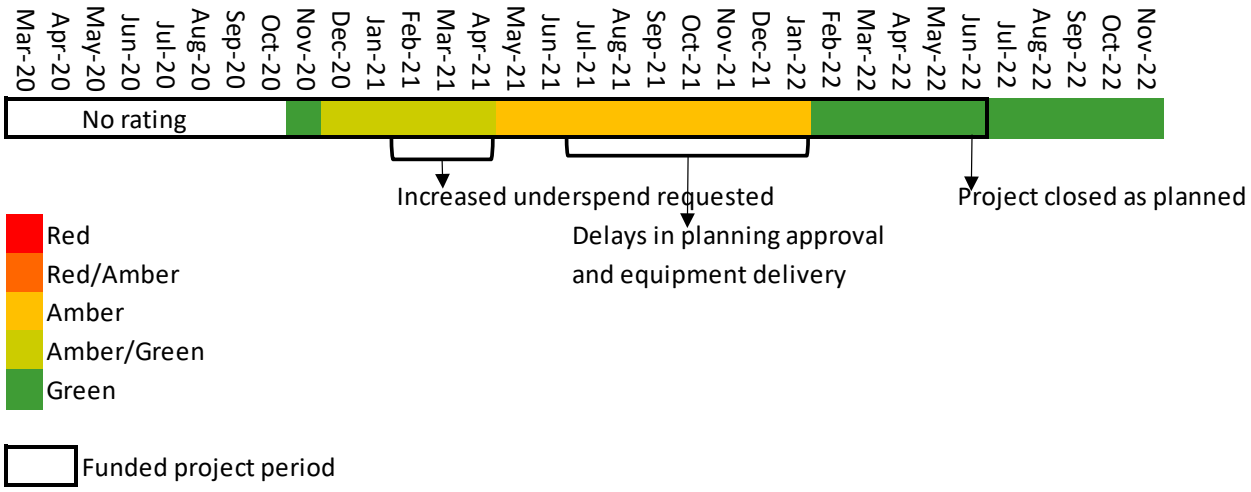
Apart from this, there were significant changes to the makeup of the consortium, with organisations needing to pull out or become dormant due to furloughs and other COVID-19 restrictions. This resulted in the project dropping a few of its previously planned use cases, such as Smart Housing – a 5G powered lodge for visitors, and Smart Busses – Semi-autonomous transport.

With regards to DCMS' support through these disruptions, stakeholders had a general positive sentiment with one interviewee pointing out the department was also dealing with the new restrictions. A majority of the stakeholders agreed that DCMS was mostly supportive and flexible in accommodating any delays caused by external actors. They felt that the process of getting the contract signed with DCMS and the due diligence process throughout the project took significantly longer than it should have. For instance, a stakeholder mentioned that by the time the contract was signed their business had almost gone bankrupt. They further mentioned that DCMS took three weeks to approve the purchase of a £400 laptop needed for the project, which again created bottlenecks.

The project also had a substantial underspend of around £1.6 million as pandemic restrictions meant that use cases were re-scoped or abandoned.

3.1.4 Timeline

Figure 3: Project timeline and delivery RAG rating, 5G Connected Forest



Source: 5GTT Delivery Dashboard

The project lasted for 27 months from March 2020 to June 2022, as outlined below. As mentioned above, throughout 2020 and the majority of 2021, the project faced significant delays and reworks due to the arrival of COVID-19 restrictions and disruptions due to other external factors such as delays in the delivery of radio equipment. These also led the project to re-profiling their spend. There was an increased underspend in 2021. The project manager experienced personal bereavement due to the pandemic, and the project was also delayed due to difficulties in obtaining planning permission to build the network at Sherwood Forest Visitor Centre.

3.2 Consortium Partners

The 5G Connected Forest project comprised of a large consortium of 10 organisations led by Nottinghamshire County Council and was one of the larger RCC projects funded by the 5GTT programme.

Table 10: Consortium members, 5G Connected Forest

Organisation	Type	Role/responsibilities on project	Staff allocated to project
Nottingham Trent University	University	Developing testbed and trials/monitoring results	2 departments
Birmingham City University	University	Developing testbed and trials/monitoring results	3 departments
Nottinghamshire County Council	Public body	Lead partner	
NETMORE IOT SOLUTIONS LTD	Private sector	Developing testbed and/or trials monitoring results	3
Gooii	Private sector	Developing testbed and/or trials monitoring results	8
ISPB	Private sector	Developing trials/ monitoring results/project support	1
Parkwood Leisure	Private sector	Participating as trial end users/monitoring results	3
Stagecoach E Midlands	Private sector	Developing testbed trials/participating as trial end users/ monitoring results	2
Harworth Group	Private sector	Developing testbed and/or trials/ participating as trial end users	3

3.2.1 Working with consortium partners

Prior to their involvement in the 5GTT programme, Nottinghamshire County Council (NCC) were looking for ways to enhance connectivity in rural Nottinghamshire and had unsuccessfully applied for funding for phase 1 of the 5GTT programme. A stakeholder mentioned that a major barrier to their phase 1 application was not being able to identify the right partners to work with. This led NCC to develop a business case along with their application for 5G Connected Forest which helped in their collaboration efforts with prospective consortium members for phase 2 and the consortium was able to come together quickly during the application process.

Members of the consortium were involved and specialised in different aspects needed for the development of the project's use cases. There was an overall positive sentiment among stakeholders regarding working as part of the consortium. A few interviewees also mentioned potential future collaboration opportunities such as working on a 5G Car park in Oban and a 5G Theme Park.

However, the project underwent a significant structural change due to the imposition of restrictions on travel and socialising in response to the COVID-19 pandemic which were put in place weeks after its commencement. Several consortium members, especially from the travel and leisure sectors (Center Parcs, Stagecoach and Harworth Development) had to pull out of the project as they had to limit operations due to the pandemic. For example, Center Parcs had to pull out since all of their employees were furloughed and their facilities were closed. Overall, stakeholders had a positive attitude towards their involvement in the consortium. Although not many details are available, one stakeholder opined that a few more members would likely have gone on furlough had they not belonged to the consortium.

3.2.2 Personnel

Interviewees mentioned that despite being one of the larger RCC consortiums, theirs was one of the smallest Project Management Office (PMO) with just nine people working on the daily operations of the project. In terms of employment generated by the project, we know from its Benefit Realisation (BR) report that six researchers were newly appointed for the development of the project's use cases. Stakeholder consultations have further revealed that the project helped Netmore build up their fibre projects and helped Gooii get new business across the UK. Besides the direct impact of the project, interviewees mentioned that The Turbine innovation centre, a spinoff of the project had employed 8 FTEs, although not all the roles were permanent.

3.3 5G Deployment

3.3.1 Approach to deployment

The 5G Connected Forest project was successful in deploying two private 5G networks across three rural and forest settings. This included both a Standalone network at the Rufford Abbey & Mill and a Non-Standalone network at the Sherwood Forest Visitor Centre. The networks were deployed by Netmore, a member of the consortium and a newer network provider in the UK. This was done despite the delays caused by external factors mentioned above, and although not all the use cases were trialled using the 5G networks before the completion of the project, it is prudent to note that deploying the 5G networks itself was a use case described by the project, which it successfully delivered.

At the start of the project, the consortium made a conscious decision to use Ofcom's shared spectrum, which was new at the time. It was felt that this would offer reasonable security of tenure for the network and the consortium wanted to build networks that lasted beyond the project's completion. Interviewees involved in network deployment reported that the use of Ofcom's shared spectrum[4] created several problems in the deployment of the network due to a lack of equipment, which was exacerbated by the enhanced COVID-19 restrictions. Furthermore, one of these stakeholders opined that although there was 4GHz of spectrum, its range and power were restricted by Ofcom licencing, which made it less favourable for the development of the project's use cases. Despite this, the stakeholder mentioned that there are currently three types of 5G deployed as part of the networks.
The consortium tracked the latency and throughput (uplink and downlink) of the networks deployed. Latency measures the time taken for data to travel between two points, throughput measures the download and upload speeds in the network. While the Non-Standalone network deployed by the project successfully met the target for network latency, although not consistently, it failed to meet the throughput targets. On the other hand, the Standalone network deployed by the project met its throughput target by the end of the project but failed to meet its latency targets. This was addressed by stakeholders who cited that it was particularly difficult to deploy 5G in a forest setting and further stated that wherever 5G fell short, Fibre powered Wi-Fi networks were used to test the use cases.

Table 11: Network indicators - latency

Network	Baseline	Target	Achieved at end of project
Sherwood Forest Visitor Centre: 5G Non-Standalone	20	15	Min 11, Avg 26, Max 44

[4] The project used the n77 shared spectrum (frequency: 3,800MHz-4,200MHz)

Network	Baseline	Target	Achieved at end of project
Rufford Abbey: 5G Standalone	Not provided	15	Min 21, Avg 26, Max 41
Rufford Mill: 5G Standalone	Not provided	15	Min 23, Avg 28, Max 43

Source: Benefits Realisation

3.3.2 Use cases

The use cases of the 5G Connected Forest project can be categorised as 5G powered visitor experiences or 5G powered environment management, each of which uniquely demonstrated how 5G could be used in a rural or forest setting. The 5G powered visitor experiences included:

- **Arrow Through Time:** This was designed as an outdoor AR experience and was the world's first ever interactive holographic movie depicting the legend of Robin Hood which originated in Sherwood Forest. The experience involved live action characters who were displayed as holograms using AR. For the experience, users wore Hololens 2 AR headsets linked with Subpac haptic backpacks.
  The Arrow Through Time application itself worked successfully during the trials. However the outdoor setting and network connectivity did provide challenges for the operation of the user trials, primarily centred around the speed and stability of the network. Despite these challenges the trials produced good levels of positive visitor feedback from 132 responses total (97 adults, 35 aged 13 or younger).

- **Rufford Ghost Walk:** This was designed as an indoor based AR experience which was conceived to entertain and educate visitors on some of the characters from the history of the abbey and surrounding areas. The ghosts were filmed as live action characters, with AR displaying them as holograms supplemented with CGI. For the experience, users wore Hololens 2 AR headsets linked with Subpac haptic backpacks.
  This use case was not trialled on the 5G network as it was not fully deployed at the time. Instead, the consortium chose to use a Fibre powered high speed Wi-Fi network for the trials. Because the network was stable, it allowed the consortium to design a lightweight app and store content online. The trials produced consistently high levels of positive visitor feedback from 137 trialists.

- **Tag in the Park:** This was designed as a mobile proximity-based outdoor treasure hunt that encourages players to explore Rufford Abbey Country Park through an interactive treasure hunt. The players are challenged to find 16 hidden locations around the park and the app uses IoT and 5G connectivity to detect the proximity of players to each of the locations.
  Although 5G functionality on the app could not be demonstrated in public trials, Nottingham Trent University researchers were able to demonstrate the 5G functionality in their own 5G campus laboratory. This was mainly because the private 5G network was not accessible for the non-Netmore SIM cards. Despite this, the results from the live trials show a high demand for such an application to encourage visitors to attractions and parks.

The visitor use cases tracked benefits such as visitor satisfaction, additionality, and value for money:

- The provision of 5G-enabled content for tourism/education recorded an uplift of 5.6% in visitor satisfaction levels compared to baseline levels.

- On average, each visitor was recorded spending an additional 35 minutes and £10.26 during their visit.

- 81.6% of visitors expressed an intention to return, while 95.5% expressed an intention to recommend the attraction to others as a result of the experience.

Besides 5G powered visitor experiences, the 5G Connected Forest project also developed two use cases aimed at 5G powered environmental management. These were:

- **Robot Forest Ranger:** The robot forest ranger use case involved analysing high speed data collected by two mechanical quadrupeds (robot dogs) as they moved around in the forest. The data gathered by the robot dogs, which included high resolution photos and videos, needed to be paired with their location and was later analysed using AI and machine learning techniques. The project compared the experience using both 4G and 5G and found that 5G was 3 to 4 times better than 4G in transmitting the data gathered by the robot dogs.

- **Robot Forest Manager:** The Robot Forest Manager use case was developed to explore the use of 5G powered Unmanned Aerial Vehicles (UAVs - drones) and robotics to support the traditional forest manager dealing with emergencies that may arise in the forest, such as fires. The use case needed 5G to facilitate high speed data collection at the cloud and the edges of the network, i.e., UAVs and robots. The consortium tested the efficiency of the use case in detecting forest fires by showing the UAV several pictures of fires. The system correctly identified all 30 videos that depicted a fire. Further, research is currently ongoing at Birmingham City University, to develop this use case beyond the capabilities showcased in the project.

The forest management use case tracked benefits such as operational effectiveness in terms of data collection time using the Ground Robot Forest Ranger, but did not record what had been achieved by the end of the project. Some other benefits considered as part of these use cases included:

- The Ground Robot Forest Rangers aimed to reduce the time of human forest rangers to carry out their day-to-day tasks and to locate and support the forest authorities in their objectives.

- The Emergency Detection Support use case tracked time reduction in relevant emergency data gathering and timely provision of emergency support.

- The drones aimed to reduce the time taken to monitor areas inaccessible by humans using drones, with the help of the reduced latency of 5G.

3.3.3 Safety and security impacts

As mentioned earlier, the 5G Connected Forest project did not have a security-specific focus. It was more concerned with the efficiency gains demonstrated through its use cases, and exploring what could be done using 5G in a rural / forest setting. In fact, 'Deploying 5G networks' was itself one of the project's use cases. So, more emphasis was given to setting up the 5G networks rather than building their security and resilience.

However, the consortium used 4G elements to power its Non-Standalone 5G network. They also set up Fibre powered high speed Wi-Fi networks as a contingency, which the project used to test use cases when the 5G network could not be set up in time. This leads us to believe that care was taken to ensure the networks deployed were functional by building contingencies, but not much explicit security testing was done.

3.3.4 Technology Readiness Levels

As can be seen from Table 12, none of the use cases of the project achieved their target levels of TRL. This was mainly attributed to the widespread disruptions faced by the project due to external factors such as COVID-19, EU exit, Global Supply Chain Crisis, and Trade restrictions with HRVs, detailed above. Despite the challenges, it is noteworthy that all the project's use cases showed an improvement compared to their Original TRL levels, with 'Rufford Ghost Tour' nearing commercialisation as a revenue generating tourist attraction.

Table 12: TRL Summary, 5G Connected Forest

	Starting TRL	Target TRL	Current/ End TRL	Target met?
5G-enabled AR content for tourism and education	5	9	5	No
SAV visitor vehicle	1	7	2	No

Forest Ranger robotic research	4	7	4	No
Forest Manager robotic research	4	7	4	No
Passive forest sensors for Health of the Forest	4	7	4	No
Tag in the park	4	7	5	No

Source: Benefits Realisation

3.4 Collaboration knowledge sharing and overcoming barriers

3.4.1 Sharing Learning and best practice

5G Connected Forest reported several lessons learnt throughout the course of the project in both its final report published in 2022 and regularly to DCMS through its BRs. These include how the consortium resolved issues around the network deployment and various aspects of use case development, such as using a phone to connect the holographic display to the network, using the correct AR/VR headsets, and planning time sync in their 5G networks, among others.

Stakeholder consultations further revealed that 'Lack of awareness' and 'Lack of funding' were viewed as the two primary barriers to 5G deployment in the UK, and stakeholders agreed that the 5GTT programme helped in alleviating both. Most of the stakeholders also credited the programme for having created awareness of the possible 5G use cases in rural Nottinghamshire, with one stakeholder mentioning that network operators such as CityFibre, ConnectFibre, and TrueFibre are now interested in bringing broadband to Nottinghamshire because of the activities of 5G Connected Forest.

Stakeholders have an overall positive opinion about DCMS as a facilitator of knowledge transfer, with one interviewee mentioning that the technical consultant appointed by DCMS was of particular help in initiating collaborations and technical knowledge transfer channels across projects. Apart from this, stakeholders agree that the 5GTT programme has in general created an environment conducive for collaboration and knowledge sharing, both within and across projects.

Having said this, interviewees also mentioned that the consortium felt that their knowledge sharing and collaboration efforts did not get taken far by DCMS because 5G Connected Forest did not focus on a technical use case. For instance, a stakeholder mentioned that they had separate knowledge sharing channels for each of their use cases including network deployment, visitor experience, and 'non-tech 5G skills', all of which was being reported to DCMS through BRs. However, learnings from other projects were not shared with the consortium in any way through DCMS.

Table 13: Publication and events summary

Dissemination Activities	Number of articles/events
Collaboration activities	2
Research outputs	3
Events and Presentations	4
Press release and communication activities	3

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

3.4.2 Interaction with the wider ecosystem

Most of the interactions that the project had with the UK5G ecosystem were in terms of attending events and presentations. While stakeholders mentioned that the consortium collaborated in sharing learnings and

knowledge directly with other projects including Rural Dorset, Worcestershire, and 5G CAL, it was mainly focused on non-technical 5G use cases. To clarify this, a stakeholder specifically mentioned that the consortium shared learnings and knowledge with UK5G, contributed to conversations and followed up on news items, but at the end it did not have an outcome to show for it.

Having said this, we know that the project actively collaborated with UK5G's 5G skill working group to develop 5G Careers, which is one of its spinoffs. It could therefore be said that interactions with the wider ecosystem generated outcomes in terms of spinoffs and tangential testbeds rather than directly impacting the project's use cases.

3.4.3 Business and industry generation

A majority of stakeholders interviewed believed that 5G in the UK is still in its early stages in terms of business readiness, skills, and awareness (an understanding of 5G is needed). This sentiment is mirrored in the key findings of a 5G business study that the project undertook with 24 businesses from various sectors in Nottinghamshire. The study indicated that:

- only 20% of respondents categorised themselves as innovators;
- only 35% respondents categorised themselves as early adopters;
- only 35% of the respondents claimed to 'know quite a lot' about 5G; and
- only 12% of respondents had started using 5G in their businesses in some way.

The study was commissioned by the project's consortium with the help of DCMS, other 5G testbed projects and the local business community. Apart from this, a majority of the stakeholders agreed that while the UK is working towards building skills and understanding, consistent efforts would be needed to develop an industry around 5G. One stakeholder further opined that the UK is faced with a 'Chicken and Egg' situation where demand cannot be generated without demonstrating what is achievable, which is in turn not possible unless there is demand.

However, stakeholders were also positive that there is future potential for the development of a 5G powered environment monitoring industry in the UK. This is indicated by the several spinoffs and tangential testbeds that were inspired by the project, including:

- **5G Careers:** UK's first 5G Careers Programme which was inspired by the activities of 5G Connected Forest. It was developed by the NCC in partnership with local schools (E.g., NUAST) and colleges (E.g., Vision West Notts College), and DCMS 5G Skills Working Group. In the absence of a major telecoms sector in the area, the project aimed to build an understanding among the students of career opportunities created by 5G in different sectors, both STEM and beyond. As of March 2022, we know that 5G Careers has worked with over 1,000 students and has been incorporated into all four of the county's FE Colleges and three of the county's non-FE youth education services.
- **Turbine Innovation Centre:** NCC in partnership with Innovation Nottinghamshire was successful in getting funding from the 'Getting Building Fund' (GBF) to create the Turbine digital innovation centre – a serviced office facility for SMEs run by NCC. To May 2022, the Turbine Innovation Centre had:
  - Created 8 new jobs using digital/5G skills;
  - Assisted 89 businesses;
  - Supported over 1,000 learners (through 5G Careers); and
  - Installed Private 5G, Lora WAN and Bluetooth Mesh networks for businesses to showcase/trial innovations.

- **SWIFt Lab:** In parallel with the project; Nottingham Trent University worked in partnership with the Digital Catapult, Midlands Engine and the D2N2 Local Enterprise Partnership to create the SWIFt Lab, a brand new state-of-the-art indoor and outdoor Private 5G and IOT commercial testbed.

Although unconnected with the project, the teams at SWIFt, 5G Careers, and the Turbine Innovation Centre are already collaborating with project partners to share and develop the four 5G Testbeds now available in Nottinghamshire.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 14: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£4,461,000	£0
Number of partners that received funding / contributed R&D	7	0

Source: Benefits Realisation

DCMS grants for the 5G Connected Forest programme amounted to approximately £4.5 million, which is roughly equal to the expected R&D budget of the consortium partners put together. The exact extent of investment from each partner is held in confidence. It is also not known whether additional expenses were incurred or third party investments made.

3.5 Programme processes and support from DCMS

Stakeholder consultations reveal that the project manager assigned by DCMS had changed repeatedly, which created difficulties in communicating the project's needs and progress. Besides this, a stakeholder also mentioned that it took a significant amount of time for DCMS to finalise the contract, which created severe financial roadblocks that hindered progress. They also mentioned that DCMS's due diligence procedures were also time consuming, creating further bottlenecks. Lastly, a majority of the stakeholders opined that the monitoring and benefits reporting procedure put in place by DCMS were overwhelming and unnecessarily tedious.

However, having said this, the stakeholders also mentioned that the project leads at DCMS were very helpful and went above and beyond in trying to accommodate any delays and disruptions that the project faced. Besides this, the interviewees also had a very favourable opinion about DCMS as a facilitator for knowledge sharing and collaborations. Furthermore, a majority of the stakeholders mentioned that any criticism towards the department must be caveated by saying that they too were dealing with the pandemic and associated restrictions.

3.6 Long term impacts

5G Connected Forest's is likely to generate long term impacts through its activities including:

- Successfully deploying two working 5G networks in a rural / forest setting despite facing several external disruptions due to COVID-19, EU exit, and the global supply chain crisis.
- Through its activities, the project has reduced barriers to 5G deployment in the UK to some extent by creating awareness in rural Nottinghamshire of the ways in which 5G could potentially be used.
- The project has generated demand for better connectivity in rural Nottinghamshire, evidenced by the fact that network operators such as CityFibre are interested in bringing broadband to the rural county.

- The project has inspired many spinoffs and tangential testbeds beyond its scope, such as 5G careers and the Turbine Innovation Centre.

- Two of the project's use cases show significant future potential for reducing the cost of public service provision in the forest management industry by reducing labour needs through the use of robots and drones.

3.6.1 Additionality

Stakeholders unanimously agreed that the programme would not have happened in the absence of the 5GTT funding. One stakeholder opined that the programme did not aim to demonstrate the benefits of a specific aspect of 5G, rather it focused on exploring how 5G could be used in different ways in a rural / forest setting. Apart from this, stakeholders also stated that the funded project helped raise awareness about 5G and its business and commercialisation capabilities, which were particularly lacking in Nottinghamshire. One stakeholder mentioned that it has successfully generated interest among operators to provide network and other services in the rural county by establishing it as a potential market for 5G and other forms of connectivity. They substantiated this by pointing out that operators who were previously hesitant, were much more ready to collaborate with the consortium members once the project received 5GTT funding. Overall, a majority of interviewees agreed that the 5GTT funding, and in turn the project, were key in letting the consortium progress its wider aim of improving connectivity in rural Nottinghamshire.

In terms of additionality of 5G over 4G and other previous generation networks, a stakeholder stated that speeds of 1 gigabyte/sec achieved by the project's 5G networks could not have been achieved on previous generation networks. Furthermore, we know from the project's final report published in 2022 that its use cases such as high-speed data transfer, holographic display, networked AR and VR experiences, drones, and proximity sensing required the high speeds and low latency of 5G and could not have been executed on 4G and other previous generation networks.

Having said that, stakeholders were also unanimous in acknowledging that elements of 4G were used to power the project's non-stand-alone 5G network. Besides this, a stakeholder close to network deployment stated that Wi-Fi networks could be used as an effective and a cheaper proxy for 5G as it stands today. This is reiterated in the project's final report which mentions that a high-speed Wi-Fi network generated using fibre connections was used to test the Rufford Ghost Walk experience due to delays in deploying the 5G network in time for the trials.

3.6.2 Sustainability

Among the project's own use cases, interviewees revealed that the consortium is commercialising the Rufford Ghost Walk in partnership with Parks and Leisure, making it a commercial revenue generating visitor experience. A stakeholder mentioned that contracts have been signed with the network provider to provide 5G and Wi-Fi networks for the next three years to support this experience. Besides this, there was also mention of ongoing talks with forest managers regarding the viability of commercialising the Robot Forest Ranger and Robot Forest Manager use cases. A stakeholder mentioned that the consortium had hired ISPB, a consulting firm, to gain their options.

Since no use case from the project has been commercialised, the exact extent of potential business that could be generated is unknown. However, the consortium estimates that the 'Rufford Ghost Walk' experience would be ready to market within 18 to 24 months without further funding, and would generate an estimated £210,000 in revenues in the financial year 2022/23.

Apart from developing its own use cases, the project has also created and inspired several spinoffs and tangential testbeds such as 5G Careers – UK's first 5G-centred careers programme, and The Turbine Innovation Centre – a new digital innovation centre in north Nottinghamshire hosting private 5G, Lora WAN and Bluetooth Mesh test networks.

Stakeholder consultations reveal that '5G Careers' has now worked with over 1000 students and is part of all four of Nottinghamshire's further education colleges. We also know from interviews that the consortium is

actively looking for funding from various sources such as Innovate UK and DCMS to develop similar testbeds and use cases. For instance, a stakeholder mentioned a use case that they were exploring in Oban aimed at developing Smart Parking[5]. Another stakeholder mentioned that members of the consortium such as Gooii and Netmore are discussing the possibility of collaborating on developing a 5G powered theme park.

[5] This is an opinion put forth by one of the stakeholders interviewed for this project. As such no information regarding a 5G testbed in Oban has been found.

4. 5G FESTIVAL

4.1 Overview of the project

The 5G Festival aimed to create the world's first 5G powered hybrid immersive festival which included both live and remote artists as well as audiences all operating collaboratively.

Table 15: Overall project summary, 5G Festival

Project	5G Festival
5GTT Competition	5G Create Window 1
Sector	Leisure/Tourism/Events/Media
Location	South-East of England
Timeline	August 2020 to April 2022
Lead consortium partner	Digital Catapult
Other consortium partners	Mativision Limited, LiveFrom Media Limited, Sonosphere Ltd, Metropolis London Music Limited, Audiotonix Group Limited, Warner Music UK Ltd, Brighton Dome and Festival Ltd, Telefonica UK Ltd
Type of network/technology deployed	Private, non-standalone network
Total project costs	£3,397,603
Funding awarded by DCMS for 5GTT	£2,187,426

4.1.1 Progress on success measures

The 5G Festival project was able to provide strong evidence of the added value of 5G technology against five of the 11 5GTT success measures outlined below:

Regarding the remaining success measures, there was some evidence of the added value of 5G technologies demonstrated against 5 of the remaining 6 success measures.

Table 16 Summary of impact, 5G Festival

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The ability to attract artists who can continue to give live shows despite challenges of COVID-19 would help to increase the profile of the UK. Knowledge that 5G networks can be used to support this helps to further that reputation.	2
Programme activities have attracted further funding within the area of 5G/5G R&D	Many of the consortium partners are planning to continue the use of the 5G networks which were utilised in this project. The additional investment was aimed at transforming the music industry and these networks improved the end product for consumers.	3
Reduction/removal of barriers has accelerated deployment of 5G in the UK	This project looked to reduce the barriers to the wider deployment of 5G technologies. There were challenges during the project through the installation of the technology at various locations, but the project demonstrated how the technology helped to improve the outcomes for venue owners.	2

Success measure	Evidence	Contribution Score
Information and knowledge is more readily transferred within the 5G ecosystem	Interviewees noted that the requirement for collaboration and shared learning was important. The working groups worked better as the project went on helping to spread the learning across the consortium and the wider programme. Several dissemination activities were carried out during the course of the projects, such as magazine articles and promotional videos, which helped to share findings of the projects across the wider 5G ecosystem.	2
5G networks are more secure than the 4G networks they replace	Interviewees found that 5G was more secure compared to previous wireless technologies. The network was used for a variety of aspects including video production and audio network provision, which provided security across the audience and the performance. Security itself was not explicitly tested during this project but it was a by-product of putting the 5G network in place.	2
Additional welfare and environmental benefits	A specific use case examined the reduction in CO2 emissions produced by the 5G Festival and compared these against non 5G events. The reduction from trucks, tour buses carrying artists and equipment not to mention virtual audiences meant that there was a 60% reduction in emissions.	3
Public services cost avoidance	This project did not look to explicitly address public service cost avoidance as part of their stated aims.	0
Development of industry 5G expertise and increased ability to use 5G for commercial activities	The 5G Festival was explicitly looking to develop 5G solutions within the music industry. The use cases were designed to operate in a commercial space and ensure that more products are available to producers widening the choices they have at their disposal.	3
Generation of 5G activities beyond the scope of the programme	Many of the consortium members made additional investment to continue developing the use cases over the course of the project. This investment demonstrated a willingness for the benefits generated in this programme to last beyond the timelines of the project.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	This project was successful in showing how live music events could operate with a new business model in a post COVID-19 world. In showing how 5G technologies could help to facilitate a more sustainable music industry, the 5G Festival project has been a positive example in showing potential viable business models.	3
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The use cases assessed as part of this project had various TRL targets. Whilst none of the applications reached their target TRL there were improvements seen in 2 of the 3 use cases. The specific network capabilities were tested but more emphasis was given on how these improvements helped ensure the use cases could be carried out specifically.	2

4.1.2 Project aims and activities

This project aimed to build a music platform that would enhance the ability of musical artists to produce performances and create a new type of hybrid/live festival experience. The project had three use cases:

- remote music production;
- virtual festival
- hybrid festival

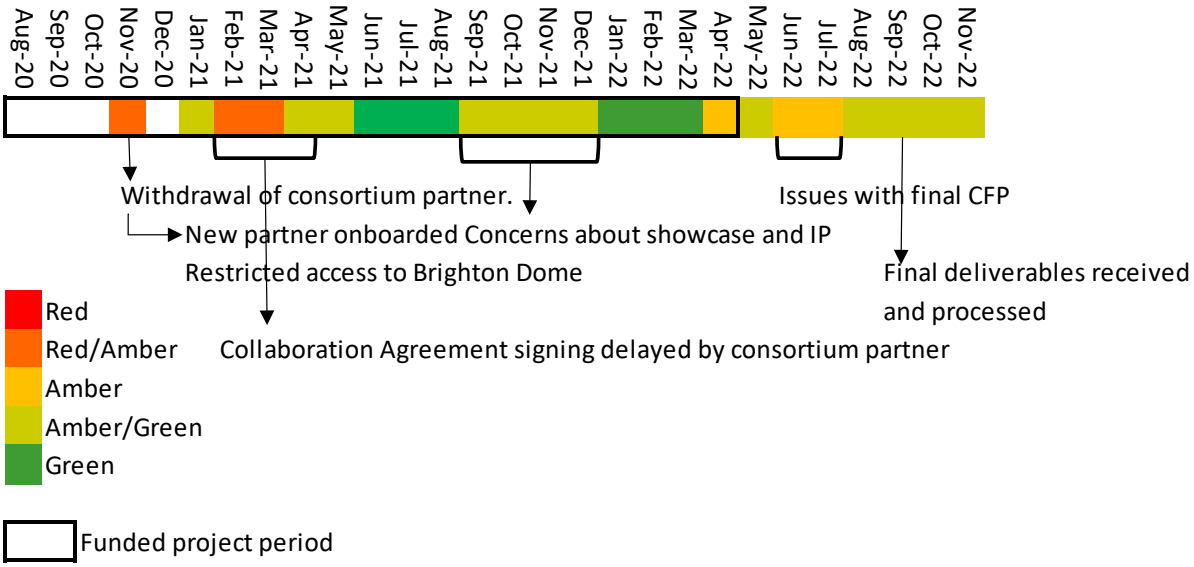
Sustainability was the main driver of the project, reducing the need to travel for rehearsals and encourage collaboration especially with young artists. The restrictions as a result of the COVID-19 pandemic also highlighted the need to use technology to support festival and venues by providing a safe performance environment for artists and high quality immersive experience for audiences. They successfully deployed networks and tested their use cases.

4.1.3 Timeline

The project ran from August 2020 to April 2022. Live trials were completed as planned and the scope of the project remained consistent throughout. Overall, the project ran to schedule and no extension requests were made.

The figure below summarises the delivery Red-Amber-Green (RAG) rating of the project as it progressed.

Figure 4: Project timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

Overall, the project was successful. Despite COVID-19 being a major concern around the middle of the project (main tests were conducted between June 2021 and March 2022), all trials were completed successfully. The planning around the project meant that the use cases could be carried out effectively and the scope of the project did not need to be reduced, but there were challenges around changes in consortium partners and IP.

4.2 Consortium Partners

The project was delivered by a consortium of nine members led by Digital Catapult. More information on the consortium members can be found below.

Table 17: Consortium members, 5G Festival

Organisation	Type	Role/responsibilities on project	Staff allocated to project
Mativision Limited	SME	Partner	4-5
LiveFrom Media Limited	SME	Partner	3
Sonosphere Ltd	SME	Partner	4-5
Metropolis London Music Limited	Med	Partner	8
Audiotonix Group Limited	Large	Partner	3
Warner Music UK Ltd	Large	Partner	6
Brighton Dome and Festival Ltd	RTO	Partner	15
Digital Catapult	RTO	Lead Partner	14
Telefonica UK Ltd	Large	Partner	6

4.2.1 Working with consortium partners

Interviewees noted that the project was highly collaborative and that DCMS emphasised the key requirement of sharing learnings across consortium members. The consortium as a whole had not worked together before and the project helped to bring these firms together in a capacity which had not previously occurred. Whilst the full consortium is not working together, groups of consortium members are working with each other on further collaborative elements.

One of the initial partners dropped out. As this happened within a few days of the project commencing it did not have any impact on the overall success of the project.

4.2.2 Personnel

Interviewees told us that with the nine partners there were over 50 people involved across the use cases. In addition to these personnel, 21 artists were involved over the duration of the project. The personnel who worked on this project were involved in a full time capacity, with others involved in a part time capacity.

4.3 5G Deployment

4.3.1 Approach to deployment

The 5G network infrastructure deployed to support the 5G Festival project use cases was key as an example for how to setup networks in a live festival environment. Precision timing along with high bandwidth and low latency were key requirements for the use cases to operate effectively. The network met user experience expectations and enabled artists and technicians to produce high quality performances. The 5G Festival were able to have a successful live demonstration with 21 artists operating simultaneously showing that the consortium could deliver a commercially viable live music event. This will be remembered as a world first 5G enabled music event.

Network Indicators included:

- End-to-end latency. By the end, the project was approaching its target of achieving speeds of less than 10ms and was successful from the artists' perspective.
- Peak Data Rate of 400 Mbps on 5G and 800 on W-fi was achieved.
- Interconnected artists who were able to perform from different venues
- The festival was able to service both remote and venue based audience members

Source: Benefits Realisation

Although the network indicators were not strictly tracked over the course of the project, the indications show that the 5G Festival project demonstrated how the technology helped to improve music industry applications.

4.3.2 Use cases

The 5G Festival projects aimed to achieve three main use cases:

- **Improving artist collaboration**. A variety of elements were tested here to try and boost this, including increasing the uptake of remote collaboration tools, reducing the cost of travel for rehearsals and leading to environmental benefits from the reduction of CO2 emissions caused by artists having to travel less.
- **Improving the experiences for remote audiences**. The main elements investigated here were increased uptake of audience members streaming festivals remotely. The amount that audience members would pay for these remote events was also closely monitored.
- **Creating a new hybrid festival experience**. The main elements investigated here was the commercial viability and revenue opportunities for providers and venues through offering remote festivals. The reduction in travel costs for artists and reduction of CO2 emissions from reduced audience travel were also elements monitored over the course of this project. Furthermore, new forms of immersive experiences, developing hybrid concerts with mixed stages (live/remote) were investigated.

Key benefits from the use cases that the project measured included:

- increasing the uptake of remote collaboration tools for artists by improving user experience;
- looking to increase the revenue streams for platform providers by licensing or subscription to the platform. This would come in the form of tie saved and costs saved by travel and accompanying expenses;
- reducing CO2 emissions from less travel;
- increasing the uptake of the platform for audiences by improving the user experience; and
- increasing range of artists able to be presented within the venue (although remotely).

Source: Benefits Realisation

4.3.3 Security impacts

Interviewees noted that 5G is more secure than previous wireless technologies. The 5G networks used were applied in a variety of scenarios for both video production and audio networks. Security was needed for both audience members and artists performing. The audience network and the network that the video and audio utilised were on the same infrastructure, but using different networks provided security by isolation. Although security enhancing aspects existed, there was little explicit security testing for this project.

4.3.4 Technology Readiness Levels

The project had mixed levels of success with regards to the TRLs of their use cases. None of the three use cases achieved the target TRL but two of the three use cases did achieve some improvement over the course of the project. It should be noted that all the used cases were still a long way from achieving the target TRL.

Table 18: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
Artist Collaboration - Immersive synced collaboration among remotely located artists	3	7	5	No
Remote - Delivery of Immersive experiences to distributed audiences from remotely located artists/performers	2	7	3	No
Venue - Implementation of Venue-based collective immersive experiences for local audiences	2	7	3	No

Source: Benefits Realisation

4.4 Collaboration, knowledge sharing and overcoming barriers

4.4.1 Sharing learning and best practice

As in several other cases, interviewees from the 5G Festival project noted that this project was key in helping to share learning across a variety of stakeholders. They noted that the project was pivotal in helping to promote the various applications of 5G and increasing curiosity across the 5G ecosystem. Sharing learnings from the various 5G projects helped others replicate what others had done. Due to the specific information within some of the other projects, it did mean that on occasion it was difficult to understand what some of the other projects were aiming to achieve. Overall collaboration between members of 5G Festival and the wider 5G ecosystem was positive and DCMS were found to be helpful in enhancing these collaborations and helped knowledge to be shared as widely as possible.

Table 19: Publication and events summary

Dissemination activities	Number of articles/events
Telecoms/communication technology industry press or events	5
Press or events with different sector audience	0

Source: Benefits Realisation

Around 37 articles about 5G Festival were produced in the 2021/2022 financial year. The project also won awards for “most innovative use of 5G technology” from the 2022 UK5G showcase and at 5G Realised in June 2021. It was also shortlisted for Live Production of the Year by TPI in April 2022.[6]

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

4.4.2 Interaction with wider ecosystem

Members from this project were part working group on skills, creative, and testbeds and trials[7] organised by the UK5G Innovation network which helped to share findings from the project with a wider audience. Members from Digital Catapult for example were present at the showcase that UK5G put together in Birmingham, helping to get different projects together, allow learnings to be synthesised and promote significant findings.

[6] https://www.tpimagazine.com/the-tpi-awards-2022-shortlist/
[7] https://uk5g.org/about/working-groups/

4.4.3 Business and industry generation

The 5G Festival project was pivotal in enhancing the UK music industry. Interviewees noted that UK creative industries are quite advanced globally, but linking immersive technologies with telecoms and networks will help to develop and progress this even further. The use of 5G technologies around immersive technologies and how these could be applied to the music industry could have some far reaching implications. The ability to create a festival experience that was insulated from widespread shocks such as COVID-19 whilst still ensuring that the user experience was safeguarded was a key aim of this project, helping to evolve the current state of the UK music industry.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 20: Funding received for the project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£4,375,000	£2,470,000
Number of partners that received funding / contributed R&D	10	9

Source: Benefits Realisation

DCMS funded around two thirds of the project, with the remaining third coming from the partners themselves. Many of the firms involved also generated additional private investment following the project's conclusion to help build on elements worked on during the 5G Festival project. Information is not available about precise amounts and sources of additional investment.

4.5 Programme processes and support from DCMS

Benefits Realisation and monitoring had mixed success. Interviewees reported that some of the benefits were difficult to measure within the lifetime of the project but would become evident in the longer term. As some of the benefits might be realised in a two to three year window long beyond the life cycle of the project, it meant that the Benefit Realisations might not have captured how successful the project actually was. The Benefit Realisations did help to capture findings around user experience that might not have been fully appreciated had there not been explicit requirements to record how the benefits were materialising.

4.6 Longer terms Impacts

4.6.1 Additionality

Interviewees noted that without this programme the project would probably not have happened and certainly not to the same extent. The 5G Festival helped to promote 5G use cases along with increasing the curiosity of investigating 5G elements as a result of the 5GTT programme. Consortium members noted that DCMS were key in helping to encourage collaboration not just between consortium members but across the 5G ecosystem more widely.

This project also helped to put in place 5G technology within concert halls such as the Brighton Dome which is not only still in place but was expanded upon following the conclusion of the project.

4.6.2 Sustainability

Many consortium members made additional investments into 5G related R&D once the project had been completed. The further investment following the completion of the project shows that the application of this 5G technology would have further impacts which would outlast the lifetime of the project itself.

As noted above, the technology, which was installed in several venues, with the culmination being a live hybrid showcase event in three venues: Metropolis Studios, O2 Blueroom and the Brighton Dome. These networks remained after the conclusion of the project, demonstrating the persistence of 5G networks. The dissemination activities carried out also helped to ensure that knowledge of 5G technologies spread across consortium members but also across the 5G ecosystem more widely.

5. 5G LOGISTICS

5.1 Overview of the project

The West of England Combined Authority (WECA) worked with 12 partners to show how 5G can lead to increases of efficiency and productivity for the logistics sector. Use cases tested the efficacy of 5G networks through a number of applications throughout Bristol and the Southwest.

The project trialled mobile edge computing as an alternative to cloud computing, and looked to combine the ability of 5G networks to handle significant amounts of data with faster communication speeds and increased security benefits.

Table 21: Overall project summary

Project	5G Logistics
5GTT Competition	Create Window 2
Sector	Transport and Logistics
Location	Bristol, Southwest of England
Timeline	Originally January 2021 to March 2022. Extended by three months to June 2022
Lead consortium partner	West of England Combined Authority (WECA)
Other consortium partners	ADVA Optical Networking Limited, Airspan Communications Limited, AttoCore Limited, Cellnex Connectivity Solutions Limited, The Bristol Port Company, Maritime Transport Limited, This is Gravity Limited, Unmanned Life, Cardiff University, Bristol University, Bristol City Council
Type of network/technology deployed	Private, standalone.
Total project costs	£4,267,906
Funding awarded by DCMS for 5GTT	£2,613,912

5.1.1 Progress against success measures

The 5G Logistics project has resulted in strong evidence of added value of 5G technology against 4 of the 11 5GTT success measures.

Table 22: Summary of Impact of 5G Logistics

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The project focused on improving the reputation of Bristol and the South-West but was not explicitly looking to improve the UK's reputation as a leading 5G centre. A number of online blogs were written by consortium members to promote the project, and the overall UK reputation. Additional funding from other nations is now planned because of 5G Logistics, which demonstrates how it has helped to put the South-West and the UK more widely on the map as a centre of 5G proficiency.	2
Programme activities have	Over £2 million of additional funding was generated highlighting the additional impact which this project has created.	3

Success measure	Evidence	Contribution Score
attracted further funding within the area of 5G/5G R&D		
Reduction/removal of barriers has accelerated deployment of 5G in the UK	Interview evidence suggests a small impact on barrier busting. The project did help to learn some of these important barriers which needed to be carried out for installing a private network.	1
Information and knowledge is more readily transferred within the 5G ecosystem	Members of this project worked well with UK5G and found that their role in the project was beneficial. It enabled project members to gain insight into the other programmes being carried out by other 5GTT projects.	3
5G networks are more secure than the 4G networks they replace	Using 5G to improve the physical security of the port site was stated as an explicit aim along with measures to assess this shows the relative success of achieving this, but there was not a specific focus on network or cyber security.	2
Additional welfare and environmental benefits	One use case indirectly aimed to improve environmental outcomes through the reduction of queuing traffic. From a wider welfare perspective, this project had a number of use cases which looked to address this more explicitly. The project also had use cases specifically geared towards theft alerts for in transit goods and real time alerts for any damaged or spoiled goods all of which helping to improve wider welfare.	3
Public services cost avoidance	Whilst not explicitly stated through working with the West of England Combined Authority, the aim of reducing public costs was always an indirect aim of the use cases.	2
Development of industry 5G expertise and increased ability to use 5G for commercial activities	The use cases focused more on security and accuracy aspect of the technology being utilised, with not a lot of attention towards the commercialisation aspect of these.	0
Generation of 5G activities beyond the scope of the programme	A number of dissemination activities took place following the project completion date to raise awareness of the elements developed during the project. Four press releases were carried out to this end and as noted previously, a lot of additional investment was carried out to help further develop the use cases worked on. There were also two additional projects that came about as spinoffs because of 5G Logistics, namely the O-RANOS project and the UK 5G DU-Volution project.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or	This project did not focus on the commercial applications of this technology. As such this element was not specified.	0

Success measure	Evidence	Contribution Score
related telecoms technologies		
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	One of the key aims of the project was to develop private networks which could be used by businesses to support various applications. They were initially going to go down the Open RAN route, but were ultimately unsuccessful in getting this aspect developed. There was the belief that the marketing around 5G readiness was in fact quite different from how market ready these technologies are to be used across a wide range of industries. As such, although this project was successful in raising awareness in 5G, the networks themselves were not sufficiently mature to be used on a wide basis.	2

5.1.2 Project aims and activities

The project had several stated objectives and expected benefits:

- improving the efficiency, reliability, security and accountability of the logistics sector and customs operations;
- opening up new economic development opportunities by allowing ports to become freeports in partnership with remote sites;
- improving road traffic management, leading to improvements in air quality for all;
- transforming the nature of port jobs by reducing repetitive tasks and growing digital skills, supporting worker retention;
- improving response to incidents in remote or hard-to-reach locations of sites;
- increasing local 5G and smart city expertise, bringing businesses, universities and public bodies together;
- supporting emerging players in the UK's 5G marketplace to increase choices and help boost the diversity of 5G network providers;
- establishing the West of England as a world leader in developing advanced fixed and mobile communication systems; and
- attracting new economic opportunities and jobs to the region.

They deployed a private network at the Port of Bristol and Gravity Smart Campus and tested a range of use cases to address the benefits and objectives outlined above and the project was generally successful in achieving its aims, although there were changes to plans to deploy an Open RAN network.

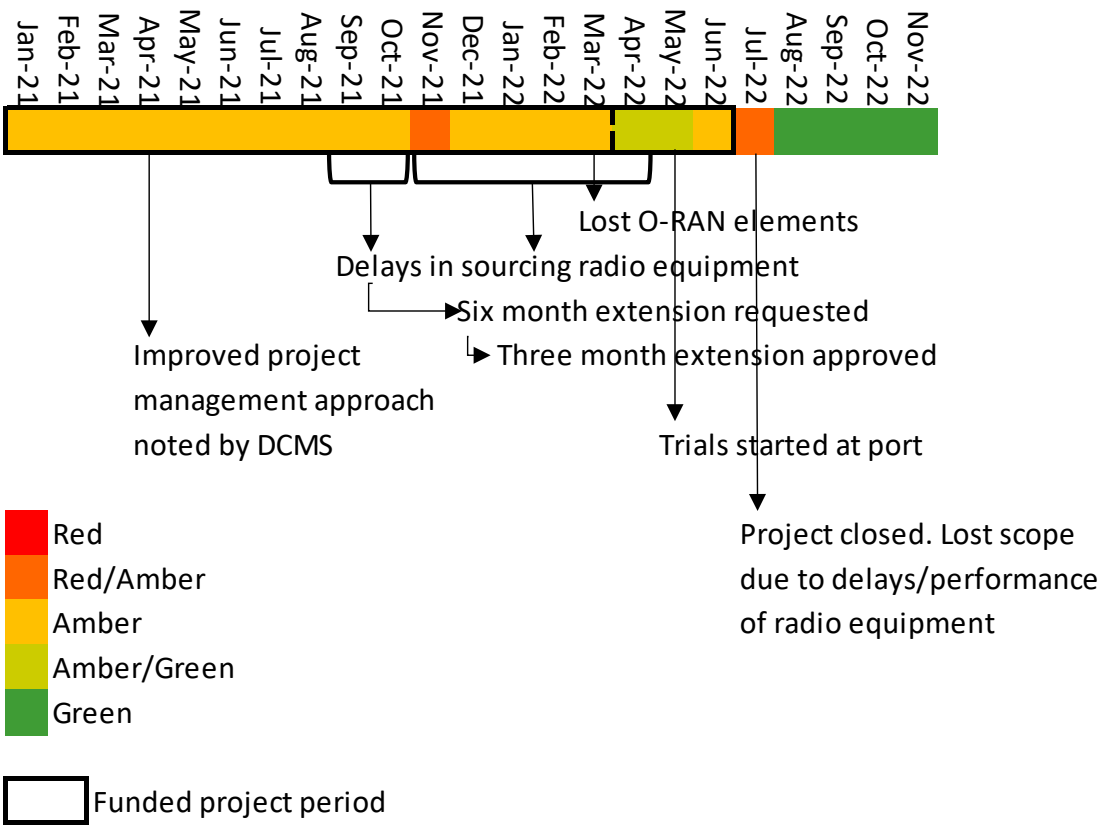
5.1.3 External factors affecting delivery

When interviewing project participants, one of our questions was around what impact external factors such as COVID-19, Britain's exit from the EU or restricted supplier lists had on overall project delivery. These elements were highlighted as risks during the project, but did not have a significant impact on delivery. COVID-19 was the top risk for this project as 13 project partners needed to travel to the port, but as entry was not restricted, this proved to not be a problem in the end. What did present more of an issue was the supply of radios needed for the use cases being carried out and the complex nature of some aspects of the programme. Interviewees noted that as most of the partners were new to research and development programmes such as this, some issues were either not sufficiently planned for or were unanticipated.

5.1.4 Timeline

The project was due to run from January 2021 to March 2022 but was extended for a further three months to June 2022. A global shortage of silicon led to equipment supply issues which impacted the timelines of the project and contributed to the project extension that occurred.

Figure 5: Project timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

Although the project was delayed by 3 months to the end of June 2022 because of the supply of radios, the three use cases developed over the course of the project were relatively successful although there was some de-scoping, including losing Open RAN elements of the network. Monitoring showed an improvement in most of the metrics against their baseline and although some further work is required to get the technology up to a market ready level, enough has been demonstrated to show the potential of this technology and the hope and expectation is that this will attract further inward investment.

5.2 Consortium Partners

The project was delivered by a large consortium of 12 member organisations led by WECA. Further information about consortium partners is shown below:

Table 23: Consortium members, 5G Logistics

Organisation	Type	Role/responsibilities on project	Staff allocated to project
West of England Combined Authority	Public body (Combined Authority)	Lead partner	3
Bristol City Council	Public body (city council)	Work Package Lead – 5G smart junctions	4

Cardiff University	Academic Institution	Report production and benefits realisation support to Lead Partner	1
University of Bristol	Academic Institution	Work package 2(?) lead and technical oversight across all work packages and use cases	1
Maritime Transport Limited	Private limited Company	Use case partner	Less than 1
This is Gravity Limited	Private limited Company (SME)	Host for 5G private network testbed and use case partner	Less than 1
UM Autonomous Systems Limited (t/a Unmanned Life)	Private limited Company (SME)	Work Package 2 key partner – Assisting University of Bristol in the development of 5G nano-cell router for asset location tracking use case and leading the port police drone operations use case	8.5
AttoCore Limited	Private limited Company (SME telecoms equipment vendor, mobile core software)	Work Package 1 key partner. Network installation and operation	3.5
Airspan Communications Limited	Private limited Company	Work Package 1 key partner. Network installation and operation	8
ADVA Optical Networking Limited	Private limited Company	Work Package 1 key partner. Network installation and operation	7
Cellnex Connectivity Solutions Limited	Private limited Company	Work Package 1 lead – network installation and operation	4-5
First Corporate Shipping Limited (t/a The Bristol Port Company)	Private limited Company	Host for 5G private network testbed and use case partner	Less than 1

Working with consortium partners
This project was the first time that all the consortium members had worked together. DCMS were noted as being particularly helpful in promoting collaboration and were overall effective in terms of their communication and project management inputs. Some of the project participants have subsequently worked with each other in a follow-on project arising from being introduced through the 5GTT project. The collaboration approach was particularly helpful in allowing consortium members to identify the relevant strengths of all the members and thus ensure that individuals were placed where they could be most effective.

Personnel
Across the project, more than 40 people were involved in some capacity during its duration. From the West of England Combined Authority there was one new job role created specifically for this project, and as it was self-professed that most of the project participants were not overly experienced in working on research and development projects such as this, it meant that it provided a perfect opportunity to develop and nurture these skills.

5.3 5G Deployment

5.3.1 Approach to deployment

The main aim of the project was to develop tailored private 5G networks. The project also aimed to deploy open-RAN, but this element could not be implemented in the lifetime of the project. Plans to deploy these private networks across Bristol and the South-West were held up by issues with the supply of the radios needed to carry out the planned use cases. This delay spilled over into an overall project delay as a result. The test networks were mostly around the Port of Bristol.

The project looked to assess latency, financial gains from reporting potential thefts, improvements in response times and efficiency gains from reduced traffic.

Network indicators included:

- digitally connected and geo-fenced Freeport Zones which achieved latency targets of between 5ms and 20ms;
- theft alert for goods in-transit which achieved a 99% average success rate when the network was operational;
- real-time alerts for goods damage/spoilage which achieved its target of 95% average accuracy when the network was operational;
- optimisation of system communications between private and public services which achieved latency speeds of less than 10ms;
- inspection time reduction through drone use which resulted in a 48% reduction of manual baseline and savings of £2,063;
- time reductions for incident response and assessment leading to a 54% reduction in manual baseline and £357 in savings; and
- reductions in lost “green light time” at traffic intersections when road users are too slow to react to green signals which showed an average improvement in journey time of 48%

Despite not being able to deploy open RAN the project was still able to meet and exceed many of the network indicator targets which it had set.

The management and continuous monitoring of the NIST Framework[8], along with potential new threats, was challenging as it was hard to manage in a document format. One of the most important lessons regarding security is the utilisation of a ticketing system of task and issue resolution to ensure correlation of security dependencies could be communicated project wide.. Device management was another security element which could have been better managed. Although there were no more than 12 devices used identifying which ones are recognised as secure and operational is a key consideration for future iterations. AI attacks were also not considered during the development of the project. This was not considered as a concern due to the experimental nature of the project.

5.3.2 Use cases

Digitally connected and geo-fenced Freeport Zones

This use case focused on the flexible creation of sites and corridors based on 5G enabled digital/virtual geofencing. This was led by the University of Bristol Smart Internet Lab, which looked to use the capacity,

[8] https://www.itgovernance.co.uk/nist-cybersecurity-framework

reliability and speed offered by 5G to take advantage of Artificial Intelligence to support logistics. The trials tested this application in three cases:

- theft of goods in transit. This had rules set on sensor measurements which indicated when containers were opened unexpectedly and triggered an alert to the user.
- mishandling of goods in transit. Rules were set to alert users to potential damaged goods based on abnormal vibrations, temperature, or humidity patterns within the containers. This corresponded to leaks or extreme temperatures set against normal readings.
- wireless identification of goods. When the container entered a smaller geofenced area within the dock, wireless scanning of goods was initiated and shared between multiple endpoints.

Measurements were collected throughout and involved observing sensor readings during everyday activities, along with latency and location accuracy within the public and private networks. Improvements were observed against the initial baseline targets.

Port police operations

This use case was led by Unmanned Life looking to leverage the benefits of 5G wireless networks in combination with Mobile Edge Computing infrastructures for more efficient and effective port inspection, surveillance and incident response. A single drone was managed and monitored over a central platform, which was responsible for putting together and processing drone sensor data from elements such as proximity sensors, GPS coordinates etc. This allowed the port police to set the type of mission and parameters such as flight height or drone speed and to see the drone location in real time along with video streaming from the drone. The drone tested three scenarios:

- Pre-planned Surveillance (Fence Inspection)
- Ad-Hoc Surveillance (Incident Response)
- Triggered Response and Emergency Services

All three scenarios saw improvements against the initial baseline measures observed at the inception of the project.

Smart Junctions

This use case, led by Bristol City Council and executed by Yunex Traffic, delivered a world-first demonstration of a 5G Multi Access Edge Computing based solution for controlling traffic signals using private 5G and public data networks. This integrated a number of technologies to create a smart traffic junction near the Bristol Port Company's Avonmouth site. This use case set out to test whether the use of 5G networks could be applied to solve a real world traffic management problem. Ultimately the use case was successful in reducing queue lengths, though in terms of 5G being effective in enhancing traffic control systems this effect was more marginal.

Key benefits that the project measured are:

- The improvement of real time alerts for goods damage and spoilage
- Ability to enhance traffic control systems with 5G core derived data
- Reduction of inspection time through drone use
- Reduced time for incident response and assessment

5.3.3 Safety and security impacts

The 5G Logistics project looked to base its security strategy on DCMS security guidelines. Each of the use cases rated their risks according to the following criteria:

- Impact – disastrous, critical, moderate, negligible
- Exposure – high, medium, low
- Exploitability
- Likelihood

Security and privacy are one of the key elements behind the adoption of private networks. In this project security was implemented following network and application best practices. There were lessons learnt from this project around security. Network security was not explicitly tested as part of this project but this is certainly an aspect which would require more attention in future applications of this technology.

5.3.4 Technology Readiness Levels

Most of the use cases made progress against their starting TRL with only the multi access edge computing TRL remaining constant during the lifespan of the project.

Table 24: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
PNNH	3	6	4	No
MEC	6	7	6	No
Core	2	6	4	No
RAN	2	7	6	No
RFID-5G-NanoCell Router	2	6	6	Yes
Autonomous Drones	4	7	7	Yes
MEC Algorithm	2	5	4	No
Probe Vehicle	2	5	3	No

Source: Benefits Realisation

However, despite this improvement, only two of the use cases met their target TRL. This might be a point to consider for future projects as to whether the TRL targets were too aggressive, or whether the lessons learned from this project would mean that in a future scenario, there is a higher probability of these target TRLs being achieved.

5.4 Collaboration, knowledge sharing and overcoming barriers

5.4.1 Sharing learning and best practice

One of the most successful elements of this project was how it led to the sharing of elements learned across not only consortium members but throughout the wider 5G ecosystem. This included sharing information about the technical aspects of deploying a 5G network and how to avoid some of the unforeseen challenges that arose during this testbed including the challenges with Open RAN and having to navigate the difficulties which COVID-19 posed. A number of conferences and events were held to encourage this knowledge sharing aspect, including the Be Better Connected collaboration conference, the 5G-Enable Smart Ports collaboration and the UK 5G showcase. All these events gave members from the 5G Logistics project the chance to show what they had learned and gain insight from the approaches which others took with their own testbeds and trials.

Additional communication activities such as press releases, online blogs, articles and social media videos were examples of the range of mediums used to share this learning with not only each other but also with the public more widely.

Table 25: Publication and events summary

Dissemination Activities	Number of articles/events
Social Media	129 posts
Posts/Articles	30
Conferences	22
Press Articles	16
Workshops	10
Reports	2

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

5.4.2 Interaction with wider ecosystem

As noted above, one of the main benefits found from the 5G Logistics project, was the collaboration that it fostered, within the consortium and with other projects in the 5GTT programme. Reports written in combination with other 5GTT projects were shared with DCMS and UK5G. Interviewees noted that UK5G had a key role in collaboration and that this understanding has been very beneficial. The input of UK5G was critical in ensuring the projects generated more success than they would have been able to, had the consortium members been operating on their own. While interviewees were unsure as to whether UK5G helped directly with any barrier busting, this organisation was a useful source in bringing individuals and firms together and helping to learn and share knowledge around some practical elements such as the installation of private networks.

5.4.3 Business and industry generation

The collaboration of consortium members of the 5G Logistics project with other members involved in the 5GTT programme helped to gain an understanding of the new technology being deployed. This collaboration is hoped to generate additional investment to further the development of the use cases worked on during the project. For example, the 5G Logistics project has led to connections with several other ports such as Port of Felixstowe and produced the 5G Smart Port Collaboration report. The collaborations are hoped to attract additional investment from countries such as Canada, Japan and Switzerland.

The spinouts generated from this project in the O-RANOS and 5G DU-Volution projects showed how the elements learned from this project would generate impact beyond the lifetime of the 5GTT programme.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 26: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£2,851,000	£1,969,000
Number of partners that received funding / contributed R&D	13	13

Source: Benefits Realisation

5.5 Processes and support from DCMS

Interviewees noted that DCMS were very effective in terms of programme management. DCMS had project managers and Benefit Realisation leads who assisted consortium leads in ensuring that these were reported appropriately. DCMS were particularly effective in promoting collaboration between not just consortium members but also across the wider 5G ecosystem.

They did find that the DCMS communication for the project was effective. The process of Benefits Realisation reporting was challenging for 5G Logistics because the terminology often used by DCMS took some time to be understood by consortium partners. This may have been because of a slight lack of clarity with regards to how benefits should be reported and also partly due to a lack of familiarity with regards to how to actually report findings from the project. These points are elements to be considered with future interventions with a clearer explanation of how reporting is to be conducted at an earlier stage to ensure all parties have a clear idea of what is required.

5.6 Long term impacts

5.6.1 Additionality

There was clear acknowledgement that the funding provided by DCMS helped the use cases to get to a more developed position that they would have otherwise. In addition, the work DCMS did to promote collaboration and bring together a wide range of stakeholders was also very beneficial in fostering relationships, which without this project would certainly not have occurred.

The development of a 5G network was one of the key elements underpinning this project, and this had mixed success. open RAN deployment was planned but could not be tested within the lifetime of the project. The 5G network that was deployed allowed for use case tests to be carried out more quickly than before, but in some instances the existence of a reliable 4G network meant that there were minimal differences between this and the 5G network.

5.6.2 Sustainability

From a sustainability aspect, a lot of work was carried out by DCMS and 5G Logistics partners to ensure that the lessons learned from this project could be built on and expanded in the future. A range of dissemination activities such as demonstration videos, press releases and attending showcases put on by UK5G and DCMS meant that not only could project participants share what they had learnt to a wider audience, but that they also had the opportunity to learn from other individuals. The additional investment and spinouts created also ensured that the work carried out in this project can continue after the project was concluded. The O-RANOS and 5G DU-Volution occurring as spinouts after the project was completed were excellent examples in demonstrating how the 5GTT programme had impacts which lasted beyond the duration of the project itself.

6. 5G WALES UNLOCKED

6.1 Overview of the project

The primary aim of the 5G Wales Unlocked project was to identify the supply and demand side features of getting rural connectivity in place. The project aimed to understand the economic drivers, dynamics, and business models which could be used to scale up services and incentivise further investment in advanced mobile access technologies in rural Wales. The project developed several demand side use cases that were stackable, had investment value, and could be scaled up. Besides this, the project deployed two 5G networks in the neighbouring counties of Monmouthshire and Blaenau Gwent in rural Wales. While some of the project's use cases could be deployed using a 4G network, 5G significantly improved their performance and allowed stacking the project's use cases to create added value.

Table 27: Overall project summary

Project	5G Wales Unlocked
5GTT Competition	Rural Connected Communities
Location	Wales
Timeline	August 2020 to April 2022
Lead consortium partner	Welsh Government
Other consortium partners	BT / EE, Cisco, Utterberry, AppyWay, Jam Creative Studios, Cardiff University, Blaenau Gwent County Borough Council, Monmouthshire County Council
Type of network/technology deployed	Public, Non-Standalone
Total project costs	£5,083,726
Funding awarded by DCMS for 5GTT	£2,793,508

6.1.1 Progress against success measures

These outcomes showcase strong evidence of added value against the following four of the 11 5GTT success measures of the programme designed by us, which we have summarised in Table 28:

Table 28 Summary of impact of 5G Wales Unlocked

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The project was focused on developing a sustainable 5G testbed in rural Wales and identifying supply and demand side levers which could incentivise further investment in advanced telecommunication technologies in rural Wales. Although there was no explicit intention to develop connectivity throughout the UK, the project can be argued to have raised awareness of its activities internationally by participating in conferences and events globally. This could, to some extent, improve the UK's reputation as a leading 5G nation.	1
Programme activities have attracted further funding within the area of 5G/5G R&D	The programme's use cases were designed to be sustainable, and the consortium is intent on developing it further and is actively looking for funding. The programme's use cases have also garnered significant interest from organisations beyond the consortium in collaboration and further development. However, no information on additional third-party funding received is made available. Furthermore, there is also no information available regarding any government funding programmes to which the consortium has applied.	2

Success measure	Evidence	Contribution Score
Reduction/ removal of barriers has accelerated deployment of 5G in the UK	Although not explicitly stated, the project's activities have increased awareness of 5G in rural Wales through its activities, press features, and participation in conferences, among other things. Apart from this, several of the project's use cases have attracted much attention from organisations outside of the consortium towards their further development. It can therefore be argued that the project's activities have reduced barriers for 5G deployment in terms of increasing awareness and developing scalable use cases.	2
Information and knowledge is more readily transferred within the 5G ecosystem	The project participated in several local and global conferences and events organised by UK5G. Stakeholder consultations reveal an overall positive attitude towards DCMS as an enabler of collaboration and knowledge dissemination. Besides sharing its progress with DCMS regularly, the project also resulted in research outputs, such as the semi-independent report prepared by the University of Cardiff detailing the project's progress.	2
5G networks are more secure than the 4G networks they replace	The philosophy of 'Security by Design' was adopted by the consortium towards network deployment and use case development. Decisions made, such as using larger MNOs to ensure full 3GPP compliance of the networks deployed and making sure that the use cases were GDPR compliant, show the acute importance that the consortium placed on security.	3
Additional welfare and environmental benefits	The project's use case focussed on increasing productivity and efficiency in several sectors including transport by using AI cameras to test vacancies in busses and car parks to optimising the process of preserving heritage buildings through 5G powered smart monitoring.	2
Public services cost avoidance	Although there is a long way to go for full commercialisation, the project's tourism and transport use cases would aid local authorities in managing public transport in rural Wales and monitoring and preserving heritage sites like Raglan Castle. As a first step, these could have an impact of reducing the cost of providing public service.	2
Development of industry 5G expertise and increased ability to use 5G for commercial activities	Project activities have helped employees build 5G specific skills and capabilities. We further know that not only were existing employees trained, but new network engineers were also hired to fill the existing gap in terms 5G expertise. Apart from this, we know that several other jobs, such as a digital champion, IoT officer, were created either directly by the consortium or as a result of its activities. Lastly, we also know that employees hired on the back of the programme on a contract basis have moved on to similar roles in different sectors.	2
Generation of 5G activities beyond the scope of the programme	The programme's sustainable use cases have resulted in the development of several mini testbeds, focused on the development of its use cases or the development of further use cases. For instance, the Diverse Rural Economy (DRE) use case has been maintained as a demonstrator for further testing and development of rural applications of 5G. Besides this, the immersive classroom has become a semi-permanent feature with several organisations looking to develop it further to monetise it in the long run. The transport use case 'totem' has become a permanent feature following the completion of the project. It can be said that most of the project's use cases are primed to be developed in the near future.	3

Success measure	Evidence	Contribution Score
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	As mentioned earlier, the project's use cases are highly scalable, which has garnered interest from several organisations for their further development. Furthermore, the project resulted in larger MNOs like BT becoming interested in developing 5G networks in rural Wales. Apart from this, the project has resulted in use cases like the immersive classroom and the DRE use case, which are either in the process of commercialisation or have been converted into a mini testbed. Lastly, the consortium has developed several tangential use cases like the AI powered cameras which are a breakthrough by themselves.	3
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The project directly resulted in two commercially provided 5G networks being deployed in Monmouthshire and Blaenau Gwent that are still functional, highly secure and resilient.	3

6.1.2 Project aims and activities

In its final report, published in 2022, the 5G Wales Unlocked project states its four primary objectives as:

- increasing the provision of 5G in rural and semi-rural locations in Wales;
- identifying the supply and demand side levers to influence the scale up of services to strengthen the business case for accelerated investment in next generation rural mobile access technologies;
- building a commercially sustainable 5G environment; and
- demonstrating the socio-economic impact of increased 5G connectivity for rural communities and stakeholders.

To achieve these objectives, two 5G networks were deployed in Monmouthshire and Blaenau Gwent. Commercially available networks were deployed to create a realistic environment to experiment with and develop use cases. The project itself developed several demand side use cases revolving around four major themes:

- **Diverse Rural Economy (DRE)**: Using 5G alongside IoT sensors and Artificial Intelligence (AI) enabled cameras, these use cases addressed the concerns of the farming community such as rural crime, security, safety, wellbeing, and social isolation.
- **Tourism:** These use cases focused on preserving heritage sites and enhancing visitor experiences therein using 5G alongside IoT sensors, AI enabled cameras, and Augmented Reality (AR). These were tested at Raglan Castle, a heritage site managed by the Welsh heritage organisation Cadw.
- **Transport:** These use cases focused on using 5G for high-speed data analytics alongside IoT sensors and AI enabled cameras, to improve transport management in rural Wales.
- **Education:** This use case involved real time streaming and 360° projection of content stored in the cloud via a 5G network. It used elements of AR, IoT, and AI powered cameras.

The focus of the consortium was on ensuring that the project's infrastructure and its use cases were stackable (could be deployed simultaneously using 5G), sustainable (could be developed further post-project), and scalable (could be commercialised through further investment). Overall the project successfully met its aims and objectives and was able to test the use cases above as planned, except analysing data from the transport use case, which had to be de-scoped due to external factors.

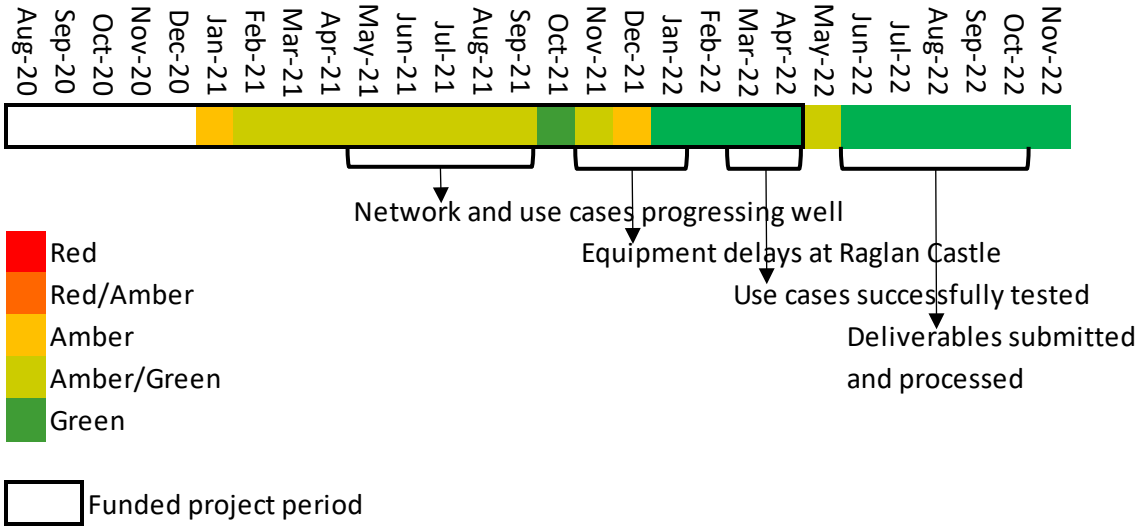
6.1.3 External factors affecting delivery

As with other 5GTT projects, 5G Wales Unlocked was impacted by external factors like COVID-19, UK's EU Exit, trade restrictions towards High-Risk Vendors (HRV), and the resulting global supply chain crisis. Stakeholders unanimously agree that starting the project during COVID-19 created several disruptions and exacerbated the delays. Difficulty in visiting the sites due to COVID-19 restrictions was mentioned multiple times during interviews. Stakeholders cited several mitigations, such as dismantling old equipment for parts and sensors, which needed to be implemented to avoid delays due to the global supply chain crisis. It was brought to light that the consortium was least affected by the restrictions on dealing with HRVs, this is attributed to the larger MNO partners in the consortium who had a pre-existing plan in place to circumvent the crisis.

Timeline

The 5G Wales Unlocked project lasted for a year and eight months, from August 2020 to April 2022. During this time, the project was successful in developing and testing its use cases. Notwithstanding the delays caused by external factors mentioned above, the project faced a significant delay due to not being able to deploy its Raglan Castle 5G network in time. This six-month delay meant that aspects of the project had to be replanned with live testing of the Raglan use cases being pushed to the back end of the project. To add to this, stakeholder consultations reveal that there was no scope for extensions, with one stakeholder stating that DCMS was clear that the end of March marked the end of the project. This hard deadline spurred the consortium to develop workarounds and test as many use cases as possible to maximise the evidence before then.

Figure 6: Project Delivery Timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

6.2 Consortium Partners

5G Wales Unlocked consisted of nine consortium members, led by the Welsh Government. As summarised in Table 29 below, the consortium was a mix of local authorities, academic institutions, larger MNOs, and local SMEs.

Table 29: Consortium members, 5G Wales Unlocked

Organisation	Type	Role/responsibilities on project	Staff allocated to project
Welsh Government	Public body	Lead partner	Not Reported
Cardiff University	University	Solution development and risk share model development	1 department
BT Networks	MNO	5G network coverage, service provision, and Support	Not Reported
Cisco	Large Business (Digital communications and technology)	Technology partner providing specialist equipment, materials, and global support network in relation to 5G video analytics, HD motion capture and virtual communications platforms.	Not Reported
Utterberry	Private SME	Sensor & application development	10
AppyWay	Private SME	Sensor & application development	Not Reported
Jam Creative Studios	Private SME	Augmented Reality Content Development	Not Reported
Blaenau Gwent CBC	Council	Partner	Not Reported
Monmouthshire CC	Council	Partner	Not Reported

6.2.1 Working with consortium partners

Stakeholder consultations revealed that member organisations had previously worked with each other individually, but 5G Wales Unlocked was the first time they collaborated as a consortium. The consortium stayed constant throughout the project except for 'Jam Creative' which joined later on. We know from the project's final report and from interviews with stakeholders, that the consortium members specialised in different aspects needed for the development of the project's use cases and reporting progress.

Larger MNOs like Cisco and BT worked on developing the education use case and deploying the 5G network. On the other hand, local SMEs like Utterberry, AppyWay, and Jam Creative supported network deployment and worked on different aspects of the 'farming', 'transport' and 'tourism' use cases. These included providing specialist equipment, IoT sensor co-ordination, and the deployment of AR, among other things.

Use cases were focused on two neighbouring geographical areas, Monmouthshire and Blaenau Gwent, whose local authorities were responsible for resource support and acted as testbed hosts. The University of Cardiff had a research-oriented role and acted as a semi-independent authority in recording and reporting the progress of the project.

Overall, stakeholders agreed that consortium members worked well with each other. Some challenges were cited such as problems working with larger partners like Cisco while they were in the midst of reorganising, and the difficulty in resource planning faced by SMEs. Multiple stakeholders mentioned that the SMEs were not able to extend credit, which was exacerbated due to external factors such as COVID-19.

In terms of consortium size, a stakeholder also opined that the consortium could not have developed its use cases with fewer members. Stakeholders also unanimously agreed that the consortium members cooperated well and have developed an enduring relationship because of the project. They also mentioned that members have signed an MOU that enables them to work together to further develop the project's use cases, after the project's completion.

6.2.2 Personnel

Although the BR doesn't say much about the number of staff involved, interviewees reported that on average, between 20 and 30 employees worked on the project's daily operations. This number peaked anywhere between 50 and 60 during crunch periods. In terms of skills and labour requirements, multiple stakeholders mentioned that the work of the consortium could have improved with additional system integration support personnel who could have worked with suppliers to identify challenges, integrate solutions, and develop necessary workarounds. This was something that the consortium actively looked to improve from there on.

Although the exact number is not known, one stakeholder mentioned that the consortium hired a few network engineers as the data analytics staff did not have 5G expertise. Further, we know from the project's Benefit Realisation (BR) reports, that the University of Cardiff recruited a data analytics researcher on the back of the project. A stakeholder further mentioned that the consortium had employed a full-time digital champion for the education use case who operates and teaches out of the 5G immersive classroom. Stakeholders also mentioned that the staff employed in temporary roles, moved on to similar jobs in different sectors after the project's completion. For instance, a stakeholder pointed out that one of the consortium's technology suppliers had hired staff who had built services for the project.

Lastly, consultations have also revealed that the local authority in Blaenau Gwent has hired a full-time IoT officer. Although this was not directly connected to the project, it became possible due to the project's activities. This could be considered evidence that the project has helped secure a pipeline of opportunities in relevant sectors, beyond its scope of operation.

6.3 5G Deployment

6.3.1 Approach to deployment

As part of the 5G Wales Unlocked project, 5G networks were deployed in the two neighbouring counties of Monmouthshire (Raglan), and Blaenau Gwent (Ebbw Vale). The consortium made a conscious choice to use commercially deployed networks instead of building a bespoke Stand-Alone 5G network. This was done to reduce resource requirements and to build a realistic experimental environment for the use cases.

Apart from this, stakeholders mentioned that the consortium wanted to ensure the sustainability of the network after the project's completion. For this reason, BT, as the consortium's MNO partner, was responsible for the network deployment at 700Mhz in both Ebbw Vale and Raglan. This was supported by the smaller SMEs in the consortium, who were also responsible for the deployment of edge components such as cameras, IoT devices, and AR for the specific use cases. Table 30 depicts the infrastructure deployed for each of the four use cases of the 5G Wales Unlocked project.

Table 30: Infrastructure Deployed for Various Use Cases

Infrastructure	DRE (Farming)	Tourism	Transport	Education
5G network	X	X	X	X
IoT Sensors	X	X	X	X
Cameras	X	X	X	X
Augmented Reality (AR)		X		X

Source: Project Final Report (2022)

Ebbw Vale Network: As the networks deployed were non-standalone, it was decided that existing 4G networks in two sites in Ebbw Vale would be upgraded to 5G networks. Apart from this, BT/EE also upgraded five additional masts in the wider South Wales region, covering Abertillery and Merthyr Tydfil. The Ebbw Vale network was deployed over a period of six weeks and was functional by March 2021.

Raglan Network: Considering the tourism and DRE use cases being developed in Raglan, the 5G network was deployed at 700Mhz , which gave a wide geographical coverage. Accordingly, an area to the west of the village was chosen for network deployment.
Unlike the Ebbw Vale network, it took more than six months to deploy 5G in Raglan, with the network becoming usable as late as the 31st of January 2022. The project's final report attributes this delay to several factors, ranging from needing landowner permissions, to needing to physically strengthen the tower. The site also needed a power upgrade and ground condition testing. Apart from this, the site was not identified as needing significant improvements until the design of the network was completed. Lastly, the 4G network on site also failed for 8 weeks in October 2021, which halted all progress on the farming and tourism use cases.

We know from both the project's final report and through interviews with stakeholders, that this delay significantly affected the development of the project's use cases and its reporting of benefits.

Table 31 compares the performance of the newly deployed 5G network with the 4G and Wi-Fi networks it replaced. As can be seen, the 5G networks have resulted in improvements both in terms of throughput (the amount of data that travels through the network) and latency (the speed at which data travels through the network). A greater improvement is seen in terms of throughput in the newly deployed 5G network. There is also some improvement in terms of latency. However, as mentioned in the project's final report, advanced use cases that need less than 12ms latency will not be able to be tested or developed in the deployed 5G networks.

Table 31: Network indicators

Network Indicator	Measure	Previous network (Baseline)	5G network (Achieved at end of project)	Improvement (%)
Raglan Network Throughput (Combined)	Megabytes per second (Mbps)	3.85 (4G)	7.80	102.6%
Raglan Network Latency	Milliseconds (ms)	58.1 (4G)	47.2	18.8%
Ebbw Vale Network Throughput Download	Mbps	81.1 (Wi-Fi)	111.5	37.4%
Ebbw Vale Network Throughput Upload	Mbps	11.2 (Wi-fi)	35.9	220.5%
Ebbw Vale Network Latency	ms	58 (Wi-Fi)	42	27.6%

Source: Project Final Report (2022)

6.3.2 Use cases

As mentioned earlier, the main aim of the 5G Wales Unlocked project was to identify the demand and supply levers that could be targeted to improve incentives for the deployment of advanced communication networks in rural Wales. The project was successful in developing the following four use cases:

- **Diverse Rural Economy (Farming):** This use case revolved around using 5G to inform farmers of trespasses and possible thefts and burglaries of their livestock, mules, and tractors, among other equipment. It primarily used video analytics for which 5G was essential. This was made possible by Artificial Intelligence (AI) powered cameras and 5G sensors connected to a 5G network. Besides being able to identify people and livestock, the video cameras could track metrics such as vibration, displacement, temperature, and humidity by working in conjunction with IoT sensors. 5G connectivity was particularly relevant for the simultaneous streaming of HD video to cloud based analytics and operating alongside IoT data for multiple parameters. This use case was tested solely in Raglan.

- **Tourism and Preservation:** These use cases were aimed at enhancing visitor experiences at Raglan Castle and monitoring the state of the castle with the intent of preservation. This was done using a 5G network and a mix of AR, IoT, and AI powered cameras.

- **Enhanced Visitor experience:** This involved three unique AR experiences where visitors could either shoot virtual CGI cannons at the walls of the castle, play bowls virtually with King Charles I, or complete a quest to learn the castle's history. These were tested at Raglan Castle and used I-Pads that visitors could borrow from the visitor centre. 5G was specifically relevant for this use case to run multiple visitors concurrently. The consortium is now exploring further development options such as centralised rendering of graphics as well as interaction between users in virtual spaces. The experience has been fully available since March 2022, and has garnered several positive responses from users. This has led to an increase in visitors to the project's Augmented Reality (AR) attraction by 8,600 from baseline. In total 51,600 visitors visited the Castle. The project's AR attraction earned a revenue of £2.50 per visitor.

- **Preservation and Security monitoring:** This involved using IoT sensors to monitor the state of the Raglan Castle and any issues already under surveillance. The IoT devices used are capable of tracking metrics such as vibration, displacement, humidity, ground condition, ambient lighting and wind speed. The objective of the use case was to collect data overtime and use the analysis to inform where careful intervention is necessary to preserve the castle. 5G was required to analyse the vast amounts of real time data. The analysis of the data from all the IoT sensors makes a model of the castle itself, as shown in the figure below. This data is uploaded to the cloud, so that the castle can be observed anytime using the internet. The project's predictive maintenance use case is estimated to increase the frequency of monitoring while saving costs in terms of time and materials.

Figure 7: 5G Wales Unlocked, Preservation Use Case

Source: Project Final Report (2022)

- **Transport:** This use case involved the use of IoT sensors and AI powered cameras installed in busses and across car parks to analyse in real time, the number of empty seats, the number of passengers, and the number of empty parking spaces, among other things. 5G was specifically useful in real time analysis of data. Although this data was sourced from live video feeds by the AI powered camera, the video itself was not available for the end user to see.

The data analysed was envisioned as being helpful to the local authorities to better manage transport requirements in rural areas. At one stage, a stakeholder mentioned that a possible future application of this use case could be that passengers could request public bus service as per their convenience, although this application has not yet been tested. This would hopefully lead to the benefit of increased passenger numbers on rural bus routes.

Besides this, as part of the transport use cases, a totem was installed which was directly connected to the 5G network. This was used as an information point where the public where real-time information of any kind could be displayed in the future. The 'transport totem' was aimed primarily at improving passengers' trust in the system through improved user experience using real time information availability for travellers/users. It could also be used for dissemination of local information and advertising.

- **5G powered immersive classroom:** We know from the project's final report and through stakeholder consultations that this use case arose as an unintended consequence of the project. As mentioned earlier, this was one of the use cases developed by the project that could not be run on a 4G network. The use case involved using AR and a 360° camera to project computer generated content on all four walls of a classroom. An I-Pad was used to livestream the content through Wi-Fi into a server room and a modem was used to transmit content in real-time from there to the wider 5G network. This immersive learning experience was piloted in four schools across both Monmouthshire and Blaenau Gwent. A stakeholder mentioned that a full-time digital champion was hired to teach using the immersive classroom. Full3sixty and Cisco provided training to the team and users so they could use the system and create their own content. The consortium has also tested a STEM learning module in the schools where the programme was piloted, which was well received.

6.3.3 Safety and security impacts

The project followed 'Security by Design' in its activities, including network deployment and use case development. Stakeholder consultations have revealed that by using a larger MNO and commercially deployed 5G networks, the consortium ensured that they contained full 3GPP compliance for security. Besides this, the project's final report identifies six elements where the consortium was focused on security, which were:

1. 5G Network
2. 5G Modems & Wi-Fi
3. IoT data capture
4. Video Capture
5. Cloud Storage & Applications
6. General Access Control

The report further mentions that the consortium viewed each of the six elements individually and introduced security measures such as conducting penetration tests and implementing two factor authentication, where applicable. The consortium also made sure that all its use cases were GDPR compliant. The report informs us that the security guidelines of the network and the edge devices were kept as simple as possible, and they were found to be adequate in all cases.

6.3.4 Technology Readiness Levels

Table 32: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
5G enabled IoT Hubs	2	6	3 (nearly 4)	No
5G enabled IoT Sensors/Devices	3	7	3	No
Video Analytics	2	6	3	No

Source: Benefits Realisation

As can be seen from Table 32, the project was not successful in reaching its target levels of TRL in any of the mentioned use cases. However, in most cases some progress from its baseline can be observed. The aim of the project was to identify the levers which could incentivise investment in rural connectivity, which it has successfully done.

6.4 Collaboration, knowledge sharing and overcoming barriers

6.4.1 Sharing Learning and best practice

The consortium regularly reported its learnings to DCMS throughout the project through its reports and BRs. Apart from this, thematic learnings have also been detailed in the projects final report, published in 2022. Stakeholder consultations reveal that learnings mainly revolved around the need for better resource planning and early action in terms of identifying challenges to network deployment and data collection, improving communication amongst consortium members, and mobilising member organisations.

They further mentioned a report prepared by the University of Cardiff which the consortium shared with DCMS. This report talked about the barriers and challenges busted, and the opportunities created by better planning and increasing the speed of deployment. Stakeholders further mentioned wider publication of this report as an academic article was being considered by the university.

Table 33: Publication and events summary

Dissemination Activities	Number of articles/events
Research Outputs and Reports	4
Press Features other communication activities	5
Events and Conferences	9
Combined Social Media Followers	264
Combined Social Media Reach (views, impressions, etc.)	46,572

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

6.4.2 Interaction with wider ecosystem

Stakeholders had an overall positive opinion regarding the UK5G network and DCMS' contribution in enabling communication and collaboration activities, both within the consortium and across the wider ecosystem. Multiple stakeholders identified 'lack of collaboration due to lack of funding' as a major barrier to the deployment of 5G in the UK, and opined that the 5GTT programme has helped bridge this gap significantly.

One stakeholder mentioned that DCMS putting requirements on a project to share and disseminate knowledge puts an onus on it happening.

Table 33 informs us of the various knowledge dissemination activities which the 5G Wales Unlocked project attended and participated. The project not only resulted in potential research publications such as the report developed by the University of Cardiff, but it also applied for a patent for 5G enabled IoT devices, developed as part of the project's use cases. Further, the consortium has attended and participated in several conferences and events, such as '5G Safety Unlocked' and 'UK-Spain 5G innovation workshop', among others. Besides this, 5G Wales Unlocked was featured in local press, such as 'Business News Wales'. Apart from this, the project also developed a wide social media network using LinkedIn, Twitter, and other sources.

6.4.3 Business and industry generation

The 5G Wales Unlocked project has been successful overall in terms of network deployment and developing its use cases. Consultations have revealed that stakeholders are positive about the potential of a new industry emerging as a result of project's activities. The project's activities have led to a wide range of private, public, and academic organisations such as the University of South Wales and Thales (a big systems integrator), among others, to expressing an interest in further developing the project's use cases. Furthermore, multiple stakeholders have cited spinoff use cases that have emerged from the project such as 'a novel sensor technology with 5G chipset' and an 'immersive reality gaming tourism experience', developed by members of the consortium.

Besides this, the 5G networks deployed by the project are still in place and are being used to run most of the project's use cases. As mentioned earlier, the project's use cases were designed to be as sustainable as possible post its completion. This is confirmed by the project's final report which tells us that:

- The Raglan Castle tourism experiences showcase tremendous potential to boost visitor numbers. Jam Creative and Cadw are working together to continue the experience through the summer season. They are also looking to analyse further survey data to build a more enhanced understanding of the impact of the use case on visitor experience.

- Cadw is also continuing its work in partnership with Cardiff University towards exploring the practical uses of video analytics. This is aimed at furthering the preservation use case. The Cisco camera equipment will remain at the site long term for this use.

- Blaenau Gwent, the sponsor of most of the transport use cases, is exploring how they could leverage the bus data for transport planning. They are also working with Transport for Wales, Fleccsi bus service, and Stagecoach to explore if and how the service has use on a wider basis.

- The immersive classroom has become a semi-permanent feature whose various implementations are being explored by Blaenau Gwent Council, Cisco, BT, Welsh Government, and academic institutions such as Cardiff Met University and the University of South Wales. The organisations are seeking to develop models for content sourcing, curation, and development. There are also plans to monetise the facility over time.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 34: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£ 2,794,000	£ 545,000

Number of partners that received funding / contributed R&D	No data	3

Source: Claim Information and Benefits Realisation

6.5 Processes and support from DCMS

Regarding the various aspects of the project such as application, monitoring, reporting, delivery, stakeholders felt that DCMS was more focused on the processes rather than their outcomes. Although the stakeholders viewed these processes as vital, there was a general agreement that they could be streamlined. Stakeholders mentioned that not enough time was given to the members to sign the contract and several details were asked therein, which would be difficult to predict before the start of the programme. Lastly, one stakeholder also pointed out that the staffing changes made by DCMS resulted in the consortium receiving contradictory feedback on their reports. Some interviewees also reported that payment processing from DCMS was consistently slower than expected which exacerbated the financial bottlenecks especially for the smaller SMEs.

However, having said this, stakeholders also agreed that DCMS was very helpful in terms of delivery. The consortium had regular dialogues with the department and DCMS tried their best to connect the project with other 5GTT consortia while making sure it was getting over hurdles. In terms of feedback, one stakeholder opined that DCMS could have done more in terms of building a team of actual experts who could help the project achieve its outcomes. They also opined that the application process could have been streamlined by providing draft contracts to bidders early on and having a dual stage application process of first pitching the project, then contracting.

6.6 Long term impacts

The key outcomes of the 5G Wales Unlocked project include:

- Deploying two commercially provided 5G networks in Monmouthshire and Blaenau Gwent that are still functional, highly secure and resilient.
- Developing use cases that are highly scalable, resulting in expressions of interest by several organisations outside the consortium for their further development.
- Signing of an MOU by the consortium members thereby confirming further collaboration to develop the project's use cases.

6.6.1 Additionality

We asked stakeholders to comment on the additionality of both the 5GTT funding and the newly deployed 5G connectivity. Stakeholders unanimously agreed that the 5G Wales Unlocked project would not have been possible without the 5GTT funding. They cited a lack of incentive for MNOs to invest in rural connectivity as the primary reason for this. One stakeholder further opined that the Welsh government would also not have taken this initiative had it not been for the 5GTT programme. They mentioned that while the government was actively looking to improve connectivity in rural Wales, they had no plans to specifically test or develop 5G use cases prior to receiving the funding. This was because telecommunications infrastructure was not devolved to the Welsh government, and was generally viewed as the responsibility of the UK government.

Regarding the additionality of 5G connectivity, we know from the project's final report that, while the use cases could have been deployed on previous generation networks such as 4G, it would not have been possible to simultaneously deploy or stack them in many cases. This sentiment is echoed by the stakeholders, one of whom mentioned that several of the project's uses cases had elements such the real time analysis of high-speed data, communicating with multiple edge devices such as AI powered cameras, AR, and IoT sensors among other things, which would not have been possible without the significantly higher bandwidth and lower latency of 5G connectivity.

Apart from significantly improving the performance of the transport, tourism, and DRE use cases, 5G was crucial for the deployment of the project's education use case, the 5G immersive classroom. The use case primarily involved projecting 360° content on the four walls of a classroom, thereby making the experience more immersive. 5G was used to extend the live experience beyond delivery to the immersive classroom to other schools. This could not have been done using 4G networks and required the low latency enabled by 5G. This, as stated in the final report, allowed for greater interaction with demonstrations and talks from live educators. Furthermore, it enabled content creation in rural and inaccessible areas.

6.6.2 Sustainability

The 5G Wales Unlocked project was focused on making sure that its infrastructure and use cases were sustainable and could be developed further after the project's completion. Towards this end, the consortium opted to deploy commercially available 5G networks instead of bespoke stand-alone networks. The 5G networks deployed by the project in Ebbw Vale and Raglan have become permanent features and are still functional.

Furthermore, the project's DRE use case has been maintained with support from Monmouth Council as a demonstrator facility where new farming technology and services could be trialled on a longer-term basis. Organisations like the National Farmers Union and the Rural Crime Commissioner have engaged with the consortium in sharing the learnings and outcomes from this newly established testbed. The tourism and transport use cases of the project have also garnered significant interest for collaboration and further development from organisations outside the consortium, such as Cadw, Cardiff University, Transport for Wales, and Stagecoach, among others. The 5G immersive classroom has also become a semi-permanent feature which the consortium is seeking to develop and monetise over time in partnership with external members such as the University of South Wales.

Apart from this, stakeholder consultations have revealed that members of the 5G Wales Unlocked consortium have signed a Memorandum of Understanding (MOU) to continue working together to further develop the project's use cases. They are actively looking for funding for this purpose, although the exact extent of funding received or applied for, is not clear.

7. CONNECTED COWES

7.1 Overview of the project

Connected Cowes tested streaming real time Virtual Reality (VR) video, using 5G technology, from on-board yachts competing in the Cowes Week Regatta in 2021. The overall aim was to create an immersive experience for a non-stadium sporting event (yacht racing), where a lot of the action takes place out of direct sight of the audience. It was hoped that this use of 5G technologies (cameras on board racing yachts, an app providing details about the event and enhanced live TV coverage) would enhance the experience of spectators both in Cowes and online and increase the audience. The project was successful in demonstrating this.

The grant was awarded through the second round of Create projects and ran from January 2021 to April 2022. The key test and unique feature of this project was a live public demonstration during Cowes Week in August 2021. The date for this was fixed and not flexible, so delivering something testable for the 5G element was a 'do or die' situation. Because of the live public event element and being able to conduct some testing of the network and use case cases, the project was delivered on time.

Table 35: Overall project summary

Project	Connected Cowes
5GTT Competition	Create Window 2
Sector	Leisure/Tourism/Events/Media
Location	Isle of Wight, South-East of England
Timeline	January 2021 to April 2022
Lead consortium partner	Cowes Week Ltd
Other consortium partners	AQ Ltd (AQL), 1851 Marine Trust
Type of network/technology deployed	Private, non-standalone network
Total project costs	£1,654,092
Funding awarded by DCMS for 5GTT	£841,910

7.1.1 Progress on success measures

The table below summarises the project's contribution towards overall programme success measures. Connected Cowes made progress against four of the 11 success measures

Table 36 Summary of Impact of Connected Cowes

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	Advanced publication of trial in international press. Cowes Week is a high profile sporting event with an international audience, so while tests were scaled back the project was able to demonstrate some capabilities and further tests are planned for the future.	2
Programme activities have attracted further funding within the area of 5G/5G R&D	AQL are investing an additional £500,000 in the network to upgrade 5G equipment	2

Success measure	Evidence	Contribution Score
Reduction/removal of barriers has accelerated deployment of 5G in the UK	Connected Cowes experienced some challenges with the equipment and around obtaining an Ofcom spectrum licence and reported these back to DCMS as part of the lessons learned from the project	2
Information and knowledge is more readily transferred within the 5G ecosystem	Evidence of engagement with 5G ecosystem (involvement in UK5G working groups and collaboration calls with similar projects to continue to develop the use cases tested in this project)	3
5G networks are more secure than the 4G networks they replace	Good practice security approach overall, but nothing specific to 5G.	1
Additional welfare and environmental benefits	Using 5G technologies provided an enhanced spectator experience for yacht racing. Satisfaction ratings for the app exceeded targets in the BR exercise. Development of the education platform for STEM subjects is still accessible and available for use by teachers in planning lessons.	3
Public services cost avoidance	Public service cost avoidance was not a focus of the study.	0
Development of industry 5G expertise and increased ability to use 5G for commercial activities	Continued interest of telecoms partner (AQL) in 5G technologies. Four new members of staff have been employed by AQL. While these did not work exclusively on Connected Cowes, they have been involved and developed skills and expertise in 5G technologies as a result of their involvement.	2
Generation of 5G activities beyond the scope of the programme	The project did not have a suitable camera so they have developed their own solution, which has commercial potential in non-stadium sports events and other industries.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	The additional sponsorship for the regatta suggests demand for an enhanced viewing experience by event sponsors.	2
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The network is still in place and there are plans to expand on the use cases in future regattas. The use cases would not have been possible with previous generations of network.	3

7.1.2 Project aims and activities

The project objectives were to

- gain insight into the unique challenges of deploying 5G technologies over water and optimising the delivery of content for a disparate audience;
- evaluate how 5G could enhance the spectator experience for sailing and other non-stadium sports (e.g. motorsports, eventing, cycling, running);

- assess the impact of 5G technologies on improving the accessibility of sailing and related non-stadium sports;
- evaluate the ways in which 5G technologies could bring added value for event sponsors, race crews and the local and regional communities around the Solent; and
- explore the opportunities that 5G provides in unlocking new immersive learning experiences for young people.

Consortium partners built a shared spectrum 5G testbed network covering the Solent where the Cowes week event took place and tested the following use cases/applications:

- Onboard equipment rigs for racing boats consisting of a 360° camera and telemetry sensor, to provide live VR video feeds and contextual position and performance data via the 5G network. This fed into online Virtual Reality headset facilities providing immersive 360° experiences of the live and pre-recorded action.
- A new Cowes Week dedicated smartphone App, available to all spectators and competitors and featuring 5G-enabled live content.
- Outdoor TV broadcast facilities to provide coverage of the Cowes Week regatta via 5G-enabled content, with live streaming and highlights package production.
- A digital education platform to promote 5G-related education experiences to young people and teachers, specifically in STEM subjects.

While the project was successful in meeting their objectives, some problems with deploying the network in time meant that tests were carried out on a smaller area than initially planned.

7.1.3 External factors affecting delivery

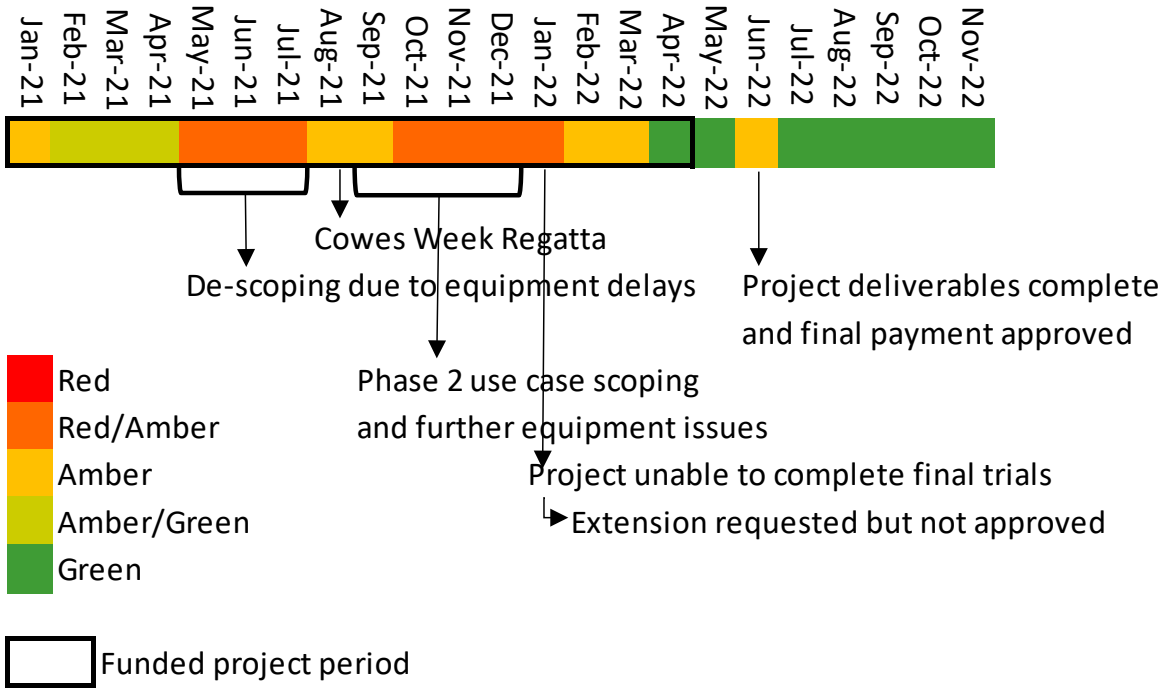
Interviewees reported that changes to regulations around the use of equipment from high-risk vendors such as Huawei had a negative impact on the project. There were problems with hardware and software elements of the kit supplied (see below for more detail). They also felt the price of equipment from other suppliers increased after EU Exit. Concerns about how much of the network and use cases would be ready to test in time for the regatta meant that while the project did receive some good press coverage prior to going live. The COVID-19 pandemic also had an impact on the test event and the practicalities of delivering the project. Interviewees would have liked to have held at least the initial meeting of consortium partners in person but this was not possible due to restrictions in place at the time. The uncertainty around lockdowns also meant fewer spectators than usual attended Cowes Week in 2021 than in other years, which meant fewer downloads of the App, and a smaller test audience than anticipated. There had also been plans to provide VR headsets at the event, but this was not possible due to COVID-19 restrictions, and testing of this element was moved to online only.

7.1.4 Timeline

Problems with the equipment meant that they were not able to demonstrate as much as originally planned, although the project partners interviewed were happy with what they were able to achieve. There are plans to upgrade the equipment and develop the use cases in future Cowes Week events. A project extension was requested as part of the network was installed after the regatta, but this was not granted (see below).

The figure below summarises the overall Red – Amber – Green (RAG) rating of the project as it progressed.

Figure 8: Project Delivery Timeline and RAG rating



Source: 5GTT Delivery Dashboard

Overall, the project ran on budget and on time. However, the consortium had some problems with the equipment initially supplied. Interviewees on this project felt there was a general lack of capacity for manufacturing 5G ready telecoms equipment in the UK compared to other places such as China. The changes to regulation aimed at limiting risk from High Risk Vendors such as Huawei was a significant challenge in this respect. They also felt the price of equipment from other suppliers increased after EU Exit.

This meant the scope of the project had to be reduced so that it had things to test at the Cowes Week event. For example problems with equipment meant that only two of the five masts planned were deployed in time which reduced the intended area of coverage (see Figure 9). Lack of certainty about how well the network would work in the lead up to the event also meant that it was not publicised as widely in the lead up, so fewer people were aware of the app. Combined with lower overall numbers attending Cowes Week due to COVID-19 restrictions, this meant that fewer people made use of some of the applications than was originally hoped.

7.2 Consortium Partners

Connected Cowes was delivered by a small consortium of three organisations. As summarised below the partnership includes two private sector organisations and one charity:

Table 37: Consortium members, Connected Cowes

Organisation	Type	Role/responsibilities on project	Staff allocated to project
Cowes Week Ltd	Small business	Lead organisation responsible for organising Cowes Week event.	2
AQL	Small telecoms business	Development of 5G network.	10

1851 Marine Trust	Education Charity	Developed Virtual Learning Experience Use Case.	10

7.2.1 Working with consortium partners

The partners in the consortium had not worked together before this project but interviewees felt they had the right number and type of organisations involved to achieve their objectives.

Due to COVID-19 they were unable to convene a kick-off meeting at the start of the project which would have been helpful in getting to know each other, but on the whole, interviewees felt the consortium worked well and would work together on a similar project if the opportunity to do so came up again.

7.2.2 Personnel

Overall, 22 people were assigned to work on the project. This included 4 new staff at AQL and 5 new staff at 1851 Marine Trust. No new job roles were created specifically to work on Connected Cowes. Interviewees felt they had the right mix of skills and people involved.

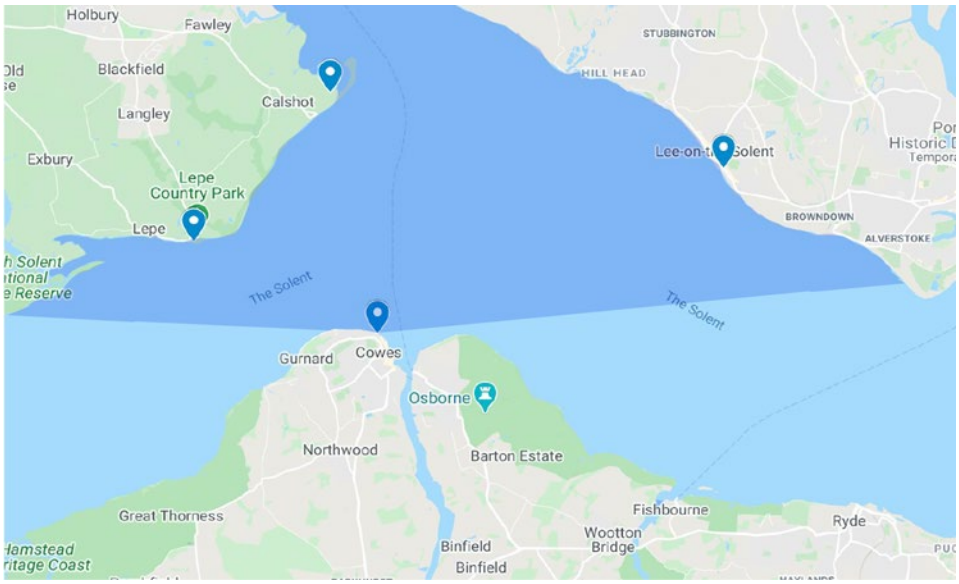
7.3 5G Deployment

7.3.1 Approach to deployment

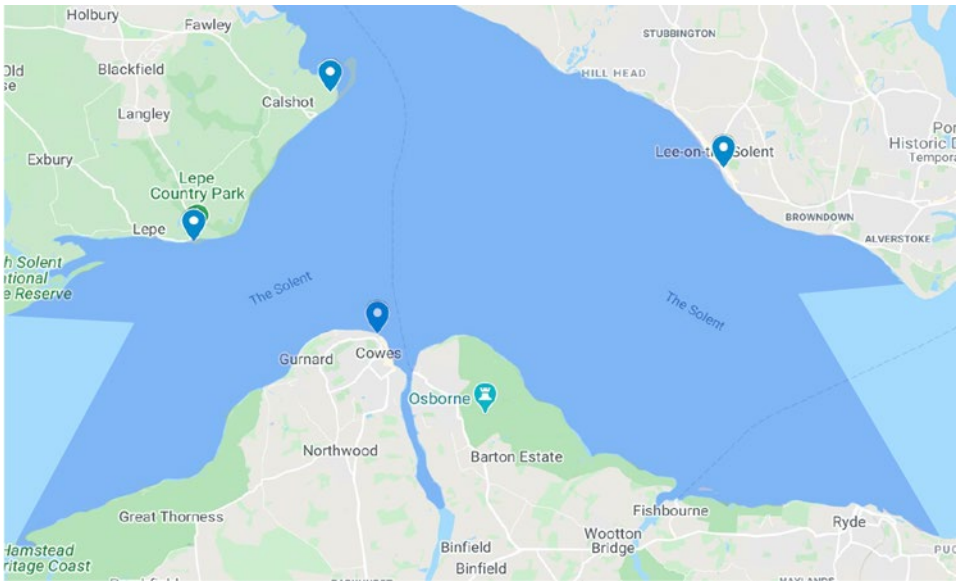
The test network was set up to provide for the local private non-standalone 5G network covering the Solent for the race. They were interested in deploying a 5G network because this needed to be fast, reliable (as it was for a live public event), have sufficient bandwidth for a large number of spectators and adequately cover the area of the sea the race took place in. The 360° cameras also had a higher uplink bandwidth requirement than standard cameras, which required specific network configuration. The network was deployed in two phases (see Figure 1), due to problems with the equipment. Only phase one was available during the 2021 race.

Figure 9: Mast sites and coverage – Connected Cowes

a) Phase 1: Cowes Week 2021



b) Phase 2: End of Project



The consortium aimed to measure latency, bandwidth, coverage, reliability and cell handover. Results are summarised in the table below.[9]

Table 38: Network indicators

Indicator	Measure	Baseline	Target	Achieved at end of project
Latency	Milliseconds	55ms	55ms	<10ms
Bandwidth (Upload)	Number of acceptable simultaneous feeds supported by a cell deployed to cover the “race start event"	0	40	55
Bandwidth (Download)	Number of acceptable simultaneous feeds supported by a cell deployed to cover the “race start event"	0	20	30
Bandwidth (Ratio)	Effect of altering the upload bias	80:20	70:30	Achieved 8UL to 1DL TDD configuration

Source: Benefits Realisation

The project did not meet the target for reducing latency, but did meet and exceed the bandwidth targets. So far the equipment required to measure the coverage and reliability of the networks has not been deployed. Therefore results are not currently reported on this.

As stated above, equipment was not as deployment ready as the consortium had originally hoped and there were some problems, which may be why the network did not achieve the target for reducing latency. Interviewees felt the original supplier of equipment chosen for this project had over-committed on what they were able to deliver and elements of hardware and software were not ready for deployment in a 5G network. Specifically, there were problems with the Baseband Unit and Remote Radio Head firmware, a lack of documentation, and unavailability of upgrades to support 50Mhz and 100Mhz bandwidths.

[9] It was not possible to measure coverage, reliability and cell handover, so these results are not reported

There were also delays in securing a spectrum licence from Ofcom. When asked about barriers to 5G deployment in the UK, interviewees felt spectrum licencing was a major one, especially for smaller network providers. Their perception was that larger MNOs were prioritised and that there needs to be provisions for smaller operators to deploy private networks in areas where it is not commercially viable for larger MNOs.

7.3.2 Use cases

As well as the network, Connected Cowes made use of equipment installed on yachts (cameras and IoT sensors). These were used to create a VR experience and enhanced live TV coverage. They also created an app for the event, and the 1851 Marine Trust created an education platform for school children.

The following sections provide some more information about the different use cases tested.

Equipment on racing yachts
The consortium deployed 360° cameras, sensors and modems on 5 racing yachts to provide information and footage for TV and VR use cases. There was no suitable 360 streaming camera on the market that was suitable for the requirements of the project. The existing cameras were also not rugged enough for filming on a racing yacht and were not suitable for the level of remote control required. The consortium had to improvise to overcome these challenges and developed a bespoke solution based around an upgraded Ricoh Theta Z1 camera with an improved waterproof enclosure, power pack and control unit.
Interviewees said that for the 2023 Regatta, they would like to build 20 cameras and put them on one class of boats so that people can follow a race in its entirety, which would be a very unique and ground-breaking experience for spectators. Barriers to commercialisation of this technology are sufficient money and time to develop this further, but interviewees were interested in taking the idea forward because it could improve the viewing experience and increase spectator numbers for yacht racing. It could also have applications in other non-stadium sports and in other sectors, for example using it for remote VR inspections on construction sites.

Live TV Production
This use case aimed to develop the live TV production and coverage of the Regatta using drones, chase boats and ability to receive any live 360° camera feed. A production studio was created in the Regatta headquarters building to make use of the 5G enabled facilities as well as the traditional shore based cameras and commentary team. This increased the number of hours of live coverage viewed.

Cowes Week App
A dedicated Cowes Week app for spectators and competitors provided information about the new weather racing programme and shoreside facilities. It also included the live TV coverage and ability to view any of the 5G enabled cameras. There are plans to expand the app in future events. They measured benefits such as improved visitor experience and engagement, and increases in sponsorship revenue.

The initial plan was also to provide publicly available VR headsets for spectators at Cowes, but this was not possible due to COVID-19 restrictions. However, the VR experience was made available online. There were also fewer spectators at the event due to COVID-19 which also impacted the overall numbers downloading the app.

Education Platform
1851 Marine Trust was responsible for developing and delivering a Digital Education Platform, covering thermoregulation, bearings, and data handling. They created lesson plans and classroom resources, which were made available to schools across the UK on the STEM crew website. They also provided a pop-up education experience at the regatta. The user experience of the education platform was received positively by teachers and students as measured through a post-event survey and downloads.

As the network was available it was possible to test all of these aspects to some extent and make improvements on them for the future.

7.3.3 Safety and security impacts

The final report for the project provides details on the security approach taken. They aimed for compliance with ISO27001 across the project as a whole. Key elements of the approach included

- No end-user personal details were stored, and consent was received from those taking part to appear in any filming or recording.
- All physical server equipment, routers, switches were installed within locked racks within controlled areas to prevent unauthorised physical access, with CCTV and other sensors deployed as required.
- Network terminations were in controlled, managed locations along with firewall and IPSEC endpoints to prevent in-transit data intercept/alteration.
- All devices were protected by strong passwords under a trusted management policy, with configurations backed up to a controlled, remote environment and firewall rules defaulting to closed.
- All network functions and MACs were monitored via a central NOC function, with rule-based reporting, centralised system logging of key systems and monitoring of the "outwards-in" threat surface for early identification of any issues caused by software vulnerabilities or accidental misconfiguration.
- Regular SWG meetings were conducted in line with major changepoints or delivery rollouts of the project. Partners and third parties were included into the SWG discussions where there was a need to incorporate their technology into the networks.

This approach is consistent with good practice management for cyber security, but is not specific to or reliant on the provision of a 5G network.

7.3.4 Technology Readiness Levels

All use cases made progress against their TRL.

Table 39: TRL Summary

	Starting TRL	Current/ End TRL	Target	Target met?
5G Network	7	7	9	No
Cowes Week App	6	8	9	No
Cowes Week live TV coverage	6	8	9	No
Cowes Week remote spectator experience	6	8	9	No
Virtual Learning experience	6	9	9	Yes

Source: Benefits Realisation

Although the current TRL of all the use cases does not meet the target of level 9 except *Virtual Learning experience*, they range between levels 7 and 9 which is close to the stated target level. This implies that all the innovative technical solutions developed through the use cases have at the very least been tested and proven through demonstration.[10]

7.4 Collaboration, knowledge sharing and overcoming barriers

7.4.1 Sharing Learning and best practice

Interviewees felt the project had successfully demonstrated that the enhanced participation (through the TV coverage and the app) was popular with spectators and that there was some demand for this type of product for viewing non-stadium based sports.

[10] The detail of the TRL can be found in UKRI (2022) Eligibility of technology readiness levels (TRL)

The project was also useful for learning about the technical aspects of deploying a 5G network to cover a marine environment, but the equipment originally installed was not as ready as consortium members would have liked, and this led to reducing the scope of the project e.g. providing coverage over a smaller portion of the racecourse than originally envisaged.

Learning and best practice has been shared with the DCMS team through the benefit realisation process. Consortium members have also attended two showcase events: The Innovate Local Southern Pioneers Technology Showcase Event and the 5GTT showcase event in March 2022.

Information about the marketing around using 5G at Cowes Week is summarised in the table below.

Table 40: Publication and events summary

Dissemination Activities	Number of articles/events
Local press	5
National press	1
International press	1
Telecoms/communication technology industry press or events	3
Press or events with different sector audience	1

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

7.4.2 Interaction with wider ecosystem

The founder of AQL was a member of the 5GTT working group (one of the working groups set up by the UK5G Innovation Network). One of our interviewees reported that AQL were interested in hearing more about 5G and the challenges of deploying it in difficult, challenging environments.

AQL were also consortium members for other projects awarded funding through the 5GTT programme – Live & Wild, Eden Universe, 5G Factory of the Future and MANY and had some contact with the projects through this link. They also learned about other projects facing similar challenges (e.g. issues with equipment or obtaining spectrum licences). One interviewee said they would have liked to have had more interaction with some of the other teams, but was constrained by COVID-19 and a lack of time. Cowes Week Ltd and the 1851 Marine Trust were less involved in the wider ecosystem.

Connected Cowes has also had collaboration calls with both Live and Wild and Project VISTA. These projects also used 5G to enhance the spectator experience at sports events, so they reviewed some of the coverage from these projects to see what other shared learnings might be applicable. Following on from their project, VISTA was working on a route to market for 5G Broadcast and Connected Cowes was looking to further develop and test sailing as a use case in that. VISTA have also been carrying out testing with live cameras connected via fibre in the Digital Catapult Future Networks Lab in Kings Cross. A collaboration with Connected Cowes would allow VISTA to show case how 5G Broadcast can integrate with 5G-fed camera content, as well as showing how different types of content can be offered over the app e.g. such as 360 views.

7.4.3 Business and industry generation

The project also attracted third party investment (additional sponsorship for the event in 2021 when the app and live TV applications were initially tested).

Additionally, there is evidence of some collaboration with other projects that were looking at using 5G to enhance the viewing experience of live sporting events. This may be attractive to sponsors in future events.

There is also evidence of the development of new technologies to support this (the camera and the Cowes Week app).

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 41: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£827,000	£827,000
Number of partners that received funding / contributed R&D	3	3

Source: Benefits Realisation

DCMS funded around half of the cost of the total project with partners funding the rest themselves. It attracted £285,000 of third party investment from additional sponsorship for the event as a whole. AQL also invested a further £500,000 to install replacement 5G equipment around the Solent Area. AQL have also been awarded further funding through a further DCMS programme – the Future Open Networks Research Challenge for a project called YO-RAN[11], to develop Open RAN components and a RIC for Neutral Host Networks in Yorkshire. The total project funding for this further project is just under £4.8 million.

7.5 Programme processes and DCMS support

Interviewees felt there was a lot of information to report and getting this out of each project partner could be challenging, and would have been more difficult across a larger consortium. Overall, they felt the BR monitoring was a bit 'over the top' and it was challenging to translate some of the language in the BR to members of the consortium who were less familiar with this type of process.

The process of reporting against specific milestones was something the interviewees were familiar with but they felt that the process was quite time consuming as relatively small changes required a change request. They observed that quarterly boundaries would have been an easier process as they had to submit a number of change requests and there were some overlaps and delays on individual requests.

Interviewees did feel the DCMS monitoring officers went 'above and beyond' in terms of support, but also felt that sometimes they were more on DCMS's side and were stressed in terms of delivering what policy makers wanted to hear.

7.6 Long term impacts

7.6.1 Additionality

Interviewees stated that the project would not have happened if the bid to the 5GTT programme had been unsuccessful. AQL are involved in other funded projects within the programme and their founder is generally interested in learning more about deploying 5G in challenging environments so this and other projects such as Live and Wild, Eden Universe, Factory of the Future and MANY have allowed them to develop their knowledge and skills in this area.

A lot of the use cases delivered, especially the creation of the live viewing experience, would not have been possible to develop using previous generations of networks.

[11] https://uk5g.org/discover/5G-projects/5G-Diversification-Projects/yo-ran/

7.6.2 Sustainability

The network is still in place. AQL is currently testing and configuring equipment to improve the network and have installed the additional masts (see Fig 1b). There are also further plans to develop and improve the different use case technologies in future Cowes Week regattas.

8. LIVERPOOL 5G CREATE

8.1 Overview of the project

The primary objective of the 'Liverpool 5G Create - Connecting Health and Social Care' project was to use a private Stand-Alone (SA) 5G network to improve the provision of public services in an urban setting. The project developed an array of use cases specifically focused on reducing the delivery and operational costs of providing health services, social care, and education in Liverpool. To test its use cases, the project successfully deployed the largest street level SA 5G network in Europe, which is still functional and in use at the time of writing this case study.

'Liverpool 5G Create' was the second project for which the Liverpool 5G consortium received funding. It evolved from, and progressed the objectives of its predecessor – The 'Liverpool 5G Testbed and Trial for Health and Social Care' project. This case study primarily focuses on the Liverpool 5G Create project. However, we give below, a brief overview of the aims, activities, and outcomes of the Liverpool 5G Testbed project for context.

Table 42: Overall project summary

Project	Liverpool 5G Create
5GTT Competition	Create Window 1
Sector	Health and Social Care
Location	Liverpool, North West of England
Timeline	Originally September 2020 to March 2022, but later extended by six months to September 2022
Lead consortium partner	University of Liverpool
Other consortium partners	Blu Wireless Technology Ltd, CGA Simulation, Docobo Ltd, Broadway Partners Ltd, Ehealth Cluster Ltd, Aimes Management Services Limited, Real Wireless, Telet Research, University of Liverpool, Liverpool John Moores University, Liverpool City Council, Mersey Care NHS Foundation Trust, NHS Liverpool Clinical Commissioning Group
Type of network/technology deployed	Private, standalone network
Total project costs	£6,399,633
Funding awarded by DCMS for 5GTT	£4,333,875

8.1.1 Progress on programme success measures

Liverpool 5G Create has resulted in strong evidence of added value of 5G technology against 10 of the 11 5GTT success measures.

Table 43: Summary of impact of Liverpool 5G Create

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The network deployed was Europe's largest SA 5G private network. The consortium conducted and participated significantly in knowledge exchange events, both within UK and internationally. This	2

Success measure	Evidence	Contribution Score
	could be viewed as having improved the reputation of the UK as a leading 5G nation.	
Programme activities have attracted further funding within the area of 5G/5G R&D	The project's final report informs us that it attracted third-party funding to the extent of £950,000 throughout its course. The project also resulted in £1.5 million additional investments in Research and Development by consortium members.	3
Reduction/removal of barriers has accelerated deployment of 5G in the UK	The project deployed Europe's largest private SA 5G network in Liverpool. The project was also the first in the UK to use 5G small cells in their network. This not only increased awareness about 5G, but has also set a precedent in the UK for further deployments of private networks for public service provision.	3
Information and knowledge is more readily transferred within the 5G ecosystem	The consortium has participated in over 50 knowledge sharing events, was mentioned in 85+ press features, has won 4 awards, resulted in 5 research outputs, and conducted two demonstrations of its use cases and network deployment. This has been both within and outside the UK5G ecosystem.	3
5G networks are more secure than the 4G networks they replace	The consortium adopted the 'secure by design' and 'secure by default' frameworks to secure their network. Apart from this, they monitored the data that was travelling through the network through Automated Infrastructure Management System (AIMS). The project developed a security framework considering the needs of the participants. They also signed SLAs which ensured that any disruption would be fixed within hours.	3
Additional welfare and environmental benefits	The project aimed to improve the welfare of the community by driving up the efficiency with which public health and social care services are provided. The consortium also developed a business case which argues for the extension of the network deployed throughout Liverpool. Although the costs of this would be high, consortium members have argued that it would potentially generate significant benefits in terms of welfare.	3
Public services cost avoidance	The project's main aim was to reduce the cost of public service provision by driving up efficiency using 5G connectivity. Several use cases have become services that are currently provided in Liverpool. During trials, the use cases have shown potential levels of cost savings to the extent of £182,000.	3
Development of industry 5G expertise and increased ability to use 5G for commercial activities	Apart from hiring 35 employees on the back of the project, the consortium has also trained 32 staff members working on use case development during the project.	3
Generation of 5G activities beyond the scope of the programme	Liverpool 5G Create aimed to be a sustainable testbed for the innovation, testing, and development of advanced communications technology. Several of the project's use cases have become services which are still provided in Liverpool. Many use cases have also been commercialised or are being developed after the programme's completion.	3

Success measure	Evidence	Contribution Score
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	Use cases focused on solving the existing problems by increasing efficiency and reducing the costs of public health, social care, and education services. This can be viewed as having assured supply certainty.	3
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The project deployed Europe's largest Private Stand Alone 5G network which, as of writing this case study, is still in place and fully functional.	3

8.1.2 Background: The Liverpool 5G Testbed and Trial for Health and Social Care project (phase 1)

The 'Liverpool 5G Testbed and Trial for Health and Social Care' project was funded as part of the first phase of the DCMS 5GTT programme. It aimed to improve the efficiency in the provision of Health and Social Care services in an urban setting using 5G connectivity. The project acted as an effective platform in supporting the development of relevant use cases starting from establishing proofs of concept to testing their potential for commercialisation.

Overall the project was highly successful. Its outputs included seven products / services that targeted specific health and social care needs such as addressing loneliness, improving patient experience, and improving assisted living, among others. We know from the project's 'Benefit, Outcomes, and Impact report' published in 2019[12], that 70% of its use cases recorded an increase in TRL while 55% reached their target TRLs during the course of the project. Following are a few of the project's most successful use cases:

- **Loneliness Quizzing and Gaming App:** Developed by CGA Simulation, a game development and virtual simulation expert, this product was designed as a game where players could participate in quizzes using video communication, irrespective of their location. The game was tested on 49 players from Kensington Community Centre, L'Arche supported living, and Breckside Park Residential home. Approximately 22% of participants reported reduced loneliness as a result of the app.

- **Push to Talk:** Developed by Defproc Engineering, a local SME, this product was designed as a button that users could press indicating their need to communicate with other users who also had pressed the button. The users were categorised depending on their circumstances and would be connected using the community 5G network deployed as part of the project. This allowed them to use landline or mobiles to communicate.

- **PAMAN:** This is a remote monitoring video call service provided to vulnerable patients at home. Provided by The Medication Support Company, it involves pharmacists assisting at-risk, vulnerable people through 4K video links at pre-arranged times. Services included enquiring about the timely consumption of medicines, to ordering repeat prescriptions.

Stakeholders have informed us that even after the project's completion in November 2019, work has been ongoing on several of its products and services. For instance, the Push to Talk use case has been further

[12] https://liverpool5g.org.uk/wp-content/uploads/2020/04/Liverpool-5G-Testbed-Benefits-Outcomes-Impact.pdf

developed by DefProc to work as an app rather than a physical button; the PAMAN use case is still being operated by the Liverpool City Council and other Local Authorities.

The project deployed a 5G network in the Kensington area of Liverpool. The network was deployed as a mesh with wireless mmWave (5G) nodes linked together at street level. The initial deployment in May 2019 consisted of 82 nodes which was extended in December of the same year to 220 nodes. By the end of the project, the network was spread across 120 outdoor sites and included six fibre connections and four building installations. Besides this, the consortium used Wi-Fi and Lora WAN technology in their network. This network, deployed in phase 1, was later upgraded in phase 2 and was made into a wider Stand-Alone 5G network using 5G small cells.

In terms of its key outcomes, the project's 2019 benefits report tells us that over the course of the project:

- Its use cases resulted in additional investments in Research and Development by the consortium members to the extent of £1.1 million.
- The consortium identified over 60 potential partners to collaborate with, for network deployment, to develop new use cases, or to further the development of existing use cases.
- The project has been mentioned in more than 160 press and media articles.
- The implementation of the project's use cases is estimated to potentially save costs of providing health and social care services to the extent of £247,688 per 100 users[13]

Besides this, stakeholders informed us that the relationships built during the Liverpool 5G Testbed project were instrumental in bringing the consortium together for the Liverpool 5G Create project in phase 2. Furthermore, they also stated that the Liverpool 5G Testbed would not have been possible in the absence of the 5GTT funding.

8.1.3 Liverpool 5G Create project aims and activities

After the tremendous success of the '5G Testbed' project, the Liverpool 5G consortium was funded for a second time in phase 2 of the DCMS 5GTT programme. This resulted in the 'Liverpool 5G Create' project. It had several stated objectives, including:

- laying a blueprint for providing public health, social care, and education services using a private 5G network, thereby driving up efficiencies and lowering costs;
- using 5G connectivity to provide meaningful solutions such as reducing digital poverty, assisting independent living, assisting schoolwork, and developing digital alternatives to face-to-face interventions in healthcare;
- providing a sustainable platform for the development and commercialisation of British built technology to support UK's recovery from COVID-19; and
- developing practical and affordable digital solutions to analogue telehealth technologies, to be made redundant in 2025.

To achieve the objectives of the project, the consortium members deployed Europe's largest private SA 5G network and developed an array of use cases focused on providing targeted solutions to specific heath, social care and education needs of the community. Overall, the project was successful in achieving its aims.

[13] This statistic is mentioned in the project's Benefits, Outcomes, and Impact report published in 2019. The report caveats it as being indicative of the potential extent to which benefits could be realised.

8.1.4 External factors affecting delivery

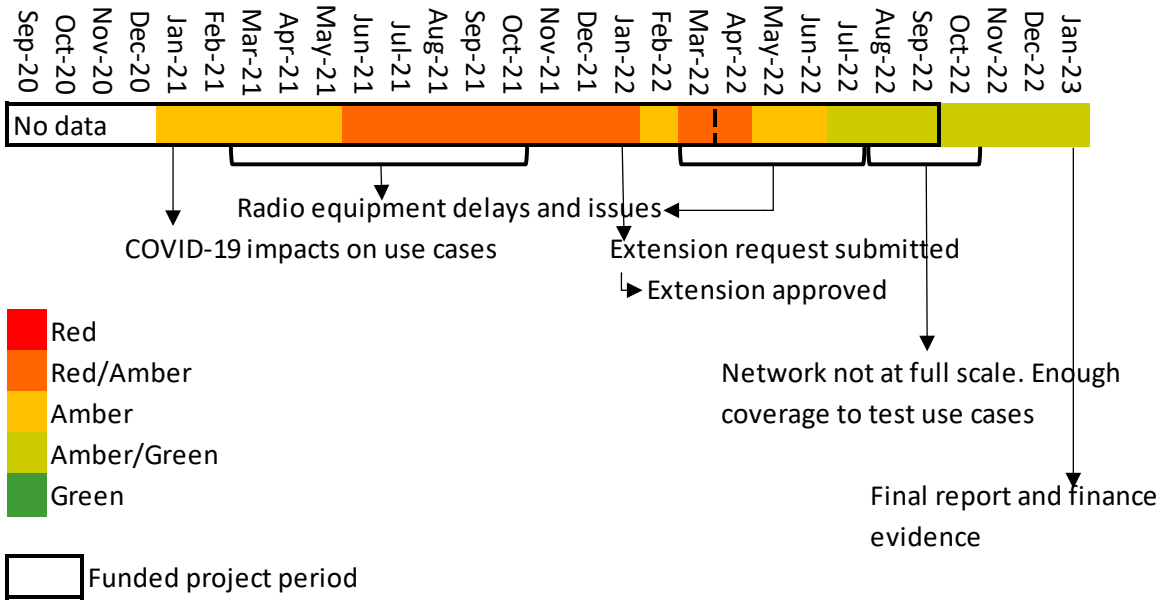
We asked stakeholders whether external factors like COVID-19, UK's EU Exit, and Trade restrictions with High Risk Vendors (HRV) had an impact on the project. Stakeholders mentioned issues such as a shortage of carers due to the EU Exit, and the need to explore alternative supply chains by consortium members responsible for providing the network infrastructure. Interviewees unanimously agreed that COVID-19 was the biggest disrupter of the project's operations. COVID-19 restrictions created huge bottlenecks and exacerbated the supply chain crisis on a global level. This caused significant delays, such as not being able to access 5G cells (a major equipment needed to deploy the network) until 12 months into the project. Besides not being able to meet face to face for the entirety of the project, stakeholders have also mentioned not being able to access care homes, and other major target demographics for the project's use cases, during the lockdown. This created further delays.

However, the stakeholders also mentioned that COVID-19 brought to light the need for better connectivity and increased the awareness and adoption readiness for remote and digital provision of services. This also motivated the consortium to explore its education use cases to aid students during the pandemic.

8.1.5 Timeline

The project lasted for two years from September 2020 to September 2022. It was originally scheduled to culminate in March 2022, but the consortium received a six-month extension owing to the significant delays and reworks, created by the external factors mentioned above. This lasted for the whole of 2021 and a majority of 2022 (till July). As a result, there was an adverse effect on network planning, installation, and commencement of the use cases. The project also had to request an additional underspend in February 2021.

Figure 10: Project timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

8.2 Consortium Partners

The Liverpool 5G Create project was one of the larger projects funded by the 5GTT programme with a consortium consisting of 13 members, led by the University of Liverpool. The consortium members include academic institutions, local SMEs, and public bodies. Members were either involved in network deployment (BLU Wireless, Telet Research, Broadway Partners), or the development of a specific use cases (Docobo, Liverpool City Council, Real Wireless). A few members of the consortium were involved significantly in

research and development (University of Liverpool and Liverpool John Moores University), while a few others mostly aided project management (Ehealth Cluster).

Table 44: Consortium members, Liverpool 5G Create

Organisation	Type	Role/responsibilities on project	Staff allocated to project
University of Liverpool	University/Charity	Lead Partner Build, test and install device as part of use case	2 departments
Liverpool John Moores University (LJMU)	University/Public Sector Organisation	Research and development	1 department
Blu Wireless Technology (Ltd)	Limited Company	Provider of mmWave equipment and consultancy	12
CGA Simulation	Limited Company	Network Design Planning Tool and Digital Anxiety Mediation Use-case	3
Docobo Ltd	Limited Company	Telehealth Use Case provider in conjunction with Mersey Care	2 Lead + Engineering Resources as required
Broadway Partners Ltd	Limited Company	Network planning, testing, rollout, and installation.	3
Ehealth Cluster Ltd.	Not for profit membership organisation, Company Ltd by Guarantee	Sub-contractor to UoL. Project Management, Use Case support, Benefits realisation	3 FTE
Aimes Management Services Limited	Digital/Cloud Services Provider	Subcontractor to UoL. Providing data hosting and fibre connections	5
Real Wireless	Technical Consultancy	Subcontractor to UoL. Consultancy Services supporting development of Green Book Business Case	4
Telet Research	Private Sector	Sub-contractor to UoL. Provision of core cellular network	5
Liverpool City Council	Public Sector Organisation	Contributing to business case development, support to network deployment via highways dept and connection to fibre backhaul, deployment of use cases within Adult Social Care and Education	3
Mersey Care NHS Foundation Trust	Public Sector Organisation	WP4 Use Cases	10 FTE TBC
NHS Liverpool Clinical Commissioning Group	Public Sector Organisation	Design and evaluation of Health Use Cases Changes to commissioned services to support 5G Use Cases	0.1

Source: Benefits Realisation

8.2.1 Working with consortium partners

Considering the unprecedented scale of external disruptions faced by the project, stakeholders have an overall positive opinion on how the consortium members worked with each other. One stakeholder mentioned that despite significant delays, the consortium worked hard together and was successful in installing the SA 5G network. They further mentioned that several members were ready and willing to accommodate additional expenses to the best of their abilities, especially early on during the lockdown. However, having said this, another stakeholder mentioned that a few members were difficult to work with and needed to be pushed to generate the outputs they had promised.

8.2.2 Personnel

The project's final report tells us that initially, 41 existing staff were allocated to the project across the consortium members. Apart from this, an additional 35 employees were hired on the back of the project. We know from the project's BR that at least 13 of the new hires were full time positions and 32 staff members working on use case development were trained during the project. Stakeholder consultations further reveal that employees hired on limited contracts for the projects, moved on to similar jobs in different sectors. Although, no concrete information about this is made available.

8.3 5G Deployment

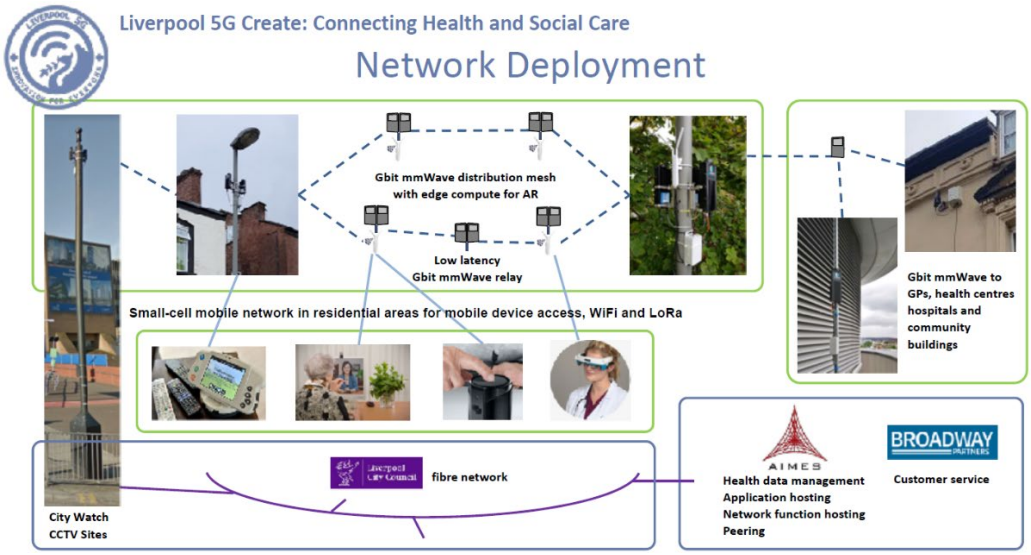
8.3.1 Approach to deployment

The 5G Create project deployed Europe's largest private SA 5G network at street level in Liverpool. It accomplished this by further developing the network established by the consortium in phase 1, as part of the Liverpool 5G Testbed project.

At the start of phase 2, the consortium had a pre-deployed 5G network covering the Kensington area of Liverpool. This network consisted of 220 5G mmWave nodes, spanned across 120 outdoor sites, included six fibre connections and four building installations. One stakeholder informed us that in phase 1, the network was designed to use Wi-Fi along with LoRAN.

In phase 2, the consortium wanted to explore if mobile connectivity could be introduced to the network. This was accomplished by using 5G small cells, which could be accessed using the SIM cards in mobile phones. Stakeholders mentioned that the Liverpool 5G Create project was the first in the UK to use 5G small cells to deploy a fully SA 5G network. One stakeholder mentioned that the consortium wanted to understand processes for deploying tech in an urban environment and for this purpose they installed 5G small cells as nodes on lamp posts, instead of installing fibre cables. The stakeholders mentioned that fibre was used as a backhaul to the core network and was deployed as an open RAN, which meant that the network could be accessed using non-proprietary equipment, which facilitated better ease of access to the network. Figure 11 depicts the architectural design of the Liverpool 5G.

Figure 11: Liverpool 5G Create, Network Design



Source: Liverpool 5G Create presentation from Be Better Connected conference, March (2021)

Towards the end of the project, the consortium had successfully extended the network deployed in phase 1 beyond the Kensington area to include Fairfield. The final network deployed included 56 small cells, 24 Fibre points of presence as backhaul, 101 intermediate mmWave sites on lamp posts, connections to 5 buildings using mmWave and 1 building using fibre. Apart from this, the consortium also set up a street level Wi-Fi network around the Phoenix School Catchment.

Table 45: Network indicators

Indicator	Measure	Baseline	Target	Achieved at end of project
Coverage	Coverage for interactive and bulk data services	0%	100%	~ 75% (50/67 small cells have been deployed)
Capacity	Capacity for bulk data transfer	Utilisation: 100%; Protection for interactive traffic: Disabled	Utilisation: >80% Protection for interactive traffic: Enabled	No specific details given. BR says: Significant progress was made in supporting advancement of RAN TRL.
Technology	5G Stand-Alone operation.	No cellular 5G standalone technology being used	Deliver Core, 5G-Router and Smartphone connectivity throughout the coverage area using only 5G Stand-Alone technology.	Achieved and demonstrated for data services with core, smartphones, and indoor routers.
Technology	Band n77 RF components	With very few deployments world-wide, upper n77 is not currently served with base-stations or antennas.	Sufficient availability of band-specific components to support commercial deployments.	Achieved with stock in place for all band-specific infrastructure components. The n77 omni antennas have been deployed at scale and perform as expected.

Indicator	Measure	Baseline	Target	Achieved at end of project
Technology	Automated mesh resilience.	Manual re-routing via alternate paths	Automatic re-routing via alternate suitable paths	The network has been deployed with manually managed loops. A review of the bridge technology confirms that it should be possible to add Spanning Tree automation later.
Dependability	Un-managed Loss of Service	Manual monitoring and management of failures	Delivery of automatic proactive alerts to service providers	LibreNMS deployment has been completed and is monitoring all of the deployed cells and network throughput by SNMP. A small-cell specific application has been developed within LibreNMS for capturing and plotting specific radio parameters
Dependability	Installation resilience	~ 12% of nodes/ installations vandalised or broken over 6 months	Influence design (within vendor ecosystem) of street furniture to ensure nodes and equipment protection. Install physically resilient site using equipment from at least one vendor	Procurement for installation kitting has continued to be a challenge due to long lead times and market shortages leading to overheads and delays.
Security	Service isolation and protection	Rudimentary processes in place, without specific tool.	Improved processes, governance, and CyberD3sign tool deployed.	Although take up of the BPMN-based tool has been limited, the value of the approach has been recognised at collaboration events.
Cost	Installation cost	Installation costs for existing deployment = ~ £150 per site for labour, tools, and overheads.	At least maintain installation cost (excluding equipment and materials) at £150. while increasing complexity of installation.	Installation costs maintained
Adoption	Increased ease and suitability of access	No direct cellular 5G access	Achieve 5G cellular direct access using use-case-preferred types of devices either during the trial or in short-term after, based on vendor roadmaps	Firewall changes have been implemented to support Android 'Firebase' (a centralised architecture supporting network-initiated inbound connections to battery-operated devices in an energy-efficient way).

Source: Benefits Realisation

8.3.2 Use cases

The Liverpool 5G Create project developed seven use cases. As mentioned earlier, many of the project's use cases could be implemented on previous 4G networks. However, the use of 5G network helped the consortium to stack the use cases. Besides, due to low overheads, deploying the use cases in a private SA

5G network helped the consortium demonstrate their cost saving benefits. The use cases focused on improving the efficiency in the public provision of Health and Social Care services, and drive up efficiencies by saving costs.

Health and Social Care use cases:

- **Pressure Ulcer Management System** – This involved the use of mobile technology in conjunction with cameras and AI imaging techniques to categorise pressure ulcers remotely and send high-quality images to practitioners for diagnosis.

- **Chill Panda** – This was designed as an interactive app to help children manage their anxiety. It used a built in AI driven recommendation engine to create personalised anxiety reduction content for users.

- **Urine Monitoring Unit** – This use case involved the use of optical techniques (use of light to probe or control matter) to detect infections in urine. It transmitted ultra-resolution images to GP surgeries for analysis. Tests revealed that the Urine Monitoring Unit's performance matched the standard tests used at the NHS

- **MySense** – Aimed primarily at aiding independent living, the consortium designed a new range of telecare equipment. These used AI to monitor nutrition, hydration, independence, and activity via Internet of Things (IoT) sensors. These IoT could be deployed around the home, and were capable of alerting supported networks to any changes in behaviour or deterioration.

- **Vitalerter** – This use case was developed to enhance the living conditions in care homes. Sensors were designed that could be deployed under the care homes' beds. The sensors monitored the vital signs of the resident using AI, and were designed to notify the staff when the resident is about to get out of bed, reducing the number of falls. During the course of the testing period, there was a 112% increase in the number of falls, but a 100% decrease in hospitalisations due to falls. Vitalerter showed that patients needed to be turned fewer times to get undisturbed sleep.

- **Telehealth Monitoring via Docobo Devices** – Used for remote GP consultations for patients from their homes, this use case was designed as a Care Portal. It included a built-in ECG monitor which informed the nurses and HCAs in the telehealth hub of the patient's condition. This was further developed by Docobo and was integrated into its remote monitoring solution that was used by Mersey Care, the NHS test clinic where this was tried.

- **Sensory vest** – This use case was designed as a 'haptic shirt' which allowed care home residents to receive remote hugs from family, reducing isolation and loneliness in care homes. Tests showed a 64% reduction in the number of care home residents who said they felt lonely often or sometimes.

- **5G WAN Pilot for NHS Sites** – As part of this use case, the Liverpool 5G consortium provided 5G connectivity to NHS sites for public access and clinical use. The aim was to reduce the cost of laying Full-Fibre WAN network, while providing reliable, high speed, low latency network to NHS. This was done to allow the NHS to better provide digital services.

The health and social use cases developed by the Liverpool 5G Create project aimed to generate several benefits, including:

- costs savings to patients and health services by reducing appointment time and hospital visits (Urine Monitoring Unit, Pressure ulcer management system, Vitalerter);

- improving detection and diagnosis (Pressure ulcer management system);

- improving patient satisfaction and improving patents' levels of wellbeing (Telehealth Monitoring, MySense AI); and

- improving mental wellbeing, access to appropriate coping mechanisms, and reducing feeling of isolation (ChillPanda app, Hug Vest)

Education use case:
As mentioned earlier, external factors such as COVID-19, brought with them several restrictions, which did not allow many children to attend school due to a lack of connectivity. One stakeholder opined that digital poverty came to the forefront. Although the use case predated the COVID-19 19 pandemic, it was given much more importance by the consortium because it had the potential to alleviate digital poverty and stress for local residents in one of the poorest wards in the country and aid children's education.

This use case provided connectivity and Chromebooks for pupils at home in Kensington. The consortium also deployed a Wi-Fi network around the Phoenix Primary School in Kensington. As part of the Liverpool Council Education offer, 49% of pupils at Phoenix Primary School identified as not being connected were connected, enabling pupils to access education from home, and engage more fully with education.

The education use cases developed by the Liverpool 5G Create project aimed to generate several benefits including increased connectivity for pupils currently unable to access online learning when required to work from home; and reduced data costs for families.

8.3.3 Security impacts

As mentioned earlier, the Liverpool 5G Create project was the second project for which the Liverpool 5G consortium had received funding. It therefore had a pre-existing infrastructure, with mature and verified security aspects in place. The project's final report informs us that the consortium was focused on limiting the inherent risk of operating as a connectivity provider. These included securing the data transmitted through the 5G network, securing the devices connected to the 5G network, and securing the network's integrity.

The network deployed by the project acted as a large intranet, which allowed the consortium to monitor the data that was shared as it was sent to the Automated Infrastructure Management System (AIMS). One stakeholder also mentioned redundancies had been put in place considering that the network would be used to provide health and social care services. They mentioned that SLAs were set up in such a way that if a problem occurred, the consortium members would fix that in a few hours.

As per the final report, the project also focused on incorporating 'security by design' and 'security by default' approaches wherever possible. This consisted of:

- Developing an 'appropriate' security governance framework that protected and secured the network without stifling innovation or development;
- Understanding the requirements for working with diverse partners in a secure and controlled manner to run a stable, secure, and resilient network;
- Developing new draft policies and procedures to ensure that security is considered; and
- Focusing on security and design during the project but also prioritising security in relation to configuration, management, and monitoring.

8.3.4 Technology Readiness Levels

Table 46: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
Urine monitor	4	6	6	Yes
Pressure Ulcer Platform	6	6	6	Yes
DN201SC mmWave nodes	7	8	N/A	N/A
Mobility NMS	5	9	N/A	N/A

Blu NMS	2	7	N/A	N/A
Planning Assistant	6	8	8	Yes
Chill Panda	7	9	8	No
Docobo 5G CAREPORTAL.	5	5	9	Yes
5G SA Radio	4	7	7	Yes
5G Network Core	6	8	7	No

Source: Benefits Realisation

As can be seen from Table 46, out of the seven products and services developed by the project, five have reached the target TRL during the course of the project, while the remaining two have also undergone significant development compared to the baseline ratings. In this respect, the Liverpool 5G Create project was highly successful.

8.4 Collaboration, knowledge sharing and overcoming barriers

8.4.1 Sharing Learning and best practice

The Liverpool 5G Create project has reported several lessons learnt in both its final report and regularly to DCMS through its BRs. These include how the consortium resolved issues around collaboration and developed workarounds for the development of certain use cases.

Lack of allocation of spectrum was viewed by a majority of stakeholders as a major barrier to 5G network deployment and cost reduction in the UK. One stakeholder mentioned that the new Ofcom shared spectrum license has been a huge step in the right direction, but thought further efforts were needed to incentivise the deployment of large scale private 5G networks in the UK. For instance, the consortium used low power 5G cells for their network deployment. While the costs of deployment and the power consumption of medium power cells and low power cells are not significantly different, medium power cells give the network far greater capacity while maintaining its range of coverage. This, the stakeholders mentioned, has the potential to significantly lower the network's running costs.

Stakeholders unanimously believe that the deployment of the SA 5G network as part of the project has broken barriers by demonstrating that it is possible. This, they mentioned, has in turn helped create awareness and opened the doors for businesses and local authorities looking to deploy private networks for public service provision. Apart from this, as mentioned above, the project's use cases have resulted in services which are currently being provided and have resulted in actual cost savings in providing public services. The use cases have also helped pupils attend schools during the lockdown at no extra cost to connect to the network.

The stakeholders had a highly positive opinion of DCMS and UK5G as effective enablers of wider collaboration and knowledge dissemination activities. One stakeholder said that DCMS went above and beyond in proactively supporting and facilitating the project's collaboration effort, especially with other 5GTT projects.

Table 47: Publication and events summary

Dissemination Activities	Number of articles/events
Research Outputs	5
Press and Media Features	85
Events organised by consortium	2
Events attended / participated	50
Award Nominations	8

Award Wins	4

Source: Benefits Realisation & Project Final Report

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

8.4.2 Interaction with wider ecosystem

The project undertook several knowledge sharing and dissemination activities as can be seen from Table 47. These include research outputs such as clinical trials conducted as part of a use case development, journal articles published by the academic partners, and prototypes created. The consortium also organised two events to showcase its findings and demonstrate its use cases. These events had a cumulative attendance of almost 200 people. Consortium members also attended and participated in over 50 national (E.g., Connected Britain) and international (E.g., Small Cell World Summit) events.

Consortium members were actively involved in the wider UK5G ecosystem and led several working groups such as Connected Places, LEPs and SMEs. The consortium also actively collaborated with other 5GTT projects including West Midlands 5G, Rural Dorset, Eden Universe, MANY, and Scotland 5G. Furthermore, the consortium also shared the Adoption Readiness Level (ARL) indicator[14] that it developed during the course of the project to help commissioners and SMEs who were developing products, which was used by some other projects to assess elements of their use case technologies.

8.4.3 Business and industry generation

Stakeholders firmly believe that the activities of the Liverpool 5G Create project has brought the UK closer to the development of a new industry. One interviewee mentioned that Liverpool could be the world's first smart city if the network is extended throughout. Another mentioned that by deploying Europe's largest private SA 5G network, the consortium has demonstrated what can be done by SMEs and local authorities, without the need for large network operators. Stakeholders also noted that this has not only promoted British innovation, but has also boosted the use of British made network components in the UK.

The project's final reports suggest its use cases have cumulatively demonstrated an annual reduction of approximately £182,000 in the cost of providing health and social care services. Over the course of the project, a total of £950,000 was sourced as third party investment from organisations outside the consortium. Besides, the project has also garnered significant interest from potential partners. The consortium has also approached international organisations such as Wipro in India for further funding, and to redesign a few of the network elements.

The consortium has developed a business case to extend the deployment of the network and is actively looking for further investment. However, it was noted that there is no incentive to invest further in improving the network, as the cost savings would take time to manifest, while a lack of spectrum allocation wouldn't let the consortium develop the existing networks. Lastly, we also know that the consortium is looking forward to working with DCMS on its FRANC project by trailing a few technologies like small cells, millimetre mesh Network cells and Lora WAN gateways.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 48: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£3,546,000	£1,559,000

[14] ehealthcluster.co.uk

Number of partners that received funding / contributed R&D	9	10

Source: Benefits Realisation

8.5 Programme processes

Stakeholders had a highly positive experience in terms of the processes involved in the project, starting from application, to monitoring, to submitting change requests and benefits reporting. There was unanimous agreement amongst stakeholders who were part of both the Liverpool 5G projects, that the processes, especially the application and the BRs were made much simpler in the second phase. While a few stakeholders did mention that submitting change requests and Benefits Realisation reporting were tedious, they agreed that these processes were necessary and that by nature they tend to be bureaucratic. Stakeholders unanimously agreed that DCMS were supportive throughout the project and were as flexible and accommodating as they could be going above and beyond to accommodate the consortium's needs.

8.6 Overall summary of contribution to success measures

8.6.1 Key outcomes and successes

The Liverpool 5G Create project has been highly successful in developing and testing its use cases and also in terms of network deployment. It has provided strong evidence for ten of the 11 success measures that we developed to determine the overall success of 5GTT projects. The activities of the projects have led to:

- The establishment of Europe's largest private SA 5G network in Liverpool at the time of writing this case study. The network deployed by the consortium is still in place is being widely used to provide public health and social care services.
- Yearly cost savings in the provision of public services to the extent of £182,000. The project also attracted close to £950,000 in third party funding and additional investment of £1.1 million from amongst consortium members during its course.
- Increase in 5G related knowledge transfer both within the UK5G ecosystem and beyond. This is evident from the 85+ press features, 4 awards, and 5 research outputs, among others that resulted from the project.
- The project also resulted in the development of 5G related skills and expertise. This is evident as 35 employees were hired by the consortium members on the back of the project and an additional 35 were trained during the project.

8.6.2 Additionality

The Liverpool 5G Create project had a significant base for further development, built by the Liverpool 5G Testbed project in phase 1. This was both in terms of the network deployment and the philosophy behind the selection of the use cases. In a manner of speaking, it could therefore be said that the 5G Create project depended on the 5G Testbed project. Having said this, stakeholders also unanimously agree that the 5G Create project would not have happened if not for the 5GTT funding.

One interviewee opined that although the infrastructure that needed to be developed was in place, deploying an SA 5G network of the scale achieved by the project would not have been possible without the significant government funding, which the 5GTT programme offered. Furthermore, stakeholders have also mentioned that the 5G Testbed project itself would not have happened if not for the phase 1 funding received by the consortium.

Regarding the additionality of 5G connectivity, most stakeholders felt that several of the project's use cases could have been deployed on 4G to a limited extent, but they agreed that 5G drove up efficiency in terms of

being able to stack (simultaneously deploy) use cases. Besides, one stakeholder opined that it would not have been possible for the consortium to have achieved its costs saving and efficiency-driving objectives using previous generation networks. They mentioned that this would mean relying on commercial network providers which would have driven up the costs. They added that using the project's own SA 5G network could potentially save costs as it had very minor overheads, and any profits generated could be reinvested in the network.

8.6.3 Sustainability

We learnt from stakeholder consultations that the SA 5G network, deployed by the consortium is still in place and that the consortium members are determined to maintain it in a fully functioning state. This was to create a sustainable environment for the development and testing of relevant use cases. As mentioned above the consortium has developed a business case for wider deployment of the SA 5G network to cover the entire Liverpool City region. One interviewee said that although the costs associated with it might seem high, wider deployment has the potential to generate tremendous benefits in terms of social welfare.

In terms of additional investments, the project's final report also informs us that it has attracted an investment of £950,000 from sources outside the consortium. We also know that the consortium is also in conversation with international companies like Wipro in India to attract further funding and redesign some network elements. It was mentioned that this would help the consortium commercialise the network. Apart from this, the consortium also received active support throughout the project, from the NHS Liverpool Clinical Commissioning Group and the Mersey Care NHS Foundation Trust, despite them not having received any DCMS funding.

9. MK:5G

9.1 Overview of the project

MK:5G aimed to demonstrate how 5G technology could be adopted for various modes of urban transportation. This project covered the deployment of autonomous delivery vehicles, drones, robots, and the use of advanced sensor networks for monitoring traffic movement. Additionally, this project aimed to explore the use of 5G technology in the hospitality industry, specifically to enhance the visitor experience around Stadium:MK.

Table 49: Overall project summary

Project	MK:5G - Milton Keynes 5G
5GTT Competition	Create Window 2
Sector	Leisure/events/tourism/transport
Location	Milton Keynes, South East of England
Timeline	Jan 2021 to April 2022
Lead consortium partner	Milton Keynes Council
Other consortium partners	BT, Smart City Consultancy, Metaswitch Networks, City Fibre Limited, Appyway, Stadium MK, Connected Places Catapult, Satellite Applications Catapult, Neutral Wireless, Imperium Drive, ECS, RDM
Type of network/technology deployed	Private, standalone network
Total project costs	£3,784,900
Funding awarded by DCMS for 5GTT	£2,440,214

9.1.1 Progress on programme success measures

MK:5G resulted in strong evidence of added value of 5G technology against 6 of the 11 5GTT success measures.

Table 50 Summary of impact of MK5G

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	Interviewees stated that the programme primarily focused on a local level. There has been some international coverage reporting Milton Keynes being the first UK standalone network. As there are a few different funding programmes which supported the development of this network, but not all of this impact can be attributed to the 5GTT programme.	1
Programme activities have attracted further funding within the area of 5G/5G R&D	It was mentioned clearly that a new consortium was formed with half of the funding secured within the partners involved to take the use cases for commercialisation. Milton Keynes City Council has attracted £9 million from the LEP.	3
Reduction/removal of barriers has accelerated	One interviewee report removing barriers to deployment boosted confidence amongst investors in commercialisation.	2

Success measure	Evidence	Contribution Score
deployment of 5G in the UK		
Information and knowledge is more readily transferred within the 5G ecosystem	Cross consortium with the 5G VISTA were evident of knowledge transfer. They also benefited from learning about other projects through the UK5G innovation network.	2
5G networks are more secure than the 4G networks they replace	Interviewees indicated the network was in place from the previous project. Testing that the network was reliable and reactive enough to control vehicles remotely was a key output but there is no evidence of a specific focus on cyber security of the 5G network.	2
Additional welfare and environmental benefits	The CAVs tested were electric vehicles so have a direct impact on lowering emissions from travel.	3
Public services cost avoidance	This was not specifically articulated but addressing last mile transport solutions, mean fewer cars travelling into cities, which reduces congestion and traffic.	1
Development of industry 5G expertise and increased ability to use 5G for commercial activities	Interviewees expressed a larger consortium had been formed to bid for a Department for Transport funding, with a clear aim to commercialise the use cases further. One of the use cases was managed by university master's students, allowing them to develop skills and expertise in robotics enabled by 5G	3
Generation of 5G activities beyond the scope of the programme	There are a range of other activities such as the establishment of the Smart City MK CIC and MK5G Accelerator programme to allow SMEs access to the testbed and wider city 5G networks.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	Interviewees explicitly mentioned strong interest from partners for further collaboration to commercialise the use cases with a workable business model.	3
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The network is still in place and being used for other purposes.	3

9.1.2 Project aims and activities

The MK:5G used funding from DCMS to extend an existing 5G network in Milton Keynes to test "last mile" transport solutions between Stadium:MK and the train station. It also explored the use of robotics technologies

and unmanned aerial vehicles (drones) to support stadium operations and provide an enhanced hospitality experience.

The use cases deployed aimed to:

- move large numbers of people in a safely using electric autonomous vehicles to the Stadium:MK and between certain elements of the main rail transport links (around Bletchley) in the area,
- employ robotics inside the stadium to deliver goods and services around the Stadium:MK,
- improve the parking turnover and making use of the space more efficiently,
- test the use of equipment of teleoperation and remote control of autonomous vehicles.

The project was successful in exploring the use of autonomous vehicles around the Stadium, but some of the use cases to improve visitor experience within the stadium were not possible.

9.1.3 External factors affecting delivery

Challenges with the supply and quality of equipment caused some delays to the project.

Interviewees stated that the UK government's decision to exclude High Risk Vendors such as Huawei caused significant challenges for the project. Huawei are world leaders on the type of equipment they provide and they reported that the equipment from alternative suppliers was of a lower quality – a lot of the equipment provided was larger and heavier which made installation more difficult. There were also significant delays and long lead times for this equipment.

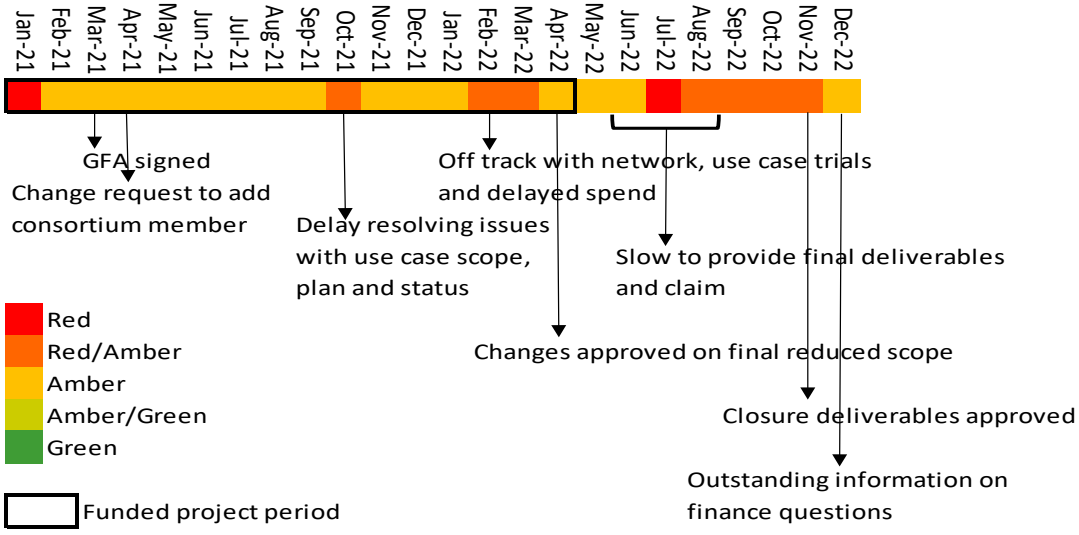
Interviewees also reported some delays from contractors due to the pandemic. The impact on installation was minimal as work was mostly conducted in a controlled outdoor environment. The COVID-19 pandemic also meant the consortium had less time to fully test the network and use cases. Only partial connections were available for some of the 5G-enabled vehicles used in the trials.

9.1.4 Timeline

COVID-19, delays in the delivery of equipment and a change in the consortium early on had an effect on the delivery of the project. A key partner withdrew their involvement early in the project, resulting in a significant setback and requiring 2-3 months for the consortium to re-scope the bid, find a new partner, and gain approval from DCMS. This meant that the project was not able to conduct all the trials and validation necessary to provide robust data to support the testing of the use cases.

The figure below summarises the project timeline and DCMS delivery RAG rating:

Figure 12: Project timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

Because of the delays in sourcing equipment the project sought an extension, but this was not granted and there were some changes in scope to the project due to a change in consortium membership early on.

9.2 Consortium Partners

The table below provides more information about the consortium partners involved in this project.

Table 51: Consortium members, MK:5G

Organisation	Type	Staff allocated to project
Milton Keynes City Council (lead)	Local Authority	3
BT	Telecommunication	4
Smart City Consultancy	Consultancy	1
Metaswitch Networks Ltd	Telecommunications	3
City Fibre Limited	Telecommunications	6
Appyway (Yellow line Parking)	Transport/mobility solutions	1
Stadium MK	Hospitality/ Sports	8
Connected Places Catapult	Research	3
Satellite Applications Catapult	Research	4
Neutral Wireless	Telecommunications/ infrastructure	3
Imperium Drive	Mobility solutions	4
ECS	IT software development	3
RDM	Mobility solutions	6

9.2.1 Working with consortium partners

Overall, interviewees felt the consortium worked well together, especially highlighting the team were willing to share information. There had been a clear division of labour regarding work assignment for example, the

Satellite Applications Catapult oversaw and co-ordinated the work other companies responsible for providing equipment; RDM and Imperium Drive supplied and operated the vehicles used in the project; the City Council worked with the stadium and ECS to develop public transport service using data from the technology deployment. There were some challenges in engaging with smaller, newer companies – some interviewees felt they did not have sufficient scale to currently meet targets for delivering equipment and their location meant there were fewer chances to meet frequently and develop a good relationship with them.

As shown in the timeline above, a key partner who was going to be involved in using the vehicles to support logistics around the stadium withdrew before the collaboration agreement was signed.

Milton Keynes Council also reported that they had further plans to work as a consortium for future projects, with the core members remaining and new partners being brought in as deemed necessary. Some examples include the Satellite Applications Catapult and Milton Keynes Council plan to continue collaborating on aspects such as regulatory change on the roads to accommodate the use of 5G-enabled transportation; and Imperium Drive, who provide some of the vehicles for the use cases have been invited to participate in a follow on project to continue their trials on vehicle safety management.

9.2.2 Personnel

The project was primarily executed by a core team of six to eight individuals, who were highly active in delivering the project. As shown in Table 51, just under 50 FTE workers were allocated to the project from across the consortium. The robotics use case was conducted by a group of six Masters students from Cranfield University.

One interviewee highlighted a risk due to the UK's exit from the UK. Before this they were finding talented engineers with experience in 5G from Spain, Germany and Italy and EU Exit has made it more complicated to recruit people from these countries, but the majority involved in delivering this project were either UK citizens or recruited for other projects under the high skills requirement programme.

9.3 5G Deployment

9.3.1 Approach to deployment

A key aspect of the 5G:MK deployment associated with the quality of the testbed, which characterised exclusively with the 5G network, and could not be achieved on 4G or other networks. The high reliability and low latency communication was especially necessary for connecting autonomous vehicles and robotic systems.

The network coverage focused on the area inside and surrounding the stadium. This coverage was extended from a previous project to also include the main rail hub, Bletchley, providing 5G coverage for autonomous vehicles. As the aim was to use CAVs, they required reliable coverage with low latency. The table below shows the network indicators measured for the project and what was achieved by the end of the project.

Table 52: Network indicators

Indicator	Measure	Baseline	Target	Achieved at end of project
Latency	Milliseconds	Downlink: < 60Mbits/s, Uplink: <23Mbits/s, latency: min - 35ms, max 120ms, average 60ms	Downlink: 150Mbits/sec Uplink: 50Mbits/sec, Latency: <10ms	Internet speed tests DL: up to 140Mbit/s, UL: up to 50 Mbit/s, latency between 30-40ms to external internet sites.

Indicator	Measure	Baseline	Target	Achieved at end of project
Coverage	Percentage of area covered by 5G network	100%	100% of site	100% around MK Dons stadium
Reliability	Uptime of connected devices	100%	100% of operating areas for critical services	>90%

Source: Benefits Realisation

The project did not meet the target for reducing latency and reliability but did meet the coverage target. The final report indicated that the previously identified issues regarding connectivity, coverage, security, speed, and reliability had been resolved. Although the target was not met, it is believed that this did not pose significant challenges for the successful deployment of the use cases.

9.3.2 Use cases

The project reported on four use cases:

Kerbside Management in identifying empty parking spaces using AI
The KPI that was evaluated was the percentage accuracy of the end-to-end solution that used cameras, networks, and artificial intelligence to identify empty parking spaces. The project had conducted two trial periods, one in the morning and one in the afternoon, using different cameras and camera angles. The first trial saw that all cameras had accurately counted cars, with only one instance of a car not being counted. In the second trial, over half of the cameras had counted cars with 100% accuracy, but accuracy on the remaining cameras ranged from 87% to 97%.

The follow-up analysis showed that car detection tended to be more accurate during the day; levels of accuracy were lowered when passing cars or camera angles temporarily obstructed the view. For busy car parks, this could be addressed through further model training. Additionally, the definition of the monitoring area and monitoring rules were critical and should have been fine-tuned to improve accuracy and account for edge cases. Detection accuracy also deteriorated when assessments had been made over longer distances, therefore additional cameras were recommended for larger spaces.

Tele-operated vehicles
Remote operated vehicles were deployed and the 5G network was used to ensure that these could be operated safely. The project measured the safety operator interventions on a per-mile and per-minute basis to assess the safety of the tele-operations system for tele-operated vehicles. The trial ran for 8 weeks, used 2 vehicles, and covered 92.7 miles over 88 journeys. Results showed interventions per mile were between 0.525 and 0.717, and interventions per minute were between 0.121 and 0.146.

Auto-pods/shuttles
Over a period of nine weeks, four-seat pods were tested along a variety of routes within and around the stadium complex. The project aimed to test that these could run safely. In total, 618 journeys were completed during the trial period, covering a distance of 369.5 kilometres and operating for a total of 67.7 hours. As part of the project, a safety operator was present at all times during the trials. The reliability of the vehicle was 99.92% when it came to fault-free operations. A dead man's handle operation rate per total number of hours of operation was observed to be 0.04, the rate per total number of kilometres covered was 0.006 and the ratio between the number of journeys with dead man's handle and total number of journeys was 0.003.

Robotics Use Case
Robotics was used to demonstrate the use case in a hotel and restaurant environment to enhance and enrich the hotel guests' and visitors' experience. They tested whether the robots would be able to deliver items to rooms on one floor of a hotel and the use of a service robot in the bar area. Issues identified during the trials

included correctly identifying and navigating through narrow spaces, and in the restaurant there were difficulties with cameras correctly identifying glass doors and obstacles close to the floor.

9.3.3 Technological readiness levels

All elements of the technology tested exceeded TRL targets by the end of the project. Some aspects were able to achieve a large change in TRL. For example, the Kerbside parking management moved from 2 to 7 by the end of the project. The average change in TRL across the 5GTT programme as a whole was 1.7.

Table 53: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
Real-time site access AI management with Kerbside	2	No data	7	Yes
Imperium Drive's RDS for car-sharing at MK Dons stadium	4	5	7	Yes
Imperium Drive's RDS for car-sharing at MK train stations	4	5	7	Yes
Personal transport for hotel guests using Auto-Pod	4	6	7	Yes
Hotel guest transport at MK Dons arena using Auto-Pod	4	6	7	Yes
Using Auto-Pod for shopper transport between Asda and M&S	4	6	7	Yes
Robotic greeting and advisory service for hotel guest arrivals	5	6	7	Yes
Robotic service for hotel guests and event attendees (hospitality service)	5	6	7	Yes
Robotic room service and servicing for hotel guests	5	6	7	Yes
Robotic Luggage service hotel guests	5	6	7	Yes

Source: Benefits Realisation

9.4 Collaboration knowledge sharing and overcoming barriers

9.4.1 Sharing Learning and best practice

The consortium held bi-weekly meetings. The group had a positive inclination to sharing information and engaging with external stakeholders (such as NHS England, Ocado, Network Rail) to gather input and ideas.

There were networking attempts to reach out to other projects. This included a number of demonstration exhibition conferences, which aimed to help interested parties understand the potential use cases and to share knowledge.

Despite being found to be more effective in sharing of information and knowledge some interviewees felt too much emphasis was placed on knowledge sharing activities. It was noted that the timing of the knowledge sharing activities could be problematic, as most issues and problems tended to arise at the beginning of the project. By the time the sharing activities took place, these problems were no longer relevant.

There was no information available about dissemination activities provided in the BR sheets. However, the project has been covered in local and national press, with many partners putting out at least one item. The consortium developed a communication and media strategy to engage as wide an audience as possible. This included running events locally and nationally, culminating in a project exposition around Stadium:MK to promote and showcase the project. This attracted attendees from government, education and industry.

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

9.4.2 Interaction with wider ecosystem

It was reported that UK5G network acted as a valuable conduit for disseminating information among different projects. For example, they approached other projects who had used CAVs through the UK5G network and were able to learn about successes and challenges elsewhere. Additionally, the two-way dialogue enabled queries about other consortiums and sharing of best practices on cell site and infrastructure deployment. Milton Keynes Council also mentioned the extra sharing opportunity he had with the wider 5G ecosystem, specifically mentioning the West Midland consortium which might share similarities in implementing the use cases.

The collaboration with 5G VISTA was part of the highlight showcasing the attempt at cross-consortia partnership. Capitalising on the existing connectivity infrastructure at Stadium:MK, 5G VISTA conducted tests on various use cases aimed at improving the audience experience through the implementation of Augmented Reality and instant live streaming for a mass audience.

The consortium have also been contacted by a large MNO who are committed to delivering advanced management systems for CAV safety and have expressed their wish to further consolidate the existing infrastructure in Milton Keynes for further testing purposes.

9.4.3 Business and industry generation

The council reports having attracted around £9 million of third party investment, from South East Midlands Local Enterprise Partnership (SEMLEP). Interviewees also reported that progress in removing some of the barriers to 5G deployment has helped to attract investment by improving investor confidence.

There were reports of ongoing initiatives to continue the project, including:

- The project has created a not-for-profit community interest company (Smart City MK CIC) to maintain the 5G and other testbed infrastructure on behalf of the local authority for future projects and the wider community.
- The council has funded a Milton Keynes Accelerator to allow SMEs to access the testbed and wider city infrastructure. This is being delivered in conjunction with the Connected Places Catapult and other industry partners.
- other smaller scale initiatives were explored. These included the commercialisation of drones for inspection purposes. Works were carried out with the Civil Aviation Authority and Cranfield University to deploy the technology within the current regulatory framework;
- Satellite Application Catapult bid for a £20 million Department for Transport project on full commercial deployment of autonomous vehicles in Milton Keynes with two other companies.

It was suggested that extending the project would have enabled more comprehensive testing and validation of the use cases, which would have boosted confidence in technological adoption. This could have strengthened the business case even further.

The table below summarises the funding received from DCMS. It also shows how many organisations contributed to R&D. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 54: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£1,778,000	£621,000

Number of partners that received funding / contributed R&D	11	8

Source: Benefits Realisation

9.5 Programme processes and DCMS support

Interviewees said they have developed a relationship with DCMS over a number of years and projects, and understood their rationale for being interested in this. Overall they felt they had a good relationship with the programme team, who were supportive and provided good advice. They did acknowledge some friction, and that there were some changes in personnel at DCMS which meant some technical decisions had to be re-confirmed with a different person.

In particular, they found the benefit realisation process confusing and felt it was a tick-box exercise with little value. They also felt this was not well articulated at the start of the project, but included later on which made picking useful metrics to measure hard.

One interviewee also felt the department could have been more flexible, for example in granting the project an extension.

9.6 Longer term impacts

The 5GMK project has resulted in strong evidence of added value of 5G technology against six of the 11 5GTT success measures:

- It has demonstrated that through collaboration and knowledge transfer the project was able to develop the use cases tested;
- It has successfully attracted further funding within the area of 5G/5G R&D with new partnership and consortium formed with further funding available;
- It has demonstrated that 5G technology can add additional environmental benefits with the adaptation of autonomous vehicles in an urban setting;
- The project resulted in the development of autonomous vehicle and AI parking, which has clear commercial potential in the future beyond hospitality sector;
- The project generated further supply with renown partners such as Microsoft, Dell, and Vodafone, who were interested in testing the new business model based on the 5GMK use case;
- The network on which further commercialisation of the use case is based is still in place, and there are plans to expand on these use cases for future use.

9.6.1 Additionality

The use cases demonstrated have made an impact on boosting confidence and tendency in adopting 5G-enabled transportation technology and in speeding up the progress of city-wide rollout of the driverless transportation services.

- Interviewees mentioned that the trial programme would not have had the same scale or the same number of uses cases tested had the funding not been available.
- If successfully deployed, the use case would further be applied to provide the city with sustainable transportation options, with that, it reduces car usage and promotes environmentally friendly alternatives.
- Milton Keynes Council reported that the project's use cases successfully demonstrated the feasibility of adopting 5G-enabled technology in an urban setting. An example was the trial of autonomous cars that

received positive feedback in a third-party technical report commissioned by the project to evaluate the feasibility of the technology. This indicates that the technology has reached a mature level to deploy driverless vehicles safely to the public.

- Satellite Application Catapult also agreed with Milton Keynes Council's point of view over the potential, non-quantifiable impact made by the project use cases. Specifically, they noted that the 5G-enabled Connected and autonomous vehicles (CAVs) improved public confidence in the safety of these vehicles, which was previously not possible when similar attempts were made on 4G network.

9.6.2 Sustainability

The Milton Keynes Council reported that the networks remain in place across the city, with the majority being in place even before the start of the project. Only minor adjustment was needed to sustain the operation of the network:

- The existing network infrastructure across the city centre was already in place before the DCMS project, with only a small proportion of it being enhanced by the project.

- The current project used a suite of 7 macro stations around the city centre. Continuation of its operation involved updating some of the radios on those stations. This was to integrate the extra capability and function that was tested through this project with DCMS.

Challenges exist regarding the continual use of Huawei equipment purchased in the previous project. Even though it was not illegal at the time to use Huawei equipment, the local authority would have to replace the equipment as soon as possible, adding to more follow-up work to sustain the use of the network and ensure its safety.

10. 5G RAIL NEXT

10.1 Overview of the project

5G Rail Next (5GRN) deployed a Stand-Alone (SA) 5G network between two stations in the Glasgow underground rail system. Its primary objective, besides bringing 5G connectivity to an underground transport setting, was to explore whether Augmented Reality (AR) could be used with 5G connectivity to advertise content and enhance consumer experience for the passengers. To test this, the consortium developed two use cases in collaboration with a similar 5G testbed project in South Korea. The use cases featured AR based interactions with virtual objects, and the option to view advertisements streamed directly onto passengers' devices, among other things.

The project was highly successful in demonstrating proof of concept through non-public trials of its use cases conducted on live trains. The results of the trials were showcased for an audience of retail brand representatives. These representatives indicated through a survey, that adoption levels are expected to increase considerably in the next two years. The 5GRN project could therefore be credited for helping to identify AR advertising as a market segment with significant potential for 5G deployment. Apart from this, 5GRN also inspired a spinoff project, 5G Sub Connect, which focused on exploring the use of 5G connectivity for maintenance activities in the Glasgow Subway. Funded by DCMS, 5G SubConnect upgraded the private SA 5G network deployed by the 5GRN project.

Table 55: Overall project summary

Project	5G Rail Next (5GRN)
5GTT Competition	International
Sector	Transport and Logistics
Location	Glasgow
Timeline	October 2019 to March 2021
Lead consortium partner	Cisco International Limited
Other consortium partners	Sublime Digital Limited, Ampletime Limited, University of Strathclyde, Glasgow City Council, Electronics and Telecommunications Research Institute, Clever Logic, Seoul Metro, Wilus Inc.
Type of network/technology deployed	Private, 5G standalone network
Total project costs	£1,589,242
Funding awarded by DCMS for 5GTT	£1,132,000

10.1.1 Progress on success measures

5GRN resulted in strong evidence of added value of 5G technology against 5 of the 11 5GTT success measures.

Table 56: Summary of impact of 5G Rail Next

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The project partnered with a similar consortium in South Korea. It could be said that this international collaboration enhanced the UK's reputation. However, the project was mainly focused on exploring	2

Success measure	Evidence	Contribution Score
	the viability of deploying immersive AR infotainment in the underground rail system in Glasgow.	
Programme activities have attracted further funding within the area of 5G/5G R&D	Although the 5GTT funding has resulted in additional investment being made by the consortium members, the extent to which it has attracted third-party funding is not clear.	1
Reduction/removal of barriers has accelerated deployment of 5G in the UK	The 5GRN network could be viewed as having promoted the deployment of 5G to some extent. Apart from this, the project also demonstrated proof-of-concept for its use cases, which has contributed towards increasing the awareness of 5G, thereby reducing barriers.	2
Information and knowledge is more readily transferred within the 5G ecosystem	Besides sharing information with DCMS through BRs, the project published its final public report on the UK5G website. Besides this, the consortium was also successful in transferring knowledge with their South Korean partners, despite COVID-19 restrictions and the time difference between UK and South Korea. However, the 5GRN project had limited interactions with other projects and the wider UK5G ecosystem.	2
5G networks are more secure than the 5G networks they replace	The software used for the core and base stations in the 5G network were 3GPP compliant. Besides this, the network also underwent 3GPP authentication each time it started up. Apart from this, Cisco was responsible for providing security solutions to the core network.	3
Additional welfare and environmental benefits	The project did not explicitly aim to realise welfare and environmental benefits; however, it was found immersive 5G technology resulted in enhanced passenger experience. Apart from this, stakeholders mentioned that potential energy efficiency gains from 5G (compared to 4G) could lead to some environmental benefit.	1
Public services cost avoidance	The project was not focused on reducing public cost of providing services.	0
Development of industry 5G expertise and increased ability to use 5G for commercial activities	Three employees of the University of Strathclyde were trained as part of the project. Stakeholders unanimously agreed that the project provided them with the necessary 5G skills and experience to work on other 5G use cases after the completion of 5GRN.	3
Generation of 5G activities beyond the scope of the programme	5GRN inspired a spinoff, the 5G SubConnect project, which further developed the network deployed during 5GRN. In addition, members of the consortium worked on 5G use cases beyond the scope of the project with external partners such as BT and BBC. The project also helped the consortium establish a strong relationship with their South Korean partners, who approached a few consortium members to work on a separate 5G related project.	3
Programme activities have generated demand/ supply certainty and or new viable	The programme conducted a Brand Readiness Survey for the use cases it developed. The survey indicated that although AR immersive infotainment is currently only valued for PR, an increase in its adoption is expected over the next two years.	3

Success measure	Evidence	Contribution Score
business models requiring 5G and or related telecoms technologies		
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The 5GRN project deployed a private SA 5G network, which was further developed by the 5G SubConnect project and is still functional at the time of writing this case study.	3

10.1.2 Project aims and activities

The primary objective of the 5GRN project was to test the technical capabilities of 5G connectivity in an underground transport setting. In particular, the project's use cases focused on developing AR and Mixed Reality (MR) based immersive advertising content powered by 5G connectivity. The project was intended as a demonstrator to explore the potential benefits of its use cases in terms of enhancing passenger experience; and creating new revenue streams and marketing channels for advertisers, media owners, and operators. To achieve its objectives, the project undertook several activities such as:

- Deploying a private 5G SA network in Glasgow's underground rail system (the Glasgow Subway) between two adjacent stations (Buchanan Street and St. Enoch);
- Developing use cases using AR and MR, and Digital-Out-Of-Home (DOOH) advertising framework, which could enhance passenger experience and demonstrate a viable opportunity for commercialisation; and
- Conducting non-public trials and using the results to survey retail brand representatives to gauge adoption and brand readiness for the use cases.

Apart from this, the project also collaborated with a similar South Korean project led by the Electronics and Telecommunications Research Institute (ETRI). The collaboration resulted in significant knowledge transfer gains. Although the type of 5G network deployed by the South Korean project differed from its UK counterpart, both projects tested identical applications of AR and MR on their respective networks.

10.1.3 External factors affecting delivery

We asked stakeholders to comment on whether external factors such as COVID-19, UK's EU exit, or trade restrictions with High Risk Vendors (HRV) impacted the project. Stakeholders unanimously agreed that the COVID-19 pandemic put a big dent in the ambitions of 5GRN and impacted every aspect of the programme. One stakeholder mentioned that it was not possible to have face-to-face interactions, which made collaboration with consortium members and the wider ecosystem difficult. They mentioned significant delays that COVID-19 created by worsening the pre-existing global supply chain crisis. They also mentioned that consortium partners could not deploy their workforce where and when needed.

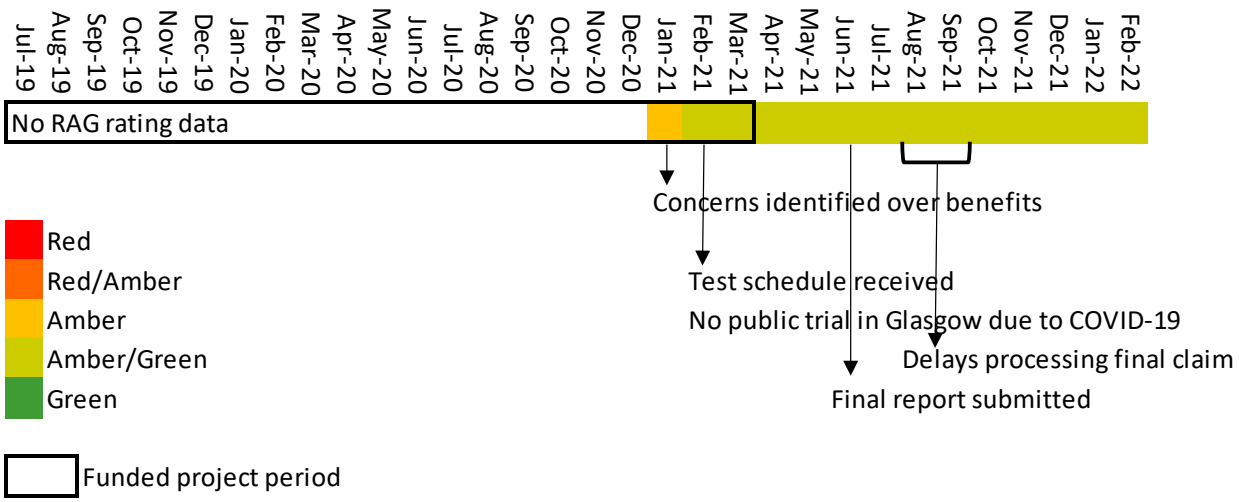
We also learnt that COVID-19 put a serious strain on effective knowledge exchange with the project's South Korean partners. This was due to travel restrictions and was exacerbated by the time difference between the countries. Besides this, another stakeholder mentioned that the national lockdown coincided to a great extent with the project's timelines which significantly delayed everything from receiving delivery of equipment at universities, to physically installing the 5G SA network and developing the AR use cases.

Stakeholders also mentioned that the project was not particularly impacted by trade restrictions with HRVs, as the consortium did not plan on using such equipment in their network. However, UK's EU exit created considerable additional work in terms of paperwork, and also impacted the project's budget, as additional VAT

had to be paid for imports of equipment from the EU. This further exacerbated the delays caused by having to go through several bureaucratic procedures to permit installation of the 5G network and develop use cases amidst the lockdown.

Timeline
The 5GRN project lasted for 18 months from October 2019 to March 2021. We have learnt from interviewing stakeholders that there was no scope for extension beyond March 2021. This, along with the delays caused by COVID-19 and other external factors mentioned above, led to the project's scope being modified. For instance, the consortium had initially envisioned conducting a month long public pilot testing of the project's use cases. This had to be dropped and in turn the consortium had to conduct non-public trials because train services were restricted due to COVID-19 regulations.

Figure 13: Delivery Timeline and RAG rating



Source: 5GTT Delivery Dashboard

As can be seen gauged from Figure 13, besides minor delays in terms of BRs and claim submissions, by the consortium, the project ran smoothly throughout. The cancellation of public trails in Glasgow did mean there was an underspend on the project.

10.2 Consortium Partners

5GRN was one of the smaller consortia funded by the 5GTT programme. Headed by Cisco, it consisted of nine members including software and tech SMEs (Ampletime, and Sublime Digital), an academic institution (University of Strathclyde), and a Public body (Glasgow City Council).

Table 57: Consortium members, 5G Rail Next

Organisation	Type	Role/responsibilities on project	Staff allocated to project
University of Strathclyde	University	Local technical leadership, management, procurement, budget, and senior interface with partners.	1 department
Cisco International Limited	Private sector / international business	Key project management lead and technology partner.	N/A

Sublime Digital Limited	Private sector	Design and build infotainment service	5
Ampletime Limited	Private sector	Performance and impact analytics	N/A
Glasgow City Council	City Council	Facilitate, manage relationships and local support	N/A
Electronics and Telecommunications Research Institute	International partner	N/A	N/A
Clever Logic	International partner	N/A	N/A
Seoul Metro	International partner	N/A	N/A
Wilus Inc.	N/A	N/A	N/A

10.2.1 Working with consortium partners

Each member of the consortium had unique responsibilities . Cisco, as the lead partner, focused primarily on project management and supported with ensuring the security of the 5G network. University of Strathclyde was focused on the technical aspects of the 5G network deployment. Ampletime and Sublime Digital worked primarily on developing the project's use cases. Lastly, Glasgow City Council facilitated relationships and provided local support.

There were no changes in the composition of the consortium, and members worked well with each other throughout the project after some initial challenges. One stakeholder mentioned that working together was slightly challenging at the start given that not all members of the consortium were familiar with the digital market space. There was also some confusion about the role played by the SME members which became clear gradually. They further mentioned that lack of face-to-face interactions due to COVID-19, made it difficult for the members to gel and work as a unit early on.

The consortium consisted of a mix of members who were new and those who had worked together prior to 5GRN. Interviewees report they have established lasting relationships, and a few have expressed interest in working together post project on developing the 5G network deployed. Apart from this, we know that the University of Strathclyde was significantly involved in the '5G SubConnect' project, a spinoff of 5GRN[15].

10.2.2 Personnel

Although the exact number of employees that worked on the project's daily activities is not clear, we know from stakeholder consultations that jobs were created on the back of the 5GRN project. We also know that a few employees were retained post project across the consortium members. The Benefit Realisation (BR) report shows that three members of staff from the University of Strathclyde were trained in Personal Track Safety (PTS) to install and test network equipment in the Glasgow Subway.

10.3 5G Deployment

10.3.1 Approach to deployment

The 5GRN project deployed a 5G Stand-Alone network between Buchanan Street and St. Enoch stations in the Glasgow Subway. As mentioned earlier, this was done to demonstrate that a 5G SA network can be

[15] Found in the final report of the 5G SubConnect project.

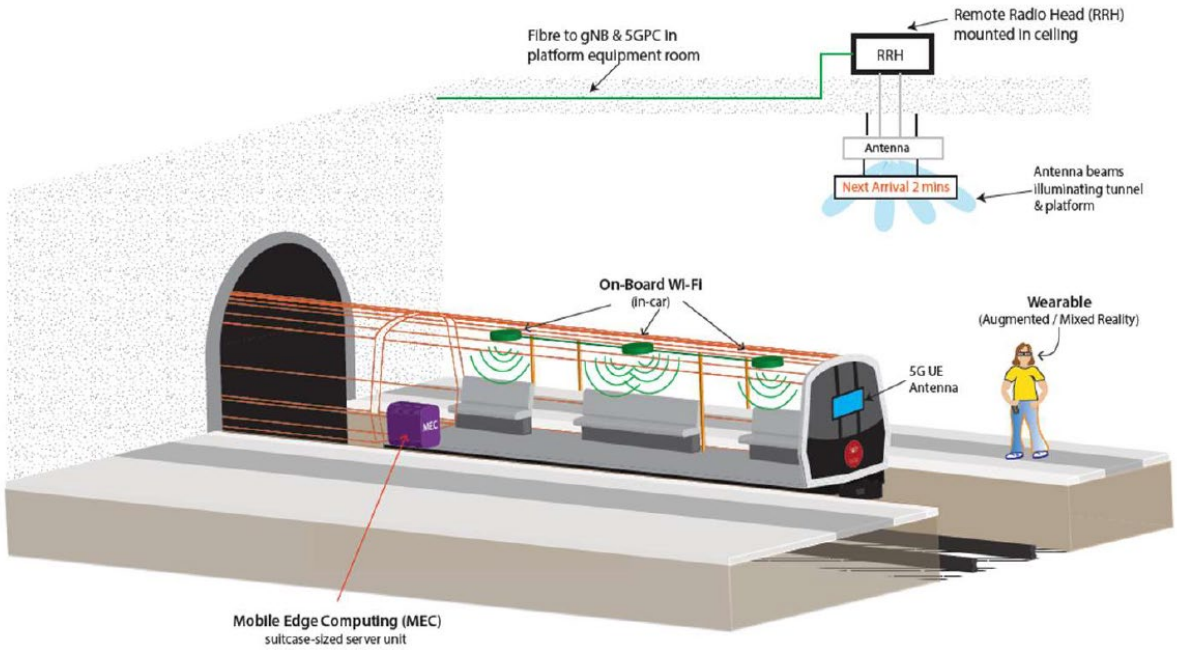
installed in an underground transport setting. Further, the project also tested its use cases on the network to establish proof of concept. The 5GRN network consisted of three main components:

- **5G Core/Next Generation Core (5GPC):** 5G Core network is the corner stone of 5G network managing all aspects of data traffic control, and Quality of service for all connected users in addition to security, access control and authorization and connectivity to other external networks.
- **5G Base Station (BS):** This is a central connection point for wireless devices to communicate with the network and other devices connected to it. The BS, along with the antennas, Remote Radio Head (RHH), and fibre optic cables, forms the Radio Access Network (RAN). The RAN deployed by the 5GRN project used the next-generation NodeB (gNB) as its BS.
- **5G Stand-Alone modem or User Equipment (UE):** The consortium used a 5G SA-capable modem as the user equipment which connected to the network infrastructure to establish connectivity within the carriage.

The network was designed as a private 5G Mobile Hotspot Network (MHN) which connected the infrastructure deployed on the stations and along the tracks, to the Wi-Fi network on the train (track-to-train connectivity). The carriage had a Wi-Fi network powered by modems, a portable 5G server, and an antenna, which provided connectivity to the passengers.

The project's final public report[16] informs us that being Stand Alone, the network operated completely on 5G technology and did not use 4G network elements to power 5G connectivity. Figure 14 illustrates the structure of the network deployed by the 5GRN project. The consortium decided to operate the network in 'n78' spectrum (3.52 GHz) using a bandwidth of 20MHz. This spectrum is licensed to public Mobile Network Operators (MNO), but the consortium obtained an 'Innovation and Trial' licence from Ofcom, which allowed them to use the spectrum on the condition that the private 5G SA network would not interfere with MNOs networks. In an underground railway environment, this worked to the benefit of the consortium as it was unlikely that their underground network would interfere with the MNO networks above ground.

Figure 14: 5GRN Network Structure



Source: Project Final Public Report (2022)

[16] Microsoft Word - 5GRailNext_PublicReport_v00-02.docx (uk5g.org)

Table 58 presents the network indicators measured by the project. This tells us whether the project has been successful in achieving the target metrics in the network deployed. The metrics used by the project are Latency (the speed with which data travels through the network), Throughput (the amount of data that travels through the network per second), and the battery duration of the edge elements connected to the network.

Table 58: Network indicators

Indicator	Measure	Baseline	Target	Achieved at end of project
Wi-Fi to User Device Connectivity	Latency	~30ms	< 7ms	~4ms
Local Cache to User Device Connectivity	Latency	~50ms	< 7ms	~4ms
Performance of Shared Spectrum Band	Throughput	~1Mb/s	> 100 Mb/s	~95 Mb/s(Downlink) ~16Mb/s (Uplink)
Battery life of headset (App running)	Battery duration	1hr 40 mins	>4 hours	1hr 40 mins
Battery life of headset (Standby)	Battery duration	3hr 30 mins	>16 hours	3hr 30 mins

Source: Benefits Realisation

As can be seen, the 5G SA network deployed by the 5GRN project exceeded its target level of overall network latency. In terms of throughput, the network did not reach its target level, although it improved it from the baseline measurement. It can therefore be said that the project successfully demonstrated that a 5G SA network can be deployed in an underground transport environment. On the other hand, it is also evident that there is no improvement in the battery life of the edge elements such as headsets. This could be an indication of the need to further develop the use cases of the project post proof-of-concept.

10.3.2 Use cases

The use cases developed by the 5GRN project focused on exploring the potential of AR, powered by 5G connectivity, to deliver infotainment to the passengers of the Glasgow Subway. For this, mobile handsets (Samsung Galaxy S20) and AR powered headsets (Jorjin J7EF) were used as edge devices connected to the 5G SA network.

- **The DOOH Advertising Framework:** This use case was an advertising framework, primarily designed to allow advertisements to be directly played into the user's device (handsets or headsets) upon scanning a QR code, which was displayed on a screen inside the train. The framework included two aspects:
  - A cloud software application designed to operate at the edge of a 5G network. This was designed to be a Software-as-a-Service (SaaS) use case, which provided vital services such as IoT device management, distribution analytics, and media content management.
  - A media player powered by IoT was installed in the displays within the trains. The media player was designed with several functionalities including QR code reading and real-time engagement tracking, among others.

  The above two aspects of the advertising framework enabled it to allow the passengers to access infotainment (ads) by scanning QR codes on screens. It also to recorded details of each interaction, such as the location and the ad that was played, among other things. The data collected by the advertising

framework could be used to monetise the provision of infotainment, such that the advertiser would have to pay a fee to the network owners each time their ad is played. This would contribute to the return on investment of deploying the 5G network.

- **AR Application:** The consortium developed two AR based mobile applications that the passengers could access through their mobile handsets and AR headsets.
  - The AR Foot Tracking/Trainer Fit Application: This application used machine learning along with the IoT sensors on the mobile handset of passengers, such as motion tracking, environmental understanding, and light estimation sensors. Although the application was powered primarily by the passengers' mobile handset, it could also be used with AR headsets which allowed additional immersive features. Using the AR headsets in conjunction with their mobile handsets enabled passengers to virtually try on shoes by overlaying the image of the sport shoes on top of real world items (the shoes worn by the passenger).
  - The VR Edify Application: Building on the Trainer Fit application, the consortium used Virtual Reality (VR) to design a virtual shop accessible by several participants simultaneously. As mentioned in the project's final report, the design of the application was similar to multiplayer-games where several passengers could participate in a virtual try-on, in a single environment.

The DOOH advertising framework, when combined with the AR applications, provided the passengers with interactive infotainment content, thereby enhancing their travel experience. It also demonstrated the commercialisation potential of interactive infotainment provision in an underground transport setting.

The consortium had initially planned on conducting public trials of the use cases spanning at least a month. However, as mentioned earlier, this was not possible due to COVID-19 restrictions. This led the consortium to conduct short, monitored, non-public trials using a few trialists whom they knew. The trialists were surveyed at the end of the trials to gauge their perception of the use cases. It was found, as expected, that the trialists preferred engaging with interactive ads over a combination of interactive and static ads. Furthermore, trialists preferred mobile handsets over AR headsets. This, the project's final report states could be because the AR headsets were 'bulky' and not streamlined at the time of the trials.

The 5G Rail Next project aimed to measure several benefits by understanding the potential marketplace and the potential users of its use cases. These included:

- Uptake and willingness of brands to use mobile AR;
- Willingness of Brands to pay for mobile AR ads;
- Consumers' preferences for using mobile phones instead of headsets for AR/MR experience;
- Level of consumers' enjoyment using the AR/MR application;

In additional to this, the project also aimed to collect information on consumers' awareness of their journey destination, and whether they cause problems to fellow passengers when immersed in the AR/MR experience. However, since public trials could not be carried out, it was not possible for the project to measure its post-baseline use case benefits.

10.3.3 Safety and security impacts

The 5GRN project deployed a private 5G SA network. This would have enabled the consortium to regulate the data travelling through it. Furthermore, the security of the edge devices connected to the network could also be ensured as the trials for the project's use cases were non-public and monitored, although to what extent this was done was not clear from the project's report and stakeholder consultations. However, we did learn from stakeholder consultations that Cisco was responsible for providing network security solutions to the 5G core.

Apart from this, we know from the project's final public report that software used for the 5GBS and 5GPC were 3GPP compliant. The report also states that the network went through the 3GPP defined connection and authentication process every time it was started. Furthermore, SIM verification processes were also carried out before connecting the network to the wider internet.

10.3.4 Technology Readiness Levels

The 5GRN project was overall highly successful in both network deployment and demonstrating proof of concept for its use cases. This is evident from Table 59 which tells us that all use cases significantly improved from their baseline TRLs and 4 out of the 5 use cases developed, reached their target TRL levels during the course of the project.

Table 59: TRL Summary

	Starting TRL	Target TRL	Current/End TRL	Target met?
Shared Spectrum	5	8 or 9	7/8	Yes
5GNR using SDR	4	7 or 8	7	Yes
Mixed Reality Advertising	4	6 or 7	7	Yes
Video and Link based Ad performance tracking	4	8	7	No
Delivery of carriage based limited access, Augmented Reality.	3	6	6	Yes

Source: Benefits Realisation

10.4 Collaboration knowledge sharing and overcoming barriers

10.4.1 Sharing Learning and best practice

The 5GRN consortium regularly shared the lessons they learnt throughout the course of the project with DCMS using BRs. The lessons learnt were focused on how the consortium overcame challenges around acquiring additional permissions for undertaking project activities like network deployment and use case testing, among other things. It also included the difficulties that the consortium faced as a result of COVID-19 restrictions and the impact this had on their inability to effectively collaborate with South Korean partners.

Furthermore, the consortium also published the project's final public report in the UKTIN (formerly UK5G) website, which contains detailed information about the project's objectives, activities, and outcomes. Apart from this, stakeholder consultations reveal that despite external disruptions, the consortium managed to share learnings and knowledge with their South Korean partners, building a lasting relationship in the process.

Table 60: Publication and events summary

Dissemination Activities	Number of articles/events
UK5G Knowledge exchange Events and Presentations	1
Press and online features	2
International collaboration with South Korean partners	35

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

10.4.2 Interaction with wider ecosystem

As mentioned earlier, the 5GRN project was highly research-oriented in nature. This meant that it did not have a specific aspect of 5G connectivity whose benefits it wanted to test. Rather, it was focused on exploring ways in which AR enabled infotainment, powered by 5G, could be used to enhance passenger experience in an underground transport setting. This exploratory nature of the project made it distinct from several 5GTT projects, which may explain why the consortium did not engage much with the UK5G network.

As can be gauged from Table 61, the main source of wider interaction in which the consortium members participated was their knowledge exchange activities with their South Korean partners. This is confirmed by stakeholders, one of whom revealed that a short trip to South Korea before the pandemic acted as the saving grace for their collaboration, especially during the early stages of the project.

Stakeholder consultations also reveal that several consortium members have participated in further 5G use cases with external partners such as BBC and BT. One stakeholder also mentioned that the consortium's South Korean partners approached members to work on a different 5G related project after the completion of 5GRN.

10.4.3 Business and industry generation

As mentioned earlier, the 5GRN consortium undertook a market / brand readiness survey to determine the commercialisation potential of the use cases developed by the project. The survey was targeted towards 7 Brand representatives from the FMCG, Fashion, Luxury, and Automotive sectors. The survey included 11 questions designed primarily to gauge whether brands were ready to adopt AR/MR in advertising. The survey results indicated that most respondents had previously used AR/MR in advertising and had gotten positive feedback from users who interacted with the ad. However, the consortium also learnt that the main obstacle to adopting AR/MR powered advertising was identified as 'lack of consumer readiness to interact with the content.' This was followed by cost of developing the technology needed to adopt AR/MR advertising. Apart from this, most respondents indicated that, at present, they viewed AR/MR advertising as a means to boost Public Relations (PR). However, they expected adoption to rise in the next two years.

Apart from the Brand Readiness survey, several activities and projects have been inspired by the success of the 5GRN project. For instance, inspired by the 5GRN project, a few members of the consortium applied for DCMS funding for a follow up spinoff project, 5G SubConnect. The 5G SubConnect project improved upon the 5G network deployed by the 5GRN project and focused on testing 5G powered subway maintenance use cases. The project was funded by DCMS and ran for five months from November 2021 to March 2022. Apart from this, we have learnt from stakeholder consultations that a consortium member proceeded to work with BT and BBC on remote live broadcasting of content, after the 5GRN project.

Table 61 informs us of the amount of 5GTT funding received and the extent of additional amount spent by the consortium members on the project. As can be seen, the project received £1.13 million as funding from DCMS. This resulted in consortium members investing an additional £583,000 in the project. The extent of third-party investment in the project is unclear. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 61: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£1,133,000	£583,000

Number of partners that received funding / contributed R&D	6	3

Source: Benefits Realisation

10.5 Programme processes and DCMS support

The stakeholders had an overall positive attitude towards the monitoring, benefit reporting, and other processes, such as submitting claims and change requests that needed to be followed throughout the project. They reported issues such as not enough time being given to applicants to build a consortium and apply for funding. One stakeholder mentioned that there is a 'chicken and egg' situation in forming a consortium in six weeks. This is because potential consortium partners require project aims to be well developed, which in turn depends on the number and type of partners that form the consortium.

Besides this, another stakeholder mentioned that DCMS changed the personnel several times during the project, which led to each new project manager needing to understand the project from scratch, further leading to delays. Regarding benefits realisation, stakeholders identified its importance but also stated the difficulty in accurately measuring benefits during the course of the projects. One stakeholder mentioned that DCMS themselves weren't sure during the early stages of projects about how to fill in the BRs. Besides this, the stakeholder also mentioned that attaching payment milestones to deliverables was not appropriate in an R&D project, given that the use cases are sometimes being developed for the first time.

Having said this, stakeholders also agreed that DCMS was very efficient in monitoring the progress of the project and acted as an enabler for the consortium to undertake the project's activities and accumulate 5G specific skills and experience. One stakeholder mentioned that the 5GTT programme has contributed to improving the UK's perception as a leading 5G country in the world.

10.6 Key outcomes and successes

The 5GRN project provided strong evidence for five of the 11 success measures that we generated to determine the overall success of projects that were funded by the 5GTT programme:

- The project also helped to identify several potential partners for further collaborations, both national and international, beyond the scope of its activities. Furthermore, 5GRN also inspired a follow up project '5G SubConnect', which was funded by DCMS.
- The project undertook a Brand Readiness survey which found that adoption of immersive AR/MR infotainment is expected to increase in the next two years.

10.6.1 Additionality

We asked the stakeholders to comment on the added value to the project, of both the 5GTT funding and 5G connectivity. The consensus during consultations was that the project would not have happened if not for the 5GTT programme. One stakeholder mentioned that they would not have invested in the project if not for the matched funding received from DCMS. Another stakeholder mentioned that the project was research oriented and exploratory in nature, and the consortium would not have considered exploring 5G use cases if the 5GTT programme had not happened. Having said that, the stakeholder further mentioned that if the consortium had not received 5GTT funding after having envisioned the use cases, they would have looked for other sources to further the project.

Overall, stakeholders felt that the 5GTT programme was a key enabler in terms of allowing the consortium to develop 5G specific skills and expertise, which enabled them to participate in further programmes that explored 5G use cases.

Regarding the additionality of 5G connectivity, stakeholders opined that most of the project's use cases would have performed decently on previous generation networks such as 4G. This, the stakeholders reiterated, was because the project's use cases did not focus on testing a specific aspect or benefit that 5G connectivity had

over 4G. Rather, the use cases were a result of the exploratory nature of the project which aimed to test the potential of 5G powered AR infotainment in the Glasgow Subway. However, having said this, the stakeholders also mentioned that 5G connectivity brought significant performance gains such as the ability to operate at different frequency bands that significantly improved bandwidth.

10.6.2 Sustainability

The 5GRN project was highly successful in demonstrating that a private 5G SA network could be deployed in an underground transport environment. It also successfully demonstrated proof-of-concept for its use cases and developed an advertising framework to monetise them. The 5GRN project's success inspired a spinoff project, 5G SubConnect, which was funded by DCMS. 5G SubConnect focused on developing underground maintenance use cases by improving the network deployed by 5GRN.

Besides being part of the 5G SubConnect project, we know from consultations that consortium members have been working on developing 5G based use cases as part of wider, non-DCMS funded projects. For instance, a stakeholder mentioned working with BT and BBC on remote live broadcasting of content. Furthermore, stakeholders also mentioned that the consortium members have developed a good relationship with the project's South Korean partners. They mentioned that the South Korean partners approached a few consortium members to work on another 5G project after the completion of 5GRN.

11. 5G NEW THINKING

11.1 Overview of the project

The primary aim of the 5G New Thinking project was to understand and mitigate the challenges of establishing reliable connectivity in hard-to-reach rural areas where large MNOs do not operate. To achieve this, the project deployed 5G networks in five remote locations in the Orkney Islands, and developed use cases focused on agriculture, healthcare, and other sectors in multiple locations in Scotland. Apart from this, the project also developed a 5G deployment toolkit to aid rural communities and smaller service providers in deploying commercially viable and sustainable 5G networks.[17]

The 5G New Thinking project evolved from the 5G Rural First project which was funded in the first phase of the 5GTT programme and included several of the same consortium members such as Cisco UK and the University of Strathclyde, among others. Although the 5G Rural First consortium was much larger than that of 5G New Thinking, the objectives of the latter were in line with, and progressed those of the former. In this case study, we focus on the aims, activities, successes, and lessons learned of the 5G New Thinking project, while briefly discussing the 5G Rural First project below for reference.

Table 62: Overall project summary

Project	5G New Thinking
5GTT Competition	Rural Connected Communities
Sector	Infrastructure
Location	UK-Wide - Orkney, Loch Lomond, South Scotland, Northern Ireland, Somerset
Timeline	March 2020 to April 2022
Lead consortium partner	Cisco International Limited
Other consortium partners	SHEFA Telecom, Cloudnet IT Solutions Ltd, Federated Wireless, Neutral Wireless, British Broadcasting Corporation R&D, Bogons, PureLeapFrog, RuralFirst, Zoetis, University of Strathclyde, University of Surrey 5GIC, University of Glasgow, Orkney Islands Council, Borderlands Council, The Rural Community Network, The Agri-EPI Centre, The Scotland 5G Centre
Type of network/technology deployed	Private, standalone and non-standalone networks
Total project costs	£7,570,260
Funding awarded by DCMS for 5GTT	£5,000,000

11.1.1 Overall summary of contribution to success measures

5G New Thinking resulted in strong evidence of added value of 5G technology against 5 of the 11 5GTT success measures.

Table 63 Summary of impact of 5G New Thinking

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The project aimed to deploy reliable connectivity in hard-to-reach rural areas and did not explicitly focus on building UK's reputation. However, the several activities and events in which the consortium	1

[17] https://toolkit.5gnewthinking.org

Success measure	Evidence	Contribution Score
	participated could be understood to have contributed towards it positively.	
Programme activities have attracted further funding within the area of 5G/5G R&D	The exact extent of further third party funding is unclear. However, we know that the consortium members invested an additional £2.75 million during the course of the project, and £115,000 for the development of the project's outputs after its completion.	2
Reduction/removal of barriers has accelerated deployment of 5G in the UK	The primary output of the project was the 5G deployment toolkit which is designed as a guide for the efficient deployment of 5G. This includes software which saves significant time for applicants in applying for licences. This toolkit, if widely adopted, has the potential to significantly increase the number of 5G networks in the UK.	3
Information and knowledge is more readily transferred within the 5G ecosystem	The project consortium participated in several knowledge dissemination events both within and outside the UK5G ecosystem. They actively collaborated with other 5GTT projects such as 5G MANY and 5G Connected Forest. Apart from this, they also conducted workshops to spread awareness of 5G in Orkney.	3
5G networks are more secure than the 4G networks they replace	The consortium adopted the 'Zero-Trust' mobile network approach which involved using a combination of E2EE, VPN, Firewall, and SSH authentication to secure its network. The security measures used met the UK NCSC standards.	3
Additional welfare and environmental benefits	Although not directly, the project's agricultural use cases involved using 5G alongside IoT to manage the grazing, health and slaughter of cattle. Increases in efficiency in such use cases has the potential to positively impact the environment.	2
Public services cost avoidance	The 5G deployment toolkit saves significant time for the applicant to apply for SAL and LAL licences. This, if widely adopted, has the potential to streamline Ofcom's process of assessing applications, thereby increasing efficiency, and reducing costs. The same could be said about the overall network deployment exercise undertaken by the project.	1
Development of industry 5G expertise and increased ability to use 5G for commercial activities	The widespread adoption of the 5G deployment toolkit has the potential to disseminate effective knowledge to reduce the time taken to deploy a private 5G network. This could be viewed as developing industry 5G expertise.	2
Generation of 5G activities beyond the scope of the programme	Several consortium members have expressed interest in collaborating to further develop the project's output. Apart from this, use cases like Smart Bow have been commercialised and several others like the toolkit and the Orkney Islands networks are likely to be developed in the future by some consortium members.	2
Programme activities have generated demand/ supply certainty and or new viable business models	The project has demonstrated proof-of-concept that a 5G network could be deployed in hard-to-reach rural areas through the Orkney network. Apart from this, the project's Balquidder network tests show that despite the lack of user trials, there are high enough number of calls, SMSs, and data throughput to warrant further deployment.	3

Success measure	Evidence	Contribution Score
requiring 5G and or related telecoms technologies		
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The project established combination of a 5G SA, a 4G/5G NSA networks in Orkney and Balquidder. Out of which the Orkney network is still functional, with plans for further development discussed by consortium members.	3

11.1.2 Background: The 5G Rural First project

The 5G Rural First project was among the first six projects funded by DCMS as part of the 5GTT programme. Consisting of 29 consortium members, it was one of the larger projects funded by the programme and ran from June 2018 to September 2019. The primary objective of the project was to deploy 5G connectivity in hard-to-reach rural areas. To achieve its objectives, the project focused on creating end-to-end 5G connectivity solutions (testbeds) in the Orkney Islands and the farmlands of Shropshire and Somerset. It was hoped that the testbeds would allow the development of new wireless and networking technologies in the rural areas. The project's use cases included:

- Exploring the feasibility of advanced technical aspects of 5G network deployment in rural areas, such as:
  - Creating multiple networks from a common physical infrastructure (Network slicing);
  - 5G Radio Access Technology at different frequencies (700MHz, 3.5GHz and 26GHz, 2.4GHz/5GHz);
  - Shared 5G spectrum as a viable option in rural network deployment; and
  - Providing access to public MNO networks across a privately deployed 5G network (Neutral Host / RAN sharing); among other things.
- Exploring unique 5G powered use cases to aid the rural communities, such as:
  - Smart Farming using drones, autonomous farm vehicles and remote veterinary inspections;
  - Broadcasting radio programmes over 5G; and
  - Applications of 5G powered IoT connectivity in renewable energy, power generation, and industrial equipment in rural areas.

Apart from this, the project also focused on developing business models to aid rural communities and smaller communication providers in deploying affordable 5G connectivity in areas where large MNOs do not operate. This was done to help rural communities reduce their dependency on the current MNO centric network provision environment for 4G and other previous generation network.

A report published by the 5G Rural First consortium, in collaboration with Plum Consulting in 2019[18] indicates that the project's successes include:

- Deploying 5G networks in its three testbed locations (Orkney Islands, Shropshire, and Somerset) from Datavita's (one of the consortium members) Tier-3 data centre in Glasgow, using a cloud platform;

[18] 5G-RuralFirst-New-Thinking-Applied-to-Rural-Connectivity-1.pdf (uk5g.org)

- Developing and testing several 5G powered use cases in Agriculture, Utilities, and Environment, among other sectors;
- Identifying demand for 5G connectivity in rural areas; and
- Developing business models which could potentially aid rural communities to deploy affordable 5G connectivity.

The project's successes and learnings inspired the 5G New Thinking project, which aimed to further the objectives of 5G Rural First.

11.1.3 Project aims and activities

the 5G New thinking project primarily aimed to mitigate the rural connectivity challenge in the UK. The consortium learnt from having completed the 5G Rural First programme that the business cases involved in deploying 4G and other previous generation networks were highly MNO-centric. This meant that rural areas where larger MNOs did not operate, also did not have reliable connectivity. Having identified this market failure, the 5G New Thinking project sought to understand and mitigate the challenges faced by hard-to-reach rural communities in establishing reliable connectivity. To achieve its objectives, the 5G new thinking consortium performed several activities throughout the course of the project, including:

- **Deploying 5G testbed networks spanning five locations in the Orkney Islands** – This involved a combination of Stand-Alone (SA) and Non-Standalone (NSA) 5G networks using cloud-based cores located in mainland UK. The network deployed was aimed at demonstrating that a 5G network can be deployed in hard-to-reach rural areas.
- **Deploying a NSA 5G network in Balquidder** (a village situated near the northern tip of Loch Lomond) – This network was aimed at informing the consortium of the challenges of rural network deployment, and in turn, aiding in the development of the 5G toolkit, a vital output of the project.
- **Developing and testing 5G powered use cases in agriculture and healthcare, and other sectors** – The 5G New Thinking project developed and tested several use cases using the 5G networks deployed as part of the 5G Rural First project. Trial locations included the Agri-EPI Centre's (APC) South West Dairy Development (SWDD) Centre, and a rural Estate in South Scotland, among other places.
- **Developing a 5G deployment toolkit** – Apart from deploying 5G networks and developing 5G powered use cases, the project also designed a 5G deployment toolkit. The tool was developed as a software to guide rural communities and smaller network providers to self-deploy 5G networks where larger MNOs do not operate.

Overall, the project was successful in terms of network deployment and testing of use cases. However, stakeholders considered the 5G deployment toolkit to be a key piece of output from the project which enabled self-provision of communication networks. This, in turn, has the potential to identify demand for connectivity and make hard-to-reach rural areas attractive for investment from larger MNOs.

11.1.4 External factors affecting delivery

Stakeholders agree that COVID-19 exacerbated the pre-existing supply chain crisis caused by trade restrictions with HRVs. Apart from not being able to meet consortium members face-to-face, stakeholders also mentioned that it was difficult to access the testing and network deployment sites, especially in remote locations such as the Orkney Islands. We also learned that these external factors caused difficulties in acquiring equipment from Europe and moving them internally as required. Stakeholders mentioned that the UK's EU exit caused minimal disruptions to the project as the project had reached its final stages by the time the terms of EU exit were finalised.

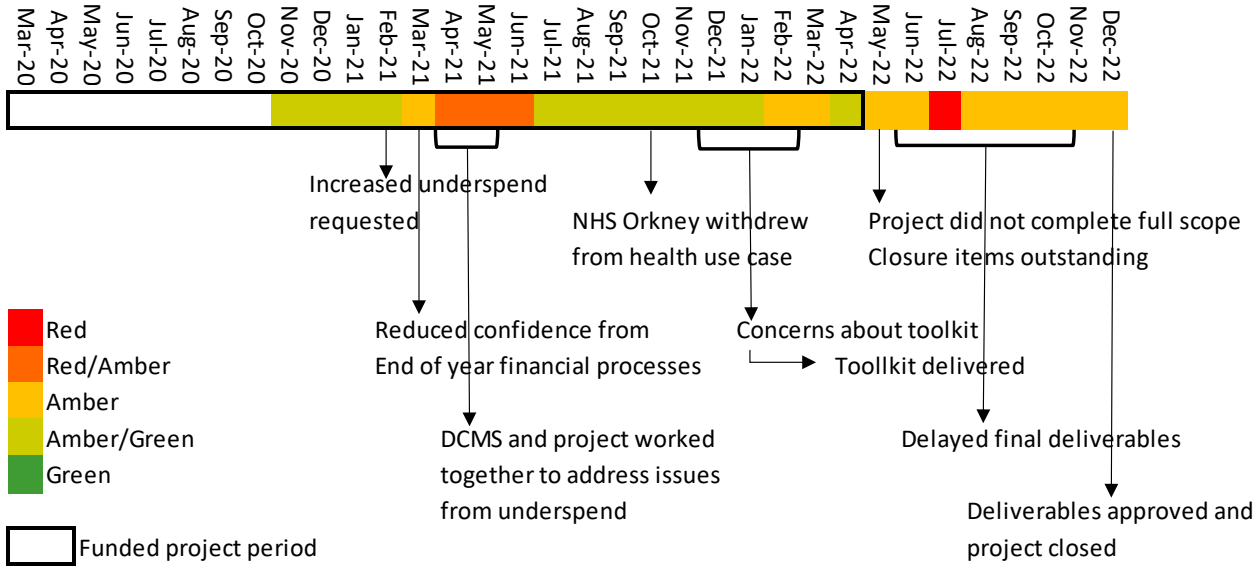
Apart from this, one stakeholder mentioned that while external factors severely impacted the network deployment aspect of the programme, the development of the 5G deployment tool was not affected to a great

extent. The stakeholder mentioned that this involved software development which didn't need site visits and could be done by working from home.

11.1.5 Timeline

As mentioned above, stakeholders cited several delays that the project had to face due to external factors, especially in deploying 5G networks. We know from the project's (draft) final report[19] submitted to DCMS by the consortium, that user trials could not be conducted in the network deployed in Balquidder. This was partly because of delays caused in acquiring the Local Area Licence (LAL), which were in turn, caused by COVID-19 restrictions. However, despite the several delays, the project's timeline remained unchanged, lasting for two years from March 2020 to April 2022.

Figure 15: Project Delivery Timeline and RAG rating



Source: 5GTT Delivery Dashboard

11.2 Consortium Partners

The 5G New Thinking project consisted of 18 consortium members, with Cisco UK as the commercial lead and the University of Strathclyde as the academic lead. Several members of the 5G New Thinking Consortium had previously worked together on the 5G Rural First project, and additional members, both UK based and international, were brought in to aid in the deployment of 5G networks, for instance, Federated Wireless and Cisco US, both of whom were U.S. based.

Table 64: Consortium members, 5G New Thinking

Organisation	Type	Role/responsibilities on project	Staff allocated to project
University of Strathclyde	Public Sector Organisation	Developing testbed, trials, and toolkit, and monitoring results	1 department
University of Surrey 5GIC	Public Sector Organisation	Developing testbed, trials, and toolkit, and monitoring results	1 department

[19] The 5G New Thinking project's draft final has been submitted to DCMS. A final version of this report is expected to be uploaded on the UKTIN website.

Organisation	Type	Role/responsibilities on project	Staff allocated to project
University of Glasgow	Public Sector Organisation	Developing testbed, trials, and toolkit, and monitoring results	1 department
Cisco International Limited	Large Multi-National	Lead Partner: Overall Management of Project & Technical Guidance	15
SHEFA Telecom	Limited Company	Developing testbed, trials, and toolkit, and monitoring results	3
Cloudnet IT Solutions Ltd	Limited Company	Developing testbed, trials, and toolkit, and monitoring results	5
Federated Wireless	Limited Company	Developing toolkit and monitoring results	7
Neutral Wireless	Small Business	Developing testbed, trials, and toolkit, and monitoring results	1.5
British Broadcasting Corporation (BBC) R&D	Large Company	Developing trials and toolkit, and monitoring results	0.5
Bogons	Small Business	Developing testbed, trials, and toolkit, and monitoring results	3
PureLeapFrog	Charity	Developing toolkit and monitoring results	1.2 FTE
RuralFirst	Limited Liability Partnership	Developing testbed, trials, and toolkit, and monitoring results	1
Zoetis	Limited Company	Developing testbed, trials, and toolkit, and monitoring results	0.55
Orkney Islands Council	Public Sector Organisation	Developing trials and toolkit, and monitoring results	1
Borderlands Council	Public Sector Organisation	Developing toolkit, and monitoring results	1
The Rural Community Network	Public Sector Organisation/Charity Undertaking Research	Developing toolkit, and monitoring results	1
The Agri-EPI Centre	Non-Profit Distributing Research and Technology Organisation (RTO)	Developing testbed, trials, and toolkit, and monitoring results	2.75
The Scotland 5G Centre	Non-Profit Distributing Research and Technology Organisation (RTO)	Developing testbed, trials, and toolkit, and monitoring results	0.1

11.2.1 Working with consortium partners

Consultations with stakeholders have revealed that overall, the consortium operated smoothly. The interviewees had a highly positive opinion about the leadership and the collaboration within the consortium. A stakeholder mentioned that consortium members specialised in and added significant value in their individual

roles. Apart from this, they mentioned that several consortium members had worked together previously on 5G Rural First, which allowed them to utilise synergies and work better with each other on 5G New Thinking. Another stakeholder mentioned that Cisco effectively led the consortium through COVID-19, and other external disruptions mentioned above, which helped the consortium remain focused on tasks that were important in the near term to successfully deploy networks and develop use cases. Stakeholders also revealed that while consortium members remain eager to work together in the future, there are currently no concrete collaboration plans.

11.2.2 Personnel

Overall, stakeholders did not mention any gap in expertise that needed to be filled by creating full time job roles for any aspect of the project. One stakeholder mentioned that the consortium members themselves specialised in network deployment and use case development. However, employment was generated in the form of consultants being hired on contracts whenever required. This, another stakeholder mentioned, accounted for at most 10 new jobs created on the back of the project. The extent of how many such newly employed staff were made permanent, or the number of employees working on the project's daily goings on, is not known. However, Table 64 suggests around 43 FTEs were working on the project throughout its course.

11.3 5G Deployment

11.3.1 Approach to deployment

The 5G New Thinking project deployed 5G networks in five locations in the Orkney Islands and a separate network in Balquidder. While the purpose of the networks were different, both the networks were managed remotely using the Cisco Bluestack 5G cloud core deployed in the University of Strathclyde. Apart from this, the project maintained and developed the previously deployed networks in AEC by the 5G Rural First project.

The Orkney Island network: The network deployed in the Orkney Islands were designed to provide a high-quality coverage over a wide region, which was fulfilled using a combination of smaller SA 5G and NSA 4G/5G networks. Deployment was executed in five remote islands in two clusters, as shown in the maps below.

- **Cluster 1** covered the islands of Westray and Papa Westray as shown in Figure 16. The project used Kirkbane as the 'hub' where the consortium erected a 5G mast. This was connected to Fibre, which in turn connected the whole network to the internet via mainland UK. The three other sites in the figure, Clestrain, Woo, and Ambulance were connected to the hub using microwave radio links. This was an NSA 4G/5G network where all four sites provided connectivity in their respective vicinities.

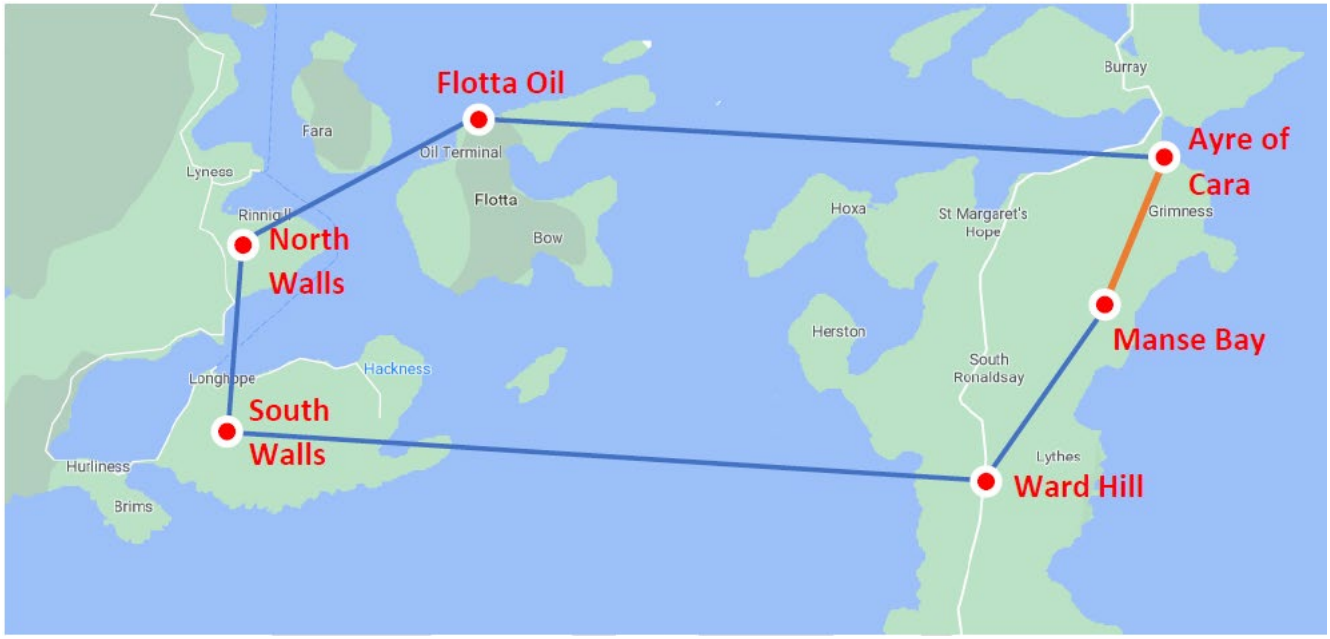
- **Cluster 2** covered the islands of South Ronaldsay, Hoy, and Flotta. The consortium chose the Ayre of Cara as the hub site, which was connected to mainland UK through undersea fibre, thereby connecting the network to the internet. The sites on Hoy (North Walls and South Walls) provided 4G/5G coverage, while Flotta Oil, Manse Bay, and Ward Hill were used as relay sites, connecting Hoy to the hub at Ayre of Cara.

All locations in both clusters used microwave links as backhaul, except for Manse Bay, which connected to the hub at Ayre of Cara through a specially laid fibre-link.

Figure 16: 5G New Thinking Orkney network cluster 1

Source: Project Draft Final Report

5G New Thinking Orkney network cluster 2



Source: Project Draft Final Report

The Balquidder network: The 5G New Thinking project deployed an NSA 5G network at Balquidder. This network deployment truly informed the consortium of the difficulties faced by hard-to-reach rural areas in terms of obtaining appropriate licences and deploying a 5G network. A local Internet Service Provider (ISP) had previously laid a reliable indoor network at Balquidder. However, the region did not have reliable outdoor connectivity.

The deployment of the Balquidder network involved using telephone pole-based masts and radios housed in cabinets at the bottom of the poles to reduce visual impact. This was because the village was located in the middle of a national park.

Initially, the consortium had envisioned implementing a 5G SA neutral host network to provide MNO services using the Balquidder network. However, time constraints didn't allow this. An alternative national roaming trial was then envisioned for the network. The project was hoping this could be completed using a Local Area Licence (LAL) from Ofcom which would allow for an NSA 5G network to be deployed at 1800 MHz and 750 MHz However, there was a significant delay of 7 months to obtain the LAL, both due to COVID-19 and the lengthy procedures involved in obtaining licences.

The consortium instead applied for a Shared Access Licence (SAL) which would allow them to at least deploy a 4G network that would carry data through the network while waiting for 5G. This was obtained comparatively faster and an NSA 4G/5G was deployed. However, user trials could not be conducted as the consortium did not get the LAL in time.

Table 65: Network indicators

Network	Indicator	Measure	Baseline	Target	Achieved at end of project
Project wide	LTE radio release	3GPP release	Rel. 14	Rel. 16	Rel.15 with Rel. 16 features
Project wide (4G/ 5G NSA/ 5G SA)	Base station reliability (radios, hardware, and software)	Percentage uptime, crash logging	90%	97-100%	90-95%
Project wide (Virtualised open source / cloud core for 4G/ 5G NSA/ 5G SA)	control plane reliability (software)	Percentage uptime, crash logging	80-90%	95-100%	90-99%
Project wide (Virtualised open source for 4G/ 5G NSA/ 5G SA)	Edge user plane reliability (hardware and software)	Percentage uptime, crash logging	80-90%	95-100%	99%
Orkney Networks (4G/ 5G NSA/ 5G SA)	Throughput	Uplink and downlink data rates	150 kbps UL 1 Mbps DL	30 Mbps DL 10 Mbps UL	130Mbps DL, 50Mbps UL
Orkney Networks (4G/ 5G NSA/ 5G SA)	Latency	Milliseconds (ms)	60+ ms	20-30 ms	15-25 ms
Balquidder Network	Number of unique general public phones served	Number of unique hashed IMSIs	New network, no baseline	No specific target. (High number of unique IMSIs	3,847 (Jan/Feb 2022)

Network	Indicator	Measure	Baseline	Target	Achieved at end of project
				→ strong case for deployment)	
Balquidder Network	Throughput statistics	Number of texts and calls served	New network, no baseline	No specific target. (High number of texts/calls and data throughputs → strong case for deployment)	Call Attempts: 968 SMS: 132 Data transferred: 40GB

Source: Benefits Realisation

Table 65 indicates several metrics that the project used to measure the performance of the networks it deployed. These include 3GPP standards, throughput (the amount of data that travels through the network), latency (the speed at which data travels through the network), and uptime (network availability – how well can the network respond to demands placed on it). The Orkney network deployments meet and sometimes exceed the target performance levels.

The project does not have baseline and target measures for its Balquidder Network. However, considering the number of phones served, calls attempted, SMSs attempted and data throughput warrants a strong business case for further network deployment.

11.3.2 Use cases

The 5G New Thinking project developed several use cases, some of which were tested on networks established as part of the 5G Rural First project. Apart from this, the deployment of the Orkney testbed network itself could be considered one of the project's use cases, as it was done to demonstrate the concept of network deployment in hard-to-reach rural areas. Apart from this, a few of the project's vital use cases include:

- **The 5G deployment toolkit**[20]**:** This was a guide for faster and more efficient deployment of 5G networks. The toolkit included guidance based on extensive research on the requirements of network deployment and best practices, along with software which could inform the applicant of spectrum availability and aid in licencing applications. Stakeholders unanimously agree that this was the most important output from the project. The project's BR also agrees with the sentiment and informs us that the toolkit allowed an applicant to assess their LAL/SAL application in 10 to 15 seconds as opposed to one month which would have been required otherwise. One stakeholder explains this by stating that sending in an application to Ofcom without knowing whether the spectrum is available may result in rejection after one month. To circumvent this, the toolkit could be used to check and identify available spectrum instantaneously.

  The consortium aimed to measure the benefits of the Toolkit in terms of:

  – Willingness to pay for access to toolkit; and

  – Number of requests for access to Toolkit.

- **Agricultural Use cases:** Apart from the networks deployed and the 5G toolkit, the 5G New Thinking project also developed several use cases focussing on demonstrating the application of 5G in rural areas. These included agricultural use cases such as:

[20] https://toolkit.5gnewthinking.org

- Smart Bow: Involved using 5G connectivity along with IoT sensors to monitor dairy cows to improve herd management, detect health issues, enable early intervention, and reduce illness related losses. This use case was aimed at improving efficiency of a dairy business, thereby cutting costs and increasing profits.
- Improving Beef Profitability: This use case also involves 5G and IoT powered monitoring of cattle to identify an optimal time to butcher a cow. This use case was aimed at increasing the efficiency of the slaughter selection process, thereby increasing the profitability of the farmers and reducing the chances of getting underpaid for carcasses.
- 5G By Air: This use case involved 5G powered drones equipped with a multispectral camera, which scans the grazing of the cows to measure biomass feed value.

The consortium aimed to measure the benefits of its agricultural use cases in terms of:

- Reduction in number of expensive pilot days (5G By Air),
- Reduction in analysis turnaround time of data from drone and decrease time of uploaded data provided (5G by Air and Smart Bow); and
- Reduction in penalties imposed through incorrect carcass specification (Improving Beef Profitability).

- **Portable Non-Invasive Radio Frequency Sensing for Assistive Living:** Developed primarily by the University of Glasgow, this use case used a 5G specific Radio Frequency (RF) sensing system which operated in the 5G-band at 3.75GHz. This was designed as a proof of concept, which could be developed in the future to be able to scan activity patterns inside homes or care homes, in order to facilitate the rehabilitation of patients without invading their privacy.

  The consortium aimed to measure the benefits of its assisted living use case in terms of:

  - Timing analysis: time taken to report a detected activity by the non-invasive activity sensing system;
  - Reduction in patient transport costs that would otherwise be needed in order for patients to travel for face-to-face consultations; and
  - Reduction in the number of consultations that have to be cancelled due to the GP being unable to travel to Papa Westray in order to hold the weekly surgery.

11.3.3 Safety and Security impacts

The 5G New Thinking project implemented a ‘Zero-Trust Mobile Network’ approach while deploying its networks in Orkney. This approach meant that the consortium did not trust any connection in the networks, core, and RAN, it deployed. This was because of the use of cloud servers which the consortium accessed over public internet. To secure the network, the consortium used a combination of End-to-End Encrypted (E2EE) using SD-WAN/ mesh VPN software, Firewall, and Secure Socket Shell (SSH) for remote access. We know from the project’s final report that its encryption algorithms met the UK government’s NCSC accreditation standards. Apart from this, we know that project used certificate based SSH for all remote management of the networks. Lastly, the project used Firewall in every network deployment that containing a core network and a RAN.

Stakeholder consultations also reveal that 5G masts installed by the consortium were taken down in protest in Orkney, where there was a widespread lack of 5G awareness. This motivated the consortium to conduct workshops to spread awareness of 5G networks and the objectives of 5G New Thinking.

11.3.4 Technology Readiness Levels

Table 66: TRL Summary

	Starting TRL	Target TRL	Current/End TRL	Target met?
N77 radio for FWA	3	7	7	Yes
5G NSA does not spot roaming	4	7	4	No
Base station KPI software	2	6	6	Yes
Open source 4G/5G core	4	6	6	Yes
LAL Application Tool Software	2/3 (Important components existed prior)	7/8	7/8 (Available for general public use, but not fully commercialized)	Yes
SAL Prospector	2/3 (Important components existed prior)	9	7/8 (Available for general, but restricted, public use)	No
SAL Automation Tool	2/3 (Important components existed prior)	9	5/6 (Many aspects implemented and demonstrated in realistic environments, but important functions such as billing not implemented)	No
A Portable Non-invasive Radio Frequency Sensing System for Assistive Living	2	5	4	No
Smartbow	6	8	8	Yes

Source: Benefits Realisation

The 5G New Thinking project can be considered an overall success in terms of developing its use cases. As can be gauged from Table 66, the project managed to achieve its target TRL levels for five of the nine use cases developed, during its course. Except for one use case which remained at baseline level, the TRLs of the remaining three use cases that did not reach their targets, also improved significantly.

11.4 Collaboration knowledge sharing and overcoming barriers

11.4.1 Sharing Learning and best practice

The 5G New Thinking project reported several lessons learned throughout its course to DCMS through the BR. These lessons revolved around how the consortium coped with disruptions such as:

- Delays and restrictions in network deployment and use case development caused by COVID-19, trade restrictions with HRVs, and other external factors;

- Barriers to investment faced by consortium members, for instance, asking SMEs in the consortium to contribute 40%; and
- Staffing and other expertise issues, and the difficulty in getting required permissions and licences.

Overall, stakeholders identified high costs, lack of access to spectrum, and lack of planning as major barriers to network deployment. However, one stakeholder mentioned that spectrum is less of a barrier than it used to be, with Ofcom introducing LAL and Shared Licencing of spectrum. Furthermore, stakeholders unanimously agree that the 5G New Thinking project has contributed to weakening the barriers through its activities, mainly by producing the 5G deployment tool. Several stakeholders mentioned that the tool itself was designed to disseminate knowledge about how to think about spectrum, how to easily obtain licences, and how to finance the deployment, among other things.

Table 67: Publication and events summary

Dissemination Activities	Number of articles/events
Research outputs	2
Collaboration events, Presentations, and Workshops	16
Communication activities	9
Award nominations	1

Source: Benefits Realisation and stakeholder consultations

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

11.4.2 Interaction with wider ecosystem

Stakeholder consultations revealed that the consortium engaged significantly in collaboration events, presentations, and workshops both within the UK5G ecosystem and beyond. This is also enumerated in Table 67, and the project's BR, which tells us that the majority of the communication events were with Ofcom and DCMS. The 5G deployment tool developed by the project was nominated for an award, which was an unexpected surprise. In addition to this, the consortium also collaborated with other 5GTT projects such as 5G MANY and 5G Connected Forest specifically for knowledge dissemination.

Stakeholders were positive about the project's contribution in disseminating knowledge through wider collaboration. One stakeholder mentioned that the 5G deployment toolkit was designed as a best practice and to disseminate information. However a few stakeholders mentioned that collaboration activities were mostly dominated by the larger partners in the consortium such as Cisco, while local rural SMEs like CloudNet were not invited as often. This, stakeholders felt gave fewer opportunities for rural SMEs to share their point of view.

Stakeholders also had an overall positive opinion about DCMS as a facilitator of collaboration activities, with one stakeholder stating that DCMS aimed to force collaboration where needed. However, there was a general concern about the lack of a Non-Disclosure Agreement (NDA) between different 5GTT consortia, which made sharing information harder.

11.4.3 Business and industry generation

The exact extent of additional funding received on the back of the project is not clear. However, we know that several consortium members are actively looking for further funding to progress the use cases developed and networks deployed as part of the 5G New Thinking project. We also know from the project's Benefits Realisation Reports (BR) that the several consortium members such as University of Glasgow, Neutral Wireless, have invested £115,000 to further the project's output after its completion.

Apart from this, the project's sustainability report submitted by the consortium to DCMS, tells us that multiple consortium members are intended to continue the development of the project's output. These includes the agricultural use cases such as Smart bow, and the 5G networks deployed in Orkney, among others. There is also a plan for the consortium members to meet to further develop the 5G deployment toolkit. The University of Strathclyde, in collaboration with Scotland 5G Centre has raised £30,000 for this purpose.

We also know from the project's BR that an international partner in the consortium, Federated Wireless, has extended U.K. business relationships with CELNEX and is continuing to look for ways to leverage underutilized spectrum in the U.K. The firm has also won additional network deployment projects in four locations in the U.S.

Table 68 informs us about the extent of DCMS funding received and the extent of additional investment in the project that this encouraged. As can be gauged, the 5G New Thinking project received £5 million in DCMS funding. This encouraged additional investment from nine consortium members, collectively amounting to £2.75 million.

The exact extent of additional private investment within the UK from outside the consortium in unknown. However, we know from the project's BR that Federated Wireless received $11.8 million for a 5G shared spectrum pilot project in the U.S.

Table 68: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£5,000,000	£2,758,000
Number of partners that received funding / contributed R&D	17	9

Source: Benefits Realisation

11.5 Programme Processes and DCMS Support

Stakeholder consultations revealed that the processes involved in the project such as application, monitoring, submitting BR and change requests, among other things, were primarily handled by Cisco, although other consortium members contributed to it in a supporting capacity. Several stakeholders found it concerning that DCMS had associated releasing payment with project milestones. One stakeholder mentioned that this was not in line with best practices for a research and development project. There was a general consensus among stakeholders that DCMS was unduly particular about processes that consumed valuable time and distracted consortium members from focussing on the project's deliverables. Regarding the one stakeholder who mentioned that DCMS had staffing challenges because of which the project managers kept changing. However, we also learnt from stakeholder consultations that they developed good and lasting relationships with staff at DCMS through the project.

11.6 Key outcomes and successes

The 5G New Thinking project has provided strong evidence against five of the 11 success measures developed by us to determine the overall success of 5GTT projects. This is evident because:

- The project established a secure and reliable 5G network in the Orkney Islands and Balquidder, thereby demonstrating proof of concept that 5G networks could be deployed in hard-to-reach rural areas. Further, the Orkney network is still in place with plans to maintain and develop it being discussed among a few stakeholders.

- The project has identified use cases powered by 5G which could be used in rural areas. Also, the tests undertaken on the networks deployed demonstrate the demand for reliable connectivity generated in the rural areas.

- The consortium participated in several events and workshops which aided in effective knowledge dissemination. Apart from this, one of the project's outputs – the 5G deployment toolkit is itself designed to disseminate knowledge.

11.6.1 Additionality

Stakeholders unanimously agreed that the 5G New Thinking project would not have been possible if not for the 5GTT funding received by the consortium. One stakeholder commented that the project demanded significant commitment in terms of time and money from a large group of organisations, which would not have been possible without the matched funding. It can be said that there is a general consensus among stakeholders regarding the significant value added by the 5GTT funding, both as an incentive for the consortium members to invest in the project, and as a catalyst for use case development.

Stakeholder consultations have further revealed that 5G connectivity has been vital, both in terms of network deployment and for the use cases developed by the project. In terms of network deployment, establishing 5G networks allowed the consortium to explore non MNO-centric business models which would aid in future self-deployment of private 5G networks in rural areas. It has allowed the consortium to understand and explore ways to move past the barrier of relying on MNOs to deploy 4G and 3G networks in rural areas.

While several of the project's use cases could be run to an extent on previous generation networks such as 4G, stakeholder consultations revealed that 5G connectivity enhanced efficiency through lower latency and higher throughput. Apart from this, the use of 5G to test the use cases also enumerated the several ways in which 5G could be used in hard-to-reach in rural areas, thereby demonstrating demand for connectivity.

11.6.2 Sustainability

As mentioned earlier, the 5G New Thinking project evolved from the 5G Rural First project and as such, several of its agricultural and health use cases were tested on networks previously installed by 5G Rural First. However, use cases such as the 'Improving Beef Profitability' and 'Smart Bow' are being used after the project's completion. Furthermore, we know from the project's sustainability report that consortium members such as AEC have invested their own resources to further upgrade the existing infrastructure at their SWDD centre.

Apart from the agricultural use cases, several consortium members are actively looking for funding to further develop the 5G deployment toolkit. This includes a £30,000 investment by the University of Strathclyde and the Scottish 5G Centre. Plans have also been proposed for several consortium members including Cisco, University of Strathclyde, Cloudnet, SHEFA, Orkney Islands Council, and PureLeapFrog, among others, to meet periodically for one year after the completion of the 5G New Thinking project to develop the toolkit. Apart from this, consortium members including Cisco, SHEFA, and Cloudnet have expressed interest in working towards maintaining and further developing the 5G networks deployed in the Orkney Islands.

Consultations have also revealed that several stakeholders are eager to further develop the project's output and collaborate in the future, although no concrete plans were shared. Apart from potential collaboration plans, the project has also resulted in international firms such as Federated Wireless growing both its UK and U.S. businesses considerably.

12. WEST MERCIA RURAL 5G

12.1 Overview of the project

This project looked to explore a different model to build and operate a 5G network within a rural setting, and how 5G can help to enhance services and generate additional benefits for residents, particularly around health and social care applications. The project utilised public 4G and 5G non-standalone networks as well as a private 5G Non-standalone networks to test how the use cases could be carried out across the spectrum of technologies.

Table 69: Overall project summary

Project	West Mercia 5G
5GTT Competition	Rural Connected Communities
Sector	Rural 5G, Health and Social Care
Location	Rural Worcestershire and Shropshire
Timeline	Originally March 2020-March 2022, later extended to June 2022
Lead consortium partner	Worcestershire County Council
Other consortium partners	BT, Airband Community Internet, TalkOut VR, Shropshire Council, NHS Herefordshire and Worcestershire Clinical Commissioning Group, West Midlands Academic Health Science Network, University of Worcester and University of Chester.
Type of network/technology deployed	Private, non-standalone
Total project costs	£1,886,018
Funding awarded by DCMS for 5GTT	£1,586,809

12.1.1 Project contribution to success measures

Wet Mercia Rural 5G resulted in strong evidence of added value of 5G technology against 2 of the 11 5GTT success measures and shows some evidence of impact against a further seven.

Table 70 Summary of impact of West Mercia 5G

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	These efforts to raise the reputation of West Mercia contributed to the overall improvement of the perception of the UK as a leading 5G nation. The sentiments expressed highlighted that though the UK had made progress there were still further steps to take.	2
Programme activities have attracted further funding within the area of 5G/5G R&D	Whilst some of the consortium partners did spend some additional money on R&D there was no recording of additional spending carried out after the project completion.	1
Reduction/removal of barriers has accelerated	This project did not have much evidence on looking at the removal of barriers of accelerated deployment of 5G. Some	2

Success measure	Evidence	Contribution Score
deployment of 5G in the UK	interviewees did note that within the medical space the project helped to accelerate 5G uses.	
Information and knowledge is more readily transferred within the 5G ecosystem	Interviewees noted that the sharing of information across the 5G ecosystem was one of the strengths of the project. They noted how there were a number of dissemination activities carried out from presenting at the Birmingham showcase event to regular meetings between consortium partners.	3
5G networks are more secure than the 5G networks they replace	The fact that the use cases were carried out on a private network and utilising patient data meant that security elements needed consideration. However, security aspects were not explicitly tested during the project, though interviewees noted this would be considered in future applications.	2
Additional welfare and environmental benefits	The environmental considerations were not explicitly considered during this project, but because of the rural context of the project these arose indirectly. The models to deliver health and social care in a rural setting would have had cost implications but also indirect environmental impacts, but further work was needed on some applications to ensure they delivered planned benefits	2
Public services cost avoidance	This was one of the key aims of the project to try and deliver health and social care solutions more effectively reducing the cost of public services. Carrying out medical appointments remotely meant that there was a large potential for savings for the NHS.	3
Development of industry 5G expertise and increased ability to use 5G for commercial activities	This project did not look to increase revenue and profits but did look to find ways to encourage mobile network operators to operate in rural areas where commercial incentives are not as strong. However, as the use cases were carried out in the medical industry the focus was not on commercial elements.	2
Generation of 5G activities beyond the scope of the programme	Interviewees noted that they were involved in showcase events at the end of the project. Ongoing press releases helped to keep the wider public aware of project progress. However, a drawback was that there was not a significant amount of additional activity generated following project completion.	2
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	The project was not focused on generating new commercial activities with the use cases looking to generate solutions in improving medical spaces.	1
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	Interviewees noted that as the previous generation networks across the region were in many cases 3G and 2G. As a result, just having increased connectivity was a key aim of the project and having 5G networks was not a specific aim of the project. Many of the care homes had very poor networks so this project	2

Success measure	Evidence	Contribution Score
	helped to at least provide additional access where it had not been present.	

12.1.2 Project aims and activities

The programme looked to investigate two key challenges:

- Exploring new models to see how 5G could be delivered and operated in rural areas
- Looking to see how 5G could help to provide new ways of delivering health and social care to rural communities.

As part of the 'Rural Connected Communities' projects being funded by DCMS the West Mercia Rural 5G project looked to address the challenges that rural locations often face when it comes to connectivity. Often because rural areas have low population density many mobile network operators are not as incentivised to set up high speed networks in these regions, leading to poor connectivity. This project sought to address these challenges and to see how improved connectivity could be brought to these communities and allow them to access all the accompanying commercial and wider public benefits that come along with improved access. Overall, whilst the project did have some success in demonstrating their use cases, the challenges experienced throughout the project meant that the benefits were not as wide reaching as initially intended.

12.1.3 External factors affecting delivery

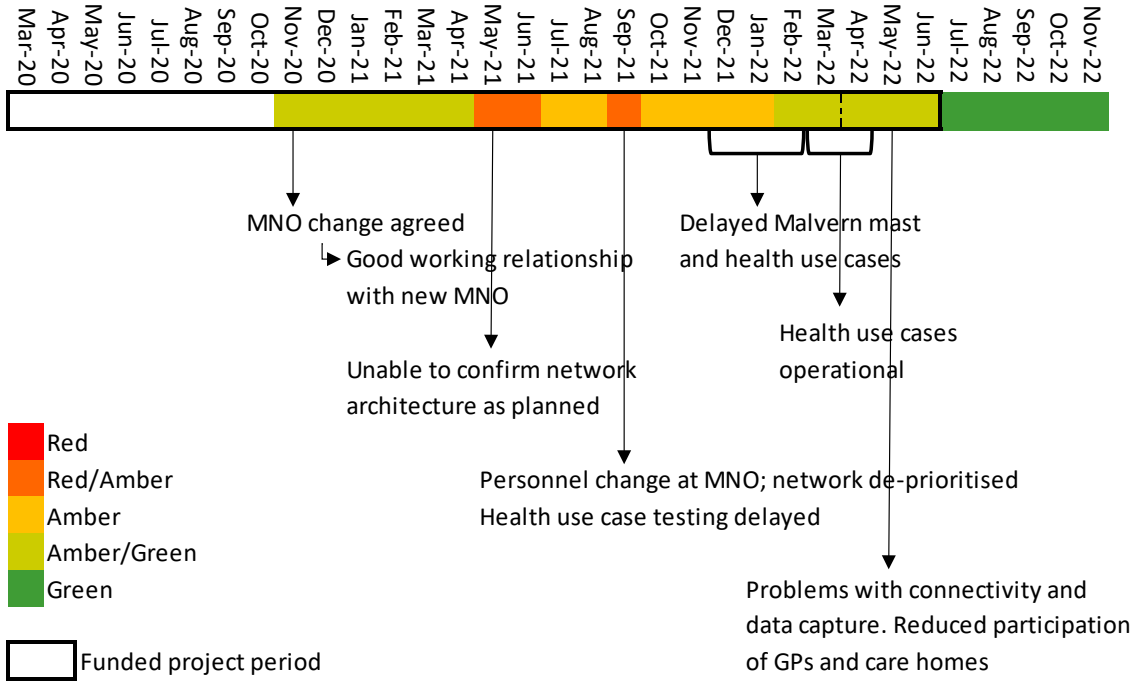
Interviewees were expressive about the challenges that COVID-19 had in the delivery of the project. Operating in a healthcare environment meant that this played a significant barrier in the ability to test and demonstrate the viability of some of the use cases. Care homes were very nervous about other staff members utilising the system and challenges with equipment meant that many of the headsets were not in place until after lockdown was over. Trying to develop a network during COVID-19 when there were constraints around building access understandably proved to be extremely difficult.

In addition, the project suffered initial challenges as the original partner acting as the mobile network operator withdrew and were replaced by BT, who themselves were in a period of transition. Interviewees also noted how equipment shortages also posed a significant challenge (see timeline below).

12.1.4 Timeline

The project originally operated from March 2020 to March 2022 and was extended until June 2022. Issues around supply of equipment, access to sites, staff testing positive and partner travel policies caused by COVID-19 as well as lock down periods led to delays.

Figure 17: Project timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

12.2 Consortium Partners

The consortium was made up of 9 organisations. Interviewees noted that although a few of the members had worked together they had never all worked together in a consortium. The change of the network provider did provide a challenge but the project overall was able to overcome this.

Table 71: Consortium members, West Mercia Rural 5G

Organisation	Type	Role/responsibilities on project	Staff allocated to project
University of Worcester	Higher Education	Research	1 department
University of Chester	Higher Education	Health and Medical Innovation & Transformation	1 department
British Telecommunications Public Limited Company	Private large	Provision of network	7
Airband Community Internet	Private SME	Provision of network	3
Luft Technologies Ltd t/a VRSS (Virtual Reality Simulation Systems)	Private SME	Use case technology provider	12

Worcestershire County Council	Local Authority	Lead partner, partner coordination, programme management and ensuring findings, & trial outputs are captured and published appropriately. Facilitate and support network deployment in Worcestershire, co-lead any social care use case development and delivery support health use case selection, design, and delivery.	2
Shropshire Council	Local Authority	Facilitate and support network deployment in Shropshire, support health and social care use case selection, design, and delivery. Lead on integration of the Bridge as a key analysis and predictive modelling tool on the project.	0.25
NHS Herefordshire and Worcestershire Clinical Commissioning Group	NHS	Lead on health and co-lead social care use case development and management including selection, design, delivery, and reporting. Ensuring findings and trial outputs are captured and published appropriately. Ensuring personal and confidential information is managed appropriately, public health assessments in relation to use cases are complete and use cases comply with required standards of the NHS.	1
West Midlands Academic Health Science Network (Associate Partner)	NHS	Support health and social care use case selection, design, and delivery.	0.2

12.2.1 Working with consortium partners

The consortium partners generally worked well together after some initial challenges at the outset of the project when there was a required change in the mobile network operator used. As some of the consortium members had worked together previously, this helped establish strong relationships during the project. Interviewees also noted that DCMS helped to keep the project moving and were generally very responsive when required and adaptive to the challenges which were faced. Overall interviewees noted that the whole 5G programme was good with DCMS very effective at overseeing and managing the project.

12.2.2 Personnel

On an FTE basis fewer than 20 staff members were involved with the overall headcount being in excess of 80. Interviewees noted that 6 to 8 individuals were core to the project carrying out around 80% of the effort. Whilst expertise was not an issue, capacity was. Some of the core members were involved in both the West Mercia Rural 5G programme as well as their day jobs which did present a challenge in being able to test the use cases thoroughly. The capacity issue is a common element within the NHS.

12.3 5G Deployment

12.3.1 Approach to deployment

The project initially looked to deploy a 5G network around Ludlow and Tenbury Wells, pat of West Mercia where the counties of Shropshire and Worcestershire meet. Interviewees noted that the challenge of deploying the masts in a rural space presented challenges as the initial mobile network operators would not have built in that location commercially were it not for the project. As noted previously the initial network operators withdrew three months into the programme which presented a challenge as the new partner did not have the same requirements or appetite for multiple new sites and wider commercial deployment. Instead the project utilised a new radio network at one site and repurposed the 5GNon standalone network at Malvern Hills, including the mast and core that was already in place at Malvern Hills Science Park.

COVID-19 was a serious challenge throughout this project and the consortium were unable to establish baseline measurements or observed measures. The network indicators identified in the BR exercise (outline what these were e.g. latency, bandwidth, coverage etc) would need further testing in any future iterations and applications of the technology.

- Malvern Hills 5G NSA N78 Internal & Mast Macro Deployment did not have any specific measures but at the end of the project good penetrations was reported.
- No baseline data was provided for the Tenbury Wells EE 4G Commercial Coverage
- No baseline data was provided for the Malvern Hills 4G/5G EE Commercial Coverage but modems were used for the performance testing of the devices utilised for the use case.

12.3.2 Use cases

There were two main use cases for this project:

- Virtual Reality Simulation Systems. This use case sought to address a number of aspects from reducing costs to patients and the economy, to increasing patient welfare through reducing the likelihood of patients missing their appointments. In addition, rolling out the simulations across the West Mercia region would help to raise the investment profile of the region and increase the innovative credentials of the area.
- Connected Worker – Wearable Video & Mobile Telemedicine – 5G Wearable Video for Rural Community Nurses and GPs. The applications across this use case were key in helping to enhance patient outcomes by accelerating the treatments available during peak periods. In addition, in a COVID-19 environment, having remote consultations not only improved the safety of GPs and patients alike but also helped the NHS to contribute to their goal of achieving net zero impact by reducing GP travel.

Key benefits from the use cases that the project measured included:

- Reducing costs for patients and carers who now no longer need to travel. Savings for patients were cited as £69.48, with the savings for carers identified as £65.40 per episode.
- Increasing the innovative credentials of the region by adding more businesses and demand to the region.
- Reduced likelihood of patients missing appointments with project reducing ‘Did Not Attends (DNAs)’ by 117, equivalent to £14,014 per year.
- Enables NHS to contribute to Net zero impact due to reduced avoidable admissions through carbon savings from GP travel resulting in 1.37 metric tonnes of carbon saved.
- A number of benefits to improve patient care through helping people to live independently, enhanced patient outcomes, ensuring access to patients during COVID-19 in a way that protects patients, carers and doctors.

Source: Benefits Realisation

12.3.3 Safety and Security impacts

As the project looked to develop a 5G network, this would have additional security benefits over and above any 4G or other previous generation technologies but use cases did not look to address security improvements specifically. As the project was operating in a region where previous networks were so underdeveloped, improving connectivity was one of the core aims of the project. In future rural applications of 5G technologies it could be that additional focus is given to how they help boost security outcomes in a rural context.

12.3.4 Technology Readiness Levels

The use cases below demonstrate that despite not all of the use cases achieving their desired target TRL, that there was improvement over the course of the project.

Table 72: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
iPhone/pad - use of LiDAR camera to track motion*	2	7	5	No
Holocap - Volumetric 3d Tracking*	2	7	5	No
Virtual Reality Simulation Systems (VRSS)	3	5	5	Yes
Airband's alternative model to deploy 5G network	3	6	6	Yes
Head-mounted cameras provide “see what I see” capability to field based care workers.	2	6	5	No

**These targets were sub-sets and ultimately fed into the VRSS target.*
Source: Benefits Realisation

Over the course of the project all the use cases tracked above demonstrated improvement from their original TRL. Of the five specific applications noted above, two achieved their target TRL and although the other three did not, there was still improvement seen against the baseline at project inception. For four of the use cases noted above, the target time to market was 2023 with one due to be market ready at the end of 2022. Consortium members felt that this project was helpful in shortening the time these projects would have taken to get to market had funding not been provided. Interviewees noted the TRLs for VRSS and the sub-set targets related to it, had been overestimated early in the project and subsequent changes to the product and the technology used took up development resource and required re-baselining. Further reflecting that the efforts made in collaboration with other projects, contributing to establishing ‘Adoption Readiness Levels’ was important especially in sectors such as health and Social Care.

12.4 Collaboration knowledge sharing and overcoming barriers

12.4.1 Sharing learning and best practice

Interviewees across the consortium noted that sharing of learnings both within the consortium and more widely was one of the biggest success points of the project. In setting up a website (www.wmr5g.org.uk) and generating a higher profile of West Mercia as a region and the use cases more specifically, consortium members commented how they were not only able to deal with misinformation effectively but also generate wider interest in what the project aimed to achieve. Interviewees commented that learning was shared across health care staff and patients all of which helped to raise the profile of the use cases developed. In getting a range of different types of organisations together and through the involvement of DCMS there was a lot of required contact between the various partners in the consortium. Furthermore the project then attracted the interest and visit of the team from Berkely Innovation Forum to share learning making an onsite visit to share learning from Smart Villages.

Whilst in general, interviewees praised the success of sharing knowledge across the consortium, there were some comments that perhaps this could have gone further. Overall though a lot of effort went into creating reports, presentations and attending ecosystem events to ensure that the findings from the West Mercia Rural 5G project could be disseminated more widely and consortium members had the chance to learn from other projects in turn. Further work perhaps needs to continue to ensure that the learnings gained from this project are not lost but it has certainly served as a very positive foundation.

Table 73: Publication and events summary

Dissemination Activities	Number of articles/events
Local press	5
National press	1
Telecoms/communication technology industry press or events	25

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

12.4.2 Interaction with wider ecosystem

As touched on above the project was generally successful in ensuring that knowledge was shared across the wider ecosystem. Interviewees noted that the UK5G Innovation network had a lot of events which West Mercia Rural 5G members attended helping the spread of knowledge. With the Innovation Network there was a variety in how involved consortium members were, with some members actively participating in the events with others simply there as attendees.

Interviewees did say that perhaps more could have been carried out to help expand the learnings of the project beyond those who were already aware. This should be a consideration for future programmes.

12.4.3 Business and industry generation

Interviewees noted that the project had helped to develop previously unused health-care solutions and that there were plans to continue this from some of the individual consortium members. Although the project might not have looked directly at increasing revenues and profits, finding methods of improving the financial viability of deploying 5G solutions in rural areas would lead to additional business generation. Not only would it directly help within the healthcare sector, but in making West Mercia a more connected region, it would help to make the region an overall more attractive place for industry investment.

The development of Virtual Reality Simulation Systems was an element which had the stated aim of leading to more commercial opportunities but as of the end of the project, the solution was not quite market ready.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 74: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£1,662,000	£374,000
Number of partners that received funding / contributed R&D	8	6

Source: Benefits Realisation

The total amount spent on this project was nearly £2 million with nearly £1.7 million of this project funding provided by DCMS.

12.5 Programme Processes and DCMS Support

Interviewees noted how helpful DCMS colleagues were in helping to keep track of how well use cases were being delivered and importantly how well the benefits were being captured. The project managers from DCMS were very helpful overall in helping to keep the project ticking over. The benefits realisation reporting had more mixed feedback. Some interviewees felt that it felt like a bureaucratic exercise which had to be carried out rather than something which was really adding a lot of tangible benefit. The consortium members did appreciate that the benefits realisation reporting was a key part of the process with a particular focus on impact, however had the focus been wider and sought generic commentary on the state of the ecosystem than on 'commercial impact' greater learning may have been achieved for the efforts made..

12.6 Overall summary of contribution to success measures

As part of the logic model developed, we generated 11 key success measures to determine the overall success of each project. In summary we found strong evidence of added value against 3 of the 5GTT success measures:

- Information and knowledge is more readily transferred within the 5G ecosystem.
- Public service cost avoidance from use cases that help reduce the burden on public services.
- Projects generated viable networks that fulfilled the specifications to support the 5G applications required.

12.6.1 Additionality

As the project took place in an area which had very low productivity the West Mercia Rural 5G use cases were crucial in helping to provide further connectivity where it previously did not exist. The development of a private network was one of the key elements of the project and helped to support the use cases which were worked on during the project. open RAN was not used during this project as the intended mobile network provider pulled out prior to the commencement of the project. The network, which was built in the end, in part utilised an existing private 5G network, augmenting this with new mast build, tier one vendor radio equipment and made the best of public 4G and 5G networks where available, showing how previous hardware elements could be repurposed into useful elements for this project. Interviewees did notice that the use cases would have potentially been possible using 4G but using a 5G network opened up additional possibilities.

12.6.2 Sustainability

Although the use cases did appear to have moderate success, there was limited evidence of additional investment which was carried out beyond the life cycle of the project. Although there was some investment from consortium members during the project, the fact that these use cases were operating in a rural location perhaps hampered how sustainable the networks were in the long run. Interviewees interestingly noted that private sector partners did not always claim as much funding as they were entitled to and this may have hampered future network developments. The fact that the technology was applied in a healthcare environment may have also presented some barriers in a sector which is already normally limited in terms of additional funding that can be provided to Research and Development initiatives.

13. WM5G TRANSPORT USE CASES

13.1 Overview of the project

The West Midlands 5G (WM5G) Transport use cases sit within the wider WM5G project, which had the stated aims of delivering 5G connectivity to this region across a range of different applications. Working across mobile network operators and providers, transport operators and the automotive industry, this project looked to find ways of implementing 5G to help make a difference to travel and transport in the region.

Table 75: Overall project summary

Project	WM5G Transport Use Cases
5GTT Competition	Urban Connected Communities
Sector	Transport and Logistics
Location	West Midlands
Timeline	September 2018 – March 2022
Lead consortium partner	West Midlands 5G
Additional lead consortium partners	Transport for West Midlands, Blacc, Immense, FirstGroup PLC, Hack Partners Limited, One.Network, University of Warwick, GoMedia Wordnerds, Icomera, AppyWay, Get Mapping, West Midlands Metro, Classone Systems, DigitalRail, Vodafone, InnovateUK, Landmrk, You.Smart.Thing, Imagemakers, Siemens, Earthsense, Vivacity Labs, Vaisala, Elgin
Type of network/technology deployed	Standalone 5G Network
Total project costs	£5,314,457
Funding awarded by DCMS for 5GTT	£3,236,013

13.1.1 Summary of contribution to programme success measures

The WM5G Transport Use Cases resulted in strong evidence of added value of 5G technology against 8 of the 11 5GTT success measures.

Table 76 Summary of impact of WM5G Transport Use Cases

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The project helped to raise the profile of the region but interviewees were unsure on how this translated into the improvement of the global reputation of the UK.	1
Programme activities have attracted further funding within the area of 5G/5G R&D	This programme was very effective in generating funding for R&D in 5G technologies. The consortium members across almost all the use cases invested considerable amounts on research and development during the project.	3
Reduction/removal of barriers has accelerated deployment of 5G in the UK	Interviewees from the consortium were very positive in how mobile network operators and SMEs were able to engage in digital technology. The stated purpose of the	3

Success measure	Evidence	Contribution Score
	project was to increase the knowledge around digital solutions to help organisations make a difference in transport.	
Information and knowledge is more readily transferred within the 5G ecosystem	Members of the consortium stated how several activities took place to share knowledge on what was occurring within the project. They attended a number of events facilitated by DCMS and also presented at a number of events outside of those consisting of 5GTT members.	3
5G networks are more secure than the 4G networks they replace	At the start of this programme, addressing security aspects using new 5G technology were explicitly considered. An independent review of each product was carried out to ensure that the security aspect was always considered. Some of the reasons behind looking to increase adoption of 5G technology was to ensure increased efficiency and security.	3
Additional welfare and environmental benefits	All use cases aimed to increase public welfare and ensure environmental improvements in how people travel. The project looked to encourage the wider use of public transport which resulted in reduced emissions and lower congestion. This achieved primary aim to increase the safety of public transport solutions would lead to wider welfare gains.	3
Public services cost avoidance	A number of local councils and universities were involved across the use cases and there was a focus on improving the access of transport for public use. The commercial focus of the use cases was also a key aim of the programme.	2
Development of industry 5G expertise and increased ability to use 5G for commercial activities	The transport use cases helped to spread knowledge of how 5G technologies can be used for additional commercial activities. This expansion of use cases within the transport industry would not have happened to the same extent without the 5GTT programme. Over 100 people were involved across the different Transport use cases showing the amount of expertise and level of involvement from a number of organisations.	3
Generation of 5G activities beyond the scope of the programme	Members of the consortium attended a range of events within the UK5G innovation network. They also participated in and presented at many events which were more focused on transport to spread knowledge of 5G technologies beyond the scope of the programme itself.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	This programme demonstrated how new 5G technologies could be used within the transport industry. The emphasis on generating commercial outcomes means that generating new business models was a central aim of the project.	3
Projects generated viable networks that fulfilled the	Interviewees noted that all the use cases could have been carried out with previous infrastructure. Despite this setting up stable 5G networks means that the use cases	2

Success measure	Evidence	Contribution Score
specifications to support the 5G applications required	are able to operate in a more effective manner than they were previously.	

13.1.2 Project aims and activities

The Transport Use cases within WM5G covered a range of different aspects. They had key aims of implementing 5G to:

- make transport more efficient and reliable;
- improve access to work, study and leisure; and
- enhance the experience of travellers by improving services and products across the transport system.

All funded projects were led by SMEs apart from the Road Sensor network project which was led by the Transport for West Midlands (TWfM) and developed a range of different technologies to achieve the aims above. Solutions developed included sensor data, machine learning capabilities and data optimisation amongst other aspects. Overall across a range of use cases, this strand of the WM5G project was successful and helped to show how transport could be carried out in an efficient and cost effective way, all the while bringing benefit to the wider West Midlands region.

13.1.3 External factors affecting delivery

Interviewees reported that COVID-19 did not have the large effect that consortium members initially anticipated. It did mean that field testing was limited and that the metro could not be used for a few weeks. In what was a challenging economic environment, where achieving the use cases was difficult, the consortium members were able to manage these issues very effectively. The amount of data that could be collected was reduced, but overall the project partners navigated COVID-19 well.

EU Exit also provided some challenges as there was an impact of some of the parts needed for the Road Sensor Network. This meant that some of the 5G infrastructure needed was difficult to obtain to implement the use cases. Again, despite this challenge, the partners were able to navigate the equipment supply issues and test their use cases.

13.1.4 Timeline

The timeline of the project stayed the same from its inception. Once the full business case had been explored and the programme was approved, the proof of concepts were then carried out, releasing the funding. Interviewees noted that they received assistance from Innovate UK in helping to oversee some use cases but that in general, everything happened as planned. The interviewees from this noted that the project stuck to the timescales laid out in the original plan, a point that consortium members were very proud of.

As the WM5G project was delivered as a ‘programme within a programme’ there is no timeline and delivery RAG rating for the transport use cases specifically.

13.2 Consortium Partners

The following section lays out the range of use cases within the Transport branch of the WM5G project. Across the Transport use cases there were a significant number of consortium members with over 25 organisations and firms involved.

13.2.1 WM5G Transport Use Cases Description

- Bus Occupancy – Comprised 2 consortium members in Hack Partners Limited and FirstGroup PLC who were looking to install 5G powered computer vision system on buses. These were designed to help

accurately count the number of passengers, carry out automatic data uploads and provide bus operators with easy access to data.

- Passenger Management – Comprised of 3 main consortium members in GoMedia, Wordnerds and Icomera. This use case sought to provide rail providers with information that could allow passengers to convey how they are feeling during their journey. This would help rail providers to ensure that passengers are having the best experience possible whilst they are travelling.

- Predikt – Primarily comprised of 2 consortium members AppyWay and Getmapping with a number of additional secondary project partners. They looked to provide an app which would show real time availability for parking to build the most accurate predictive availability product on the market. This app looked to help cut down driving time by up to 30% with significant opportunities for reduced congestion and improved environmental outcomes.

- Transport Accessibility – Comprised of primarily 3 consortium members, Go Media, Birmingham City University and Icomera Ltd working with a number of other partners. They were using 5G to get timely and accurate information to passengers who need additional assistance while in a station or transport network particularly in reference to allowing the visually impaired to have more independent journeys whilst using public transport.

- Urban Tourism – Comprised of 4 main consortium members: You.Smart.Thing., Landmrk, Imagemakers and Oodl. This use case looked to use 5G to generate a travel assistant service enabling consumers to navigate between venues and events to help address the downturn that Covid caused to the leisure industry.

- Capacity Manager - Comprised 5 consortium members in black, Immense, Elgin, University of Warwick and O2. Looking to create a tool to show what the percentage of network capacity is available at any one time to help carry out real time scenarios to be run and gauge the impact of proposed works to help manage networks in a proactive and coordinated way.

- Road Sensor Network – Comprised Over 10 consortium members including universities such as the Universities of Birmingham and Warwick and a range of businesses and public bodies including Siemens, Vodafone, Jacobs, Hickford Construction Ltd and Transport for West Midlands. Put in place several sensors to help improve the traveller experience and give more information to improve traffic management helping to increase efficiency and improve environmental outcomes.

- Other projects included HPOMS (Holistic Pantograph Monitoring System to monitor damage to overhead power lines on trains); Polytrack which monitored railtracks using low costs sensors; and CURBS (road infrastructure monitoring with sensors on public vehicles to detect potholes)[21]

13.2.2 Working with consortium partners

With such a large project and so many disparate use cases, this could have presented some challenges but overall interviewees were positive about how the consortium worked together. One firm dropped out at an early stage of the project but apart from this the consortium remained consistent. Interviewees noted that COVID-19 meant some mobile network operators struggled to engage with the projects. The universities and SMEs had different aims and objectives, but these perspectives were extremely valuable in addressing different strands of the project and providing expertise. Organising all these entities to work cohesively took effort and time but again in the end the outcomes were successful. By and large though, despite these minor grievances, there were no large critical issues and interviewees remarked how they enjoyed working with such a diverse range of partners.

[21] These projects, particularly HPOMS were highlighted as very successful by interviewees, but no benefit realisation reporting data was received for them. Information from interviews and the final report has been included where available.

13.2.3 Personnel

As the table above illustrates, there were a large number of personnel involved in this project with over 100 people involved over the course of the programme. The number of people involved meant that significant coordination needed to be in place to ensure that the project was able to successfully achieve the use cases intended.

13.3 5G Deployment

13.3.1 Approach to deployment

This project aimed to develop 5G networks but with the specific aim of ensuring that these were up to a commercial standard to be used widely. Interviewees noted that the use cases could have probably operated on non-5G networks as the commercial aspect of the networks was the primary focus.

This project looked at a range of different network indicators. Just some of these indicators included:

- Increased data upload speed coupled with additional system accuracy
- Increased precision, improved predictive ability and additional data accuracy and granularity
- The ability to scale solutions without having to use or invest in additional infrastructure
- The ability to handle more and more dense data was relevant across all use cases.
- The availability of associated apps with improved predictive ability for the Predikt and Passenger Movement use cases
- Additional robustness of the networks being used and the reduced need for time and effort to be spent in maintaining these networks.

Overall most of the indicators were valuable for all of the use cases as they all required information to be transferred at faster speeds than had been possible on previous generation technology.

The network tests above focus on a range of aspects which centre around their crucial ability to be used in commercial aspects. Looking to establish the robustness, precision and accuracy of the network are all key elements which need to be in place to ensure that all the use cases could effectively operate as proof of concept for commercial viability.

13.3.2 Use cases

The use cases looked to develop several products and practices. Interviewees from the consortium noted that the project overall was more successful than initially expected and a large part of this was due to the success of the use cases. The transport use cases addressed many aspects such as increasing system accuracy with the bus occupancy use case, generating a commercially viable data model for the capacity manager use case and predictive accuracy in terms of available parking spaces for the Predikt use case.

Just some of the many benefits which were identified during this project included:

- Ensuring that the solutions developed had a higher level of accuracy than those used previously.
- The faster video processing capabilities which 5G provided that were not available with previous generation technology.
- The cost saving aspect which the use cases presented through passengers gaining early insight into potential issues allowing them to be dealt with more quickly and effectively than they were previously.

- The use cases also provide safety benefits to vulnerable passengers as they can now quickly and discreetly feedback on issues they are experiencing on their journeys.
- Finally the environmental and wider social benefits from reduced congestion are key gains generated allowing improved user experience and making the region an overall more attractive prospect to visit and invest in.

The project closure report contain value for money analysis of the different projects and examples are summarised.

Table 77: Monetary benefits of WM5G Transport Use Cases

Project	Employment (Permanent jobs created)	Costs savings	Present Value of Benefits (amount)	Benefit Cost Ratio (BCR)
Bus Occupancy	2	N/A	£872,466	8.64
Passenger Management	20	6,000 hours per year saved for train operators from staff no longer having to monitor chat forums	£9,373,550	23.91
Predikt	2	6,500 hours per year saved for individuals navigating peak times of travel	£793,299	0.82
Road Sensors Network	2	3,600 hours per year saved for TfWM staff taking surveys of road traffic; 29,576 hours per year saved for commuters due to improved traffic management	£4,298,272	0.44
Transport Accessibility	3	N/A	£1,180,699	2.91
Polytrack	5	£95 000 per year saved from early indications of problems on train lines; 5,000 hours per year saved for train operators and passengers from reduced delays through early rectification of track issues	£2,904,651	10.80
HPOMS	2	Train operator cost savings occurring from reduced maintenance due to early identification of issues and less staff patrols needed to evaluate overhead wires.	£10,264,009	22.81

13.3.3 Security impacts

Products and services which transfer data over mobile networks have the risk of being hacked and security implications need to be considered. This project was aware of this from the outset and to this end ensured that there was an independent review of cyber security elements for each of the products and services being

developed. A primary aim of the WM5G use cases was to increase not only commercial viability but also to ensure that these products being developed were also sufficiently secure for wider public use. This security aspect was highlighted throughout the project and the fact that an independent review was set up to oversee this is testament to how large a priority this was as an overall project objective.

13.3.4 Technology Readiness Levels

The transport use cases were very successful with nearly all of them progressing from their initial levels with only a couple remaining constant over the project duration.

Table 78: TRL Summary

Use Case	Technology	Starting TRL	Target TRL	Current/ End TRL	Target met?
Bus Occupancy	Passenger counting system	7	9	9	Yes
Capacity Manager	One Network (previously Elgin)	9	9	N/A	N/A
Capacity Manager	Immense	5	7	5	No
Capacity Manager	Spatio-temporal Machine Learning	3	5	3	No
Passenger Management	Live micro surveying model	4	7	7	Yes
Passenger Management	AI- led complaint categorisation for public transport	5	8	8	Yes
Passenger Management	Visualising complaint data to maximise value for public transport	5	8	8	Yes
Passenger Management	Predictive rail model	2	4	4	Yes
Predikt	Camera hardware	3	6	6	Yes
Predikt	AI analytics solution	1	6	7	Yes
Predikt	Predictive availability	3	6	7	Yes
Urban Tourism	Urban Tourism 5.0 Solution	6	8	5	No
Transport Accessibility	Navigation	6	8	8	Yes
Transport Accessibility	Journey Information	5	8	8	Yes
Transport Accessibility	Explore Surrounding	2	7	8	Yes

Source: Benefits Realisation

Several use cases either met or exceeded their target TRLs. This was one of the highest success rates against any of the other 5GTT projects carried out indicating the overall success level of the transport use cases as a whole. In some cases such as the Predikt or Transport Accessibility, some of the growth experienced was spectacular with the starting TRL progressing from 1 to an end level of 7 with another example of the TRL progressing from a 2 initially to an 8 overall. Across the 5GTT programme as a whole the average increase in TRL was 1.7, from around 4 to around 6. There were a few use cases which did not progress beyond their starting TRL, but these were definitely exceptions rather than norms. Overall these use cases appeared to be some of the most successful across the whole programme.

13.4 Collaboration knowledge sharing and overcoming barriers

13.4.1 Sharing Learning and best practice

Interviews from consortium members were very positive about how learning was shared. As the consortium was comprised of a large number of organisations, particular attention was paid to ensure that they all felt

involved and were engaging in the project. The cyber security assessments mentioned previously were key in ensuring that all the project participants were kept informed of key features which the project was trying to achieve. This was just an example of how project members attempted to remain cohesive and ensure that best practice was maintained across all businesses involved. Regular meetings between the consortium members and DCMS on collaboration and deployments was also a key element to ensure learnings were consistently being shared.

Table 79: Publication and events summary

Dissemination Activities	Number of articles/events
Telecoms/communication technology industry press or events	68

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

13.4.2 Interaction with wider ecosystem

Consortium members as with other projects were actively encouraged to share their learnings not just across the consortium but more widely. Interviewees noted how a number of dissemination activities such as conferences, articles and presentations were carried out. In addition, consortium members engaged with other organisations outside of the programme such as Highways UK to share some of the findings from the programme across wider industry participants. Interviewees were also very positive about the role the UK5G Innovation network played in dissemination and collaboration both in sharing the findings from other 5GTT projects but also in allowing members of the WM5G programme to share elements that they had found during the project's duration. They remarked how engagement with this network was high and across a range of different regions and the collaboration events which they held were very helpful in carrying this out.

13.4.3 Business and industry generation

This project was very effective in generating additional investment from consortium members. This funding exceeded the funding generated from DCMS showing that the consortium members were committed in helping to progress the use cases from this programme. Further investment from third parties and additional investment following the project has not been as strong but there are signs that the collaboration will lead to further investment and growth opportunities.

This project has been very effective in generating new commercial opportunities within the transport industry. Throughout the project a number of new products were created and developed helping to show how the transport industry could operate in a more efficient and environmentally friendly manner. The way in which the large consortium combined several different types of organisations from SMEs to large mobile network operators and local councils showed how 5G could help bring lots of organisations together to help the whole transport industry develop. Interviewees noted that the project was even more successful than initially anticipated. The level of engagement from the transport community and SMEs was a particularly positive element of the programme.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 80: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£2,346,000	£2,334,000

Number of partners that received funding / contributed R&D	18	16

Source: Benefits Realisation

13.5 Processes and support from DCMS

The benefits realisation process was perhaps the only major area of the project that consortium members found difficult. Whilst interviewees noted that DCMS were supportive across the project in many elements, such as helping to set up the business cases and facilitating regular reviews, the benefits realisation reporting was not always the clearest. They remarked how the documents were cumbersome and not always the easiest to understand, in addition to there being so much information to complete. In terms of improvements, it was suggested that the reporting needed to be more streamlined, with the steps and processes better explained. Overall, the WM5G members understood the importance of the benefits reporting and why it had to be carried out, but they believed that the way it was set up and communicated was not very effective. The information omitted from the benefit realisation sheets indicate that the project members did struggle to track the metrics suggested at the business case stage. This required support throughout the project and should be a consideration when looking at which future metrics can be easily assessed as the project progresses.

13.6 Key outcomes and successes

The WM5G project demonstrated strong evidence of the added value of 5G technology against 8 of the 11 5GTT success measures:

- It demonstrated how programme activities could attract further funding within the area of 5G. This was through how most of the consortium members put in considerable investment into their use cases over the course of the project.
- The project was successful in demonstrating the removal of barriers which accelerate the deployment of 5G in the UK. The aim of the project to provide knowledge of digital solutions in the transport industry was a pivotal one in this programme.
- The project demonstrated how information and knowledge is more readily transferred within the 5G ecosystem. Consortium members went to a number of events both as attendees and participants to ensure this knowledge could be disseminated.
- The project demonstrated the security of 5G networks over previous generation technology. The fact that this was a stated aim at the start of the programme and the success achieved against this was a pivotal part of the project overall objectives.
- On the point of additional welfare and environmental benefits, the project was very successful in this regard. By looking to improve welfare of the wider public and reduce environmental impacts the project was successful in showing how the transport industry could be transformed.
- The project was effective in showing how 5G could be used for commercial activities. This was a stated aim of the programme with the use cases demonstrating this effectively.
- The programme through the range of dissemination activities carried out showed how 5G activities could be generated beyond the scope of the programme.
- The programme was able to demonstrate viable business models requiring 5G solutions. The emphasis of the use cases being focused on commercial viability was and the success of these, highlighted how the 5G could generate new solutions in the transport industry.

13.6.1 Additionality

Interviewees noted that all the transport use cases were utilising commercial 5G. Although there was a small amount of private network, this strand of the project mostly relied on the available commercial 5G. With this as context, interviewees remarked that most of the use cases could have been carried out with non-5G capabilities. However, this was not a surprise as all the use cases were looking to develop technologies which were commercially viable. The use cases needed to operate without full reliance on 5G as these networks are not available nationwide so they need to maintain a level of flexibility. The WM5G programme was set up

specifically because of the 5GTT project. Without the initiative of this programme, the use cases being worked on would not have been developed.

13.6.2 Sustainability

The fact that this project was focused on transport use cases, meant that there was a regular emphasis on ensuring that the 5G technology utilised was sustainable both from a network perspective and from an environmental standpoint. Interviewees noted that environmental aspects such as reducing congestion, carbon emission reductions and fuel savings were key objectives of the use cases. Encouraging behaviours which are more sustainable, such as utilising public transport, will lead to improved environmental solutions. However, this would only occur if the 5G networks being developed can sustain the use cases after project completion. To this end the focus on generating networks which were sustainable was a key element of the transport use cases.

14. 5G AMC2

14.1 Overview of the project

This project, led by a tier 1 construction company, supported by a 5G software company and Research and Technical Organisation (RTO). designed, developed and deployed two private, standalone 5G networks using an open RAN approach. This project explored the benefits that 5G and increased connectivity can deliver on construction sites.

A key feature of the project was assessing how high quality 5G networks could operate in remote, rural environments to allow the construction sector to work in a more effective and efficient manner. Two networks were used to test how the use of digital solutions could be accelerated.

Table 81: Overall project summary

Project	5G AMC2
5GTT Competition	Create Window 2
Sector	Construction
Location	Scotland – Shetland and North Lanarkshire
Timeline	November 2020 – March 2022, with a 6-month extension to September 2022
Lead consortium partner	BAM Nuttall
Other consortium partners	AttoCore, BRE
Type of network/technology deployed	Private, Standalone
Total project costs	£1,655,266
Funding awarded by DCMS for 5GTT	£839,078

14.1.1 Project progress on success measures

The AMC2 project has resulted in strong evidence of added value of 5G technology against 6 of the 11 5GTT success measures.

Table 82 Summary of impact of AMC2

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	Whilst this was not an explicit aim of the project, ,deploying a 5G network in a remote location indirectly helped raise the global profile of the UK as a leading 5G nation.	2
Programme activities have attracted further funding within the area of 5G/5G R&D	The project generated some additional investment from consortium members and third party investment . However, the funding was not widespread across the consortium. Follow on projects such as 5G-CONQuEST are examples where AMC2 consortium members have been able to receive additional funding for construction investment. Whilst this was through Innovate UK, the 5GTT project helped to raise the awareness of consortium members of available government funding.	2
Reduction/removal of barriers has accelerated	The project has helped raise awareness of the challenges of deploying 5G in remote, rural regions and in the construction sector. Whilst not all the challenges were overcome as a result of the	3

Success measure	Evidence	Contribution Score
deployment of 5G in the UK	project, it helped to show how 5G based solutions could occur within the construction sector.	
Information and knowledge are more readily transferred within the 5G ecosystem	Consortium members met with other 5GTT construction adjacent projects such as 5G Logistics to learn and share learnings from other organisations. Work by DCMS to facilitate meetings across consortiums and working with the UK5G innovation network was key in spreading knowledge of 5G solutions more widely.	3
5G networks are more secure than the 4G networks they replace	The fact that the network was standalone did provide a security benefit. However, although security assessments were carried out early in the project, these networks were effectively building on existing 4G infrastructure. This is perhaps an area to be built on in future rollouts of 5G technology.	2
Additional welfare and environmental benefits	During the project, welfare and environmental benefits were given focused attention. From not having individuals needing to travel off site, this generated significant environmental benefits from the reduced footprint and travel time, freeing up time to be spent on other tasks. Also with the project operating in the construction sector, the ability for individuals to carry out work in a safer manner with equipment had sizeable welfare improvement benefits.	3
Public services cost avoidance	Avoiding accidents at remote construction sites would result in reduced public services NHS costs due to a lower rate of hospitalisations. This was not explicitly investigated, but is a potential indirect benefit of the project.	1
Development of industry 5G expertise and increased ability to use 5G for commercial activities	A critical aim of the project was showing how the technology could be used in a commercial area and demonstrating that construction is a high-tech industry. Through the project use cases, interviewees commented that this has probably helped to bring development forward by 3-5 years. By combining construction firms with technical expertise, this project was able to make more progress than what could have happened in the absence of this programme.	3
Generation of 5G activities beyond the scope of the programme	The project led to knowledge spreading beyond core consortium members. Through bringing together technological and construction specific expertise, this project was able to achieve much more than what would have happened otherwise. In addition, interviewees remarked how DCMS facilitated conversations and events with UK5G Innovation Network and other 5G projects, which ensured that the impact spread beyond just the AMC2 project itself.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	This project was pivotal in showing how new 5G technologies could be used to help transform the construction sector. Interviewees noted that although further investment is needed, great progress has been made over the course of the project. It has helped to show what is possible and the numerous benefits which could accrue to the construction industry and UK more widely through adopting 5G solutions.	3
Projects generated viable networks that	Though the maturity of 5G was low, and this presented challenges for deployment, the project was successful in some of the 5G	2

Success measure	Evidence	Contribution Score
fulfilled the specifications to support the 5G applications required	examples they looked to put in place. Interviewees noted that a private network was not necessarily needed and that although the use cases had some successes, this project was effectively building on existing 4G infrastructure.	

14.1.2 Project aims and activities

The 5G AMC2 project aimed to:

- show the benefits of using O-RAN networks instead of traditional proprietary networks and tap into the benefit of a possible integration of hardware and software components from multiple vendors rather than being confined to one vendor's proprietary technology.
- demonstrate how the deployed private 5G network integrated with existing construction data management systems installed at a BAM Nuttall construction project in Shetland and Northern Scotland, as well as the BAM offices and depot in Kilsyth.
- deploy and test 5G-enabled solutions for on-site data capture, such as IoT, sensors, surveying drones, and cameras, to enhance conventional and computer-vision solutions and enable Advanced Surveying and Data Streaming that avoided the existing and traditional approach of relaying information through large data sets through point cloud scans.
- deploy and evaluate 5G-enabled management solutions and test the safe deployment of ultra-low latency 5G for Connected and Autonomous Plant. An autonomous prototype vehicle was deployed at Kilsyth and tele-operation of Boston Dynamics Spot robot successfully deployed at Shetland
- assess how 5G supports the evolution of construction plants to meet future industry needs, providing a real-world 5G testbed for the demonstration of a possible remote-control/autonomous plant.
- reduce headcount for future construction sites and explore how 5G can provide access to expert knowledge and advice without the need for travel to site.
- use the ultra-low latency 5G network on the construction site to provide Mixed Reality solutions, such as Microsoft HoloLens, to facilitate communication and reduce the latency barriers to adoption, allowing for Augmented, Virtual, and Mixed Reality and improving construction productivity.
- Quantify the benefits of 5G enabled management solutions in terms of improved productivity, safety and outcomes.
- develop business models for 5G-enabled solution deployment on construction programmes, integrating 5G into physical assets to supply a permanent network, and support services beyond the immediate scope of infrastructure construction and operation.
- share and disseminate learning with the construction and telecommunication sectors.

14.1.3 External factors affecting delivery

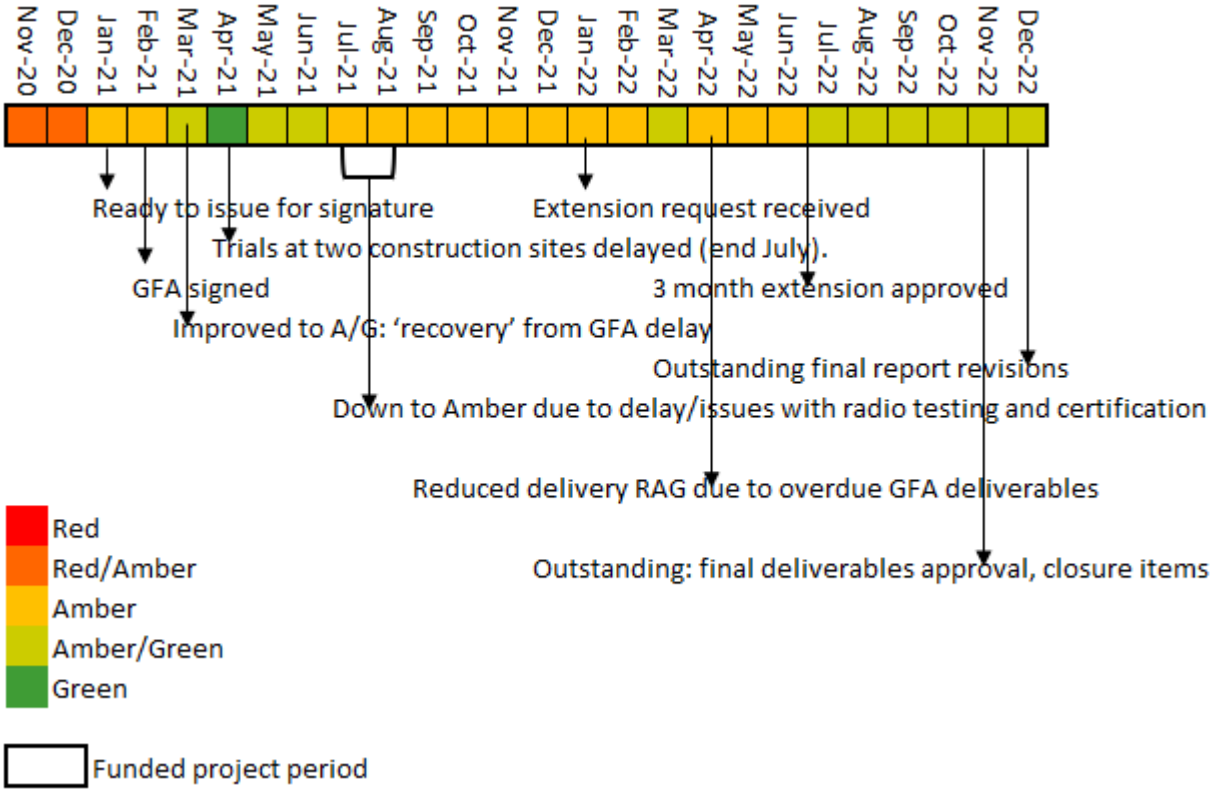
Overall, COVID-19 did pose a problem, but the project overcame most issues. Technology readiness of suppliers was the most important factor for the project to be completed within the timeline. EU Exit, however, was mentioned by the interviewees in that it caused slowdowns in the movement of materials across borders, with some parcels taking over a week to clear customs due to paperwork challenges. A few members of the project were required to carry some items as hand luggage when crossing the border since it was more efficient than having it delivered. In terms of the government requests to avoid high-risk vendors like Huawei, it was not specifically mentioned by the interviewees as posing any difficulty for the completion of the project.

Overall, the challenges mentioned were securing components and devices from suppliers who overpromised product quality.

14.1.4 Timeline

The project received extensions and could not be completed as planned due to supplier issues and devices not being ready. The initial deadline was March 2022, but at that stage the project was not in a position to generate reasonable output and results. The project was granted two sets of three-month extensions, with the latest one ending in September 2022. The interviewees emphasised that the extension was essential as the project had hit a roadblock. A supplier for the radios was selected, but they were far from being ready. At the end, up to 60% of the radios had to be replaced, as the components did not exist and they could not just be switched, causing delay and the need for an extension.

Table 83: RAG rating summary



Source: Programme Monitoring – Success Measures (project funding ended on 30 September 2022 and work was self-funded thereafter)

14.2 Consortium Partners

The project was delivered by a consortium of three members led by BAM Nuttall. More information on the consortium members can be found below.

Table 84: Consortium members, 5G AMC2

Organisation	Type	Role/responsibilities on project	Staff allocated to project
BAM Nuttall	Large	Site provision, exemplar deployment,	Circa 25

AttoCore	SME	5G expertise	6
Building Research Establishment Ltd (BRE)	RTO	RTO	6 (c.1.5FTE)

14.2.1 Working with consortium partners

Interviewees reported smooth collaboration and good teamwork among partners with no changes happening during the project towards the end. BRE and BAM Nuttall had prior experience working together, while AttoCore was a newcomer. The interviewees said the consortium members would apply for future funding from Innovate UK and other sources and would be willing to work together again. This was later confirmed when the existing members were all involved with the next 5G programme 5G-CONQuEST as part of the funding from Innovate UK Smart Grants.

14.2.2 Personnel

The project involved several hundred people over its duration, with 4 to 5 working full-time. No new jobs were created, but existing employees were reassigned to the project. It was reported that AttoCore may have hired additional staff as a result of the project.

14.3 5G Deployment

14.3.1 Approach to deployment

Two Stand Alone private 5G networks were installed on a BAM Nuttall construction project in Shetland and the BAM offices/depot in Kilsyth (housing staff managing the Shetland project), with an integrated network connecting to existing BAM construction data management systems. The 5G network infrastructure deployed to support the 5G AMC2 project use cases was key as an example of how to set up networks in a construction environment. The testbeds were strategically chosen to be established in two separate locations. This meant that the project could reduce the risks when one network broke down, there still existed another network to continue the test and trials of the use cases. The network infrastructure across the two places played different roles in supporting the project, and featured different environment and characteristics of the worksite in which the 5G network infrastructure was deployed.

The testbed located in Kergord, Shetland was purported to test the network in a remote location, sometimes under extreme weather conditions such as high winds. The Shetland HVDC project had a multi-disciplinary 3D model which includes both temporary works and permanent works assets. With the assistance of the IoT sensors and the network that connected the model to the work asset, the team could view how the project appeared at any given point in the programme, which was enabled through 5G-enabled Wi-Fi connectivity using a selection of routers compatible with a private standalone 5G network.

The testbed in Kilsyth was more easily accessible than the Kergord testbed. It was the BAM's regional office and contained a plant workshop and materials storage yard. Some use cases such as Connected and Autonomous Plant were carried out in Kilsyth to demonstrate the delivery of items around the worksite.

The Network Indicators focused on as part of this project included:

- Reduced latency
- Increased reliability of the network with a target during the project of 99% availability of 5G networks during office hours.
- Improved user feedback with the target of a 90% "good" rating
- Improved throughput with a 50Mbps target

Benefits realisation reporting was not able to capture what was achieved at the completion of the project and awareness of more measurable targets will be a key point of consideration for future programmes.

14.3.2 Use cases

The main use cases from this project were the following:

- The enabling of unhindered access by all the site team to BAM's Digital Construction Workspace which is a cloud-based platform for hosting software and data.
- Advanced surveying and data streaming (ASDS) - Fixed cameras/Mixed Reality products delivering IP streams backhauled directly over 5G.
- Advanced Surveying and Data Streaming (ASDS) - Use of a UAV (drone) to stream high-definition live video through the 5G network - interactive live remote site visit
- High Accuracy Asset Location and Tracking (HAALT)
- One Source of Truth / BAMCAM: Use by on-site managers for day-to-day programme management
- Connected and Autonomous Plant (CAP) - Autonomous vehicle for material delivery on site
- CAP - Use of Trimble X7 scanner in conjunction with Boston Dynamics 'Spot' robot for on-site surveying

Key benefits from the use cases that the project measured included:

- The increase in productivity which was generated from many of the activities taking place remotely.
- The environmental and safety gains realised from not needing people to travel on site along with not needing to place construction workers in potentially dangerous situations
- The improvement in the data collection capabilities of site performance due to new machinery and processes in place
- A reduction in the number of construction site defects and lower costs as a consequence of the site operating more effectively.

The following will give the detail of the cost saved as demonstrated by each of the use cases, and the amount of cost avoided based on the estimation of an expanded scenario with a hypothetical project that lasted for four years.

Advanced Surveying and Data Streaming (ASDS)
The drone was used weekly throughout the project in order to survey the site from a general perspective, with feeds/images being recorded for later review by site managers. Drones could also provide live data streams for a 'virtual' site meeting involving, for example, 10 people who would otherwise be required to travel to the site. There would be 48 meetings over the course of the 4-year project if these visits were held monthly.

Benefits and savings: A typical site engineer day rate is £139. The cost of a team of 5 surveyors working for 3 weeks is: £209 per person x 5 people x 15 days = £15,675

Over the course of a 4-year construction there would be 24 of these surveys, leading to savings of £376,200

Benefits and savings owing to virtual meetings=£300,960.

14.3.3 Security impacts

The interviewees emphasised the benefit of the network being completely standalone. Early security assessments were conducted. Several measures were carried out to ensure the safety of the project network:

- The presence of multiple edge points and types significantly increased the risk of attack. It was mitigated by the fact that the consortium had control over the implementation of the private network.
- New traffic patterns: Mesh, east/west and internal traffic flows could be susceptible to attacks from one part of the network to another. This was mitigated by the private network design that connected only to BAM's secure internal network.
- Network slicing. Every slice entailed risks that necessitated per-slice policies and a coherent defence strategy across all slices. Since the onset of the implementation of the network, it included a single network slice, which was exclusively for use by BAM personnel, and that public network devices did not work on the private network.
- Public cloud edge: The move of some workloads to the public cloud introduced new security concerns for service provider networks. In the first instance, BAM mitigated this by hosting all applications on its secured network.
- Botnet playground. Internet of Things devices had low-security measures embedded at the endpoint. This made them an ideal target for coordinated malware attacks. IoT support was not included in the initial implementation of the network until a future time when these security concerns would be addressed.

In general, the project concluded that combining a private network with a standalone network can improve testbed security, providing more control over the network for the users, who are able to place more restrictions and measures over the network's coverage and accessibility so that outsiders cannot access it.

14.3.4 Technology Readiness Levels

The project had mixed levels of success with regards to the TRLs of their use cases. None of the three use cases achieved the target TRL but two of the three use cases did achieve some improvement over the course of the project. It should be noted that development and work in the future such as 5G CONQuEST[22] could further improve the TRL.

Table 85: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
Digital Construction Workspace (DCW)	4/5	Minimum 7	N/A	N/A
Advanced surveying and data streaming (ASDS).	4/5	Minimum 7	6	No
High Accuracy Asset Location and Tracking (HAALT)	4/5	Minimum 7	N/A	N/A
Connected and Autonomous Plant (CAP)	4/5	Minimum 7	N/A	N/A
AI analysis of live video feeds from sites.	4/5	Minimum 7	6	No
5G network for construction	4/5	Minimum 7	N/A	N/A

Source: Benefits Realisation

14.4 Collaboration knowledge sharing and overcoming barriers

14.4.1 Sharing Learning and best practice

Interviewees agreed that the project was able to disseminate the knowledge and lessons learned from the trials to the wider industry, demonstrating the potential for cost-saving practices to be adopted thanks to 5G's availability. Furthermore, by participating in a **variety of events and activities** outside of the construction industry, it was able to reach out to a completely different audience groups who might not always be familiar

[22] GtR (ukri.org)

with construction applications and use cases. An example of such dissemination was the second *'5G in Construction'* roundtable discussion organised by Constructing Excellence on 22 September 2022, where a White paper was created to communicate the key points of the discussion to the wider construction industry. In terms of public engagement, the project was featured on BBC Click and the B1M YouTube channel, which has 2.6 million subscribers, in addition to the dissemination and promotion featured on BAM's own social networking platforms on Twitter and Instagram.

Table 86: Publication and events summary

Dissemination Activities	Number of articles/events
Local press	e.g. BBC Radio Shetland interview
National press	Multiple construction and telecoms media channels
International press	Multiple including BBC Click
Telecoms/communication technology industry press or events	At least 8
Press or events with different sector audience	At least 2

Source: Benefits Realisation and interviews

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

14.4.2 Interaction with wider ecosystem

5G AMC2 was the only construction company among all the 5G projects funded by DCMS that focused on construction-related use cases. The interviewees also reported participating in meetings with industrial partners from other consortiums, including the **Eden Project, 5G Logistics, 5G CAL**, and **Smart Junctions**. These meetings allowed them to discuss resourcing issues stemming from the supply chain crisis and exchange information and views on how 5G technology could be adopted in different contexts. As a construction consortium, the interviewees felt that these were valuable chances to share how 5G technology could be adopted in the challenging environment unique to the construction industry. Interviewees emphasised the advantages of participating in events and forums and getting to know suppliers like Plinx, who they would not have otherwise known about. These connections added significant value to the project, especially using the 5G-enabled Plinx transmitter and hard hat mounted location transponder for the use case High Accuracy Asset Location and Tracking.

5G-AMC2 was shortlisted for several awards, showcasing their active role in the ecosystem. They won the Business Excellence category of the 2022 BAM Nuttall Digital Awards and participated in the BAM UK & Ireland Divisional Digital Awards. Additionally, the project won the NCE Techfest award for Best Use of Technology: Smart Data Collection in Construction. These initiatives helped to increase awareness of the potential value that 5G might have for the construction industry within BAM and the broader construction sector in general.

As mentioned, the consortium **further formed 5G-CONQuEST project** (5G Construction Quick Easy Sustainable Technology) to bring together the knowledge and expertise of other members in the wider ecosystem: Glideology, BRE, Leading Edge Power, AttoCore and BAM. Some of the members belonging to the wider ecosystem were not the core members for 5G-AMC2, but had played a part in the successful delivery of 5G-AMC2.

14.4.3 5G Business and industry generation

As mentioned under sustainability section, the original members of the group went on to form a new consortium 5G-CONQuEST following their collaboration in AMC2. Building on this work 5G-CONQuEST aims to test the viability of a private, standalone 5G network for construction site communication. The leaders of the

project would be Glideology, AttoCore, and Leading Edge, with BAM representing the customer and providing site access and insight. The Building Research Establishment would take the role to quantify the benefits and disseminate the results to wider stakeholder groups and the public. Note that Leading Edge, a new SME member leading the 5G-CONQuEST, was responsible for the renewable power system at Kilsyth during their involvement in 5G AMC2. This was successfully awarded funding by Innovate UK in September 2022.

The table below summarises the funding received from DCMS and how many organisations contributed to R&D on this project. It is not possible from the information available to disaggregate how much was received through third party investment.

Table 87: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£845,000	£1,322,000
Number of partners that received funding / contributed R&D	3	2

Source: Benefits Realisation

14.5 Programme processes and DCMS support

Interviewees noted that the funding application was difficult due to the fact that the consortium was not established before. They also felt some of the reporting elements required for the consortium by DCMS were challenging and at times over elaborate as it was unclear whether specific elements required focus or not. Some of the documents were locked down and hard to edit and required help from DCMS. The general benefit realisation reporting in the end was remarked as fine but just another document to fill in.

Interviewees noted that DCMS were effective in joining calls with other project stakeholders. The DCMS assigned project manager was helpful in assisting project members in filling out the reporting requirements. When required DCMS were helpful with escalation calls with suppliers and their support was useful with certain challenging conversations.

14.5.1 Marketing and communications

Interviewees noted that being part of the UK5G network was effective and helpful in ensuring that the AMC2 project got wider exposure and knowledge of their use cases spread. There were workshops held with the UK5G Innovation network which were well received. The working group sessions held were also effective in providing insight to other consortium members of how the project was progressing but also in providing information on activities within other individual projects. They also noted how the marketing and communication around the programme was well structured. An array of awareness events and slide decks were made available to help share knowledge of what was occurring within the project.

14.6 Key outcomes and successes

The 5G AMC2 project demonstrated strong evidence of the added value of 5G technology against 6 of the 11 5GTT success measures:

- It demonstrated the reduction/removal of barriers which has accelerated deployment of 5G in the UK. In looking to put in 5G technology in rural locations, this project took steps to show the construction benefits of 5G based solutions.
- It was very effective in showing how information and knowledge can be more readily transferred within the 5G ecosystem. The work put in place across the consortium and DCMS helping to connect consortium members with UK5G Innovation network was clear evidence of helping to share knowledge widely.

- The project was effective in showing the environmental and welfare benefits from 5G. In supporting remote applications and helping improve site safety, construction workers not only had to travel less but could carry out tasks with a much reduced chance of physical harm.
- The project was also helpful in developing industry expertise of 5G and using 5G commercially. With 5G solutions and knowledge being at an early stage, this project was helpful in showing how the construction sector could benefit and sharing this expertise with experienced construction industry individuals to share this more widely.
- The project was helpful in generating activities beyond the scope of this programme. Through the events organised and facilitated by DCMS, consortium members were able to learn and share learning of knowledge acquired. By combining expertise this knowledge could be extended much more widely than if members were operating in silos.
- The project was key in showing how new business models requiring 5G could be beneficial. Although not at the finished stage, consortium members were able to recognise how the construction specific applications of 5G could be transformative for their industry along with the significant efficiency gains and new operating models which could surface as a consequence.

14.6.1 Additionality

Interviewees agreed that the project's success was dependent on funding from DCMS. The funding was crucial in speeding up the testing and trials necessary to adopt 5G technology in construction worksites. Interviewees also noted that another construction company (not funded by DCMS) that was attempting to establish 5G connectivity only built a single network with one radio, compared to 5G AMC2's two separate networks with three radios each.

Interviewees from construction site owners also added that about four to five months ago, the project appeared to be wasting funding, but now in retrospect it successfully demonstrated the use cases and benefits were starting to become apparent. The construction industry's relatively low growth and margins made it unappealing for investment from large network providers like Nokia or Vodafone. As a result, the sector found it more challenging to attract funding in comparison to other sectors. Government funding for the construction sector is therefore playing a crucial role in addressing the lack of incentive, with an estimated delay of at least three to five years without it.

Interviewees highlighted that most use cases provided significant and immediate efficiency gains, as well as environmental benefits from reduced travel time. It would not be possible to demonstrate these benefits without DCMS which accelerated progress through increased collaboration among parties.

Finally, an important key area was the use of an O-Radio Access Network (O-RAN). The fact that the network was established and put together using Open RAN technology demonstrated that it was possible to diversify network providers and suppliers, and integrate various hardware and software components from multiple vendors, rather than being confined to one vendor's proprietary technology.

14.6.2 Sustainability

Two networks were situated at the worksite of the Shetland HVDC project in Kergord, Shetland and the BAM regional offices and depot at Kilsyth in Scotland. It was decided that there was no internal business justification for further spending to maintain and upgrade the equipment remaining at Kergord, partly due to the remoteness of the work site. However, if external R&D funding could be acquired in the future, the networks would continue to be functional and accessible as testbeds. 5G AMC2 stated they will maintain communication with the supply chain partners and provide support for additional software testing after the deployment of their lab setup, which was made possible through the project.

The testbed location at Kilsyth is more accessible, and there were more parties interested in continuing utilisation of the network. Other programmes such as 5PRING programme and Scotland 5G Centre inquired

about the possibility of accessing the testbed. However, further work needed to be done to ensure the working of the testbed before any commitment was made.

Some of the members of the group went on and formed new partnerships amongst themselves. A new project that directly formed out of 5G AMC2 was 5G-CONQuEST, which was established to test the viability of a private, stand-alone, cellular 5G network solution for communication within the construction worksite. 5G-CONQuEST would be led by UK System Integrator Glideology with SMEs AttoCore (5G-core) and Leading Edge (off-grid energy). The original members of 5G AMC2, construction contractor BAM, would represent the customer and user while providing site access and insight, whilst another 5G AMC2 member, Building Research Establishment (BRE), would be responsible for quantifying the benefits for construction and leading dissemination of the results. Note that the new SME member within the 5G-CONQuEST, Leading Edge, was responsible for the development of the renewable power system at Kilsyth, critical for the powering up of the radio device.

In terms of project assets, there were several purchases made during the 5G AMC2 project. These included 6 Benetel RAN650 radios, 3 Comms 365 5G Mini routers, and 2 Robustel routers. However, it was reported that they were procured for the sole purpose of enabling the use cases for the 5G-AMC2 project and are only compatible with private 5G networks, therefore, limiting their value for use in other contexts and setups. The 5G routers have potential to support the 5G-CONQuEST project, which was set to commence in January 2023.

15. 5G FACTORY OF THE FUTURE

15.1 Overview of the project

The 5G Factory of the Future project aimed to find new and efficient manufacturing methods. Over a two year period, this project used 5G solutions in a manufacturing context across 5 use cases. The project explored ways to improve manufacturer performance through lowering latency, increasing bandwidth and seeking to ensure these use cases could be carried out across a secure network.

Table 88: Overall project summary

Project	5G Factory of the Future
5GTT Competition	Create Window 1
Sector	Manufacturing
Location	Sheffield and Northwest of England
Timeline	August 2020 to August 2022, extended to March 2023[23]
Lead consortium partner	AMRC Northwest and the University of Sheffield
Other consortium partners	BAE Systems (Operations) Limited, IBM United Kingdom Limited, AQ Limited, Machine Tool Technologies Limited, Miralis Data Limited, Digital Catapult.
Type of network/technology deployed	Private, standalone 5G network
Total project costs	£9,297.426
Funding awarded by DCMS for 5GTT	£4,971,431

15.1.1 Progress against programme success measures

5G FoF resulted in strong evidence of added value of 5G technology against 7 of the 11 5GTT success measures.

Table 89 Summary of impact of 5G Factory of the Future

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	This project had some limited impacts of increasing the profile of the UK as a leading nation. In showing how 5G could be used in the industrial space, it provided a signal that the UK was a leader in generating innovative and creative 5G solutions.	2
Programme activities have attracted further funding within the area of 5G/5G R&D	Miralis carried out any additional investment in 5G related technology following the project and a limited amount of third party investment was generated. The final report highlights three projects that have been awarded further funding as a result of the network in place at the AMRC site.	2
Reduction/removal of barriers has accelerated	Interviewees noted that this project was useful in reducing barriers to 5G technology within the manufacturing sector. Although there was a range across the effectiveness of the use cases, on the	3

[23] This project completed in March 2023 and this case study was prepared in January-February 2023. Final BRs and project final reports were not available at this time.

Success measure	Evidence	Contribution Score
deployment of 5G in the UK	whole the project was useful in showing how these technologies could be used more effectively.	
Information and knowledge is more readily transferred within the 5G ecosystem	Interviewees were positive about the effect of the project in allowing learnings to be shared both across consortium members and also across the wider 5G ecosystem. The extension of the project also ensured that further findings and subsequent dissemination could take place. Interviewees were generally positive about the marketing around the 5GTT programme overall.	3
5G networks are more secure than the 4G networks they replace	This project had a specific security expert who looked extensively at the security of the network. Interviewees noted that the project helped to improve knowledge of the security capabilities of 5G within a manufacturing context.	3
Additional welfare and environmental benefits	This project had a specific aim to look at the environmental benefits which arose from using 5G solutions in manufacturing. There were a few use cases which specifically looked at how manufacturing facilities were able to operate in a more environmentally conscious manner. The savings and improvements generated in this area indicate that this was a successful arm of the project.	3
Public services cost avoidance	This project did not specifically look to target public sector improvements but instead how the manufacturing sector could benefit from 5G technologies. Whilst there may have been some public sector benefits, these were not focused on in this project.	0
Development of industry 5G expertise and increased ability to use 5G for commercial activities	This project was almost exclusively focused on developing 5G technologies to use within the commercial space. Although the use cases had varying success, overall interviewees noted that this project was effective in increasing expertise in how 5G could be used commercially in the manufacturing sector. They noted how the project helped to bring solutions which were not close to being commercialised forward by at least two years.	3
Generation of 5G activities beyond the scope of the programme	Interviewees noted that there were a number of conferences where learning was shared across the ecosystem. The dissemination activities carried out also helped to share learnings of the project beyond just consortium members, and as stated above, they have received further funding for other projects.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	The project focused on a number of applications to help manufacturing firms operate more effectively. Across a number of areas from reducing waste, to reducing the number of defects present, many of the use cases were able to show how 5G could help manufacturing firms operate more effectively.	3
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	Despite delays, this project was relatively successful in showing how 5G could support manufacturing use cases.	2

15.1.2 Project aims and activities

The 5G Factory of the Future had many stated aims. It looked to demonstrate the cost-efficiency of manufacturing related 5G technology; accelerate deployment and testing of new solutions and services to companies of various sizes; and encourage collaborative research and innovation projects. It was hoped that this project would create a blueprint which could be followed within the manufacturing sector for smart factory connectivity and take advantage of the benefits that arose from industrial digitalisation. Overall, the 5G Factory of the Future was aiming to provide new ways to facilitate UK manufacturing to improve efficiency, productivity and safety. Overall, this project was fairly successful in achieving their aims. Whilst there were delays caused by equipment issues, those involved with the project noted that it was successful in sharing knowledge, improving security and demonstrating how 5G could be used in an industrial setting.

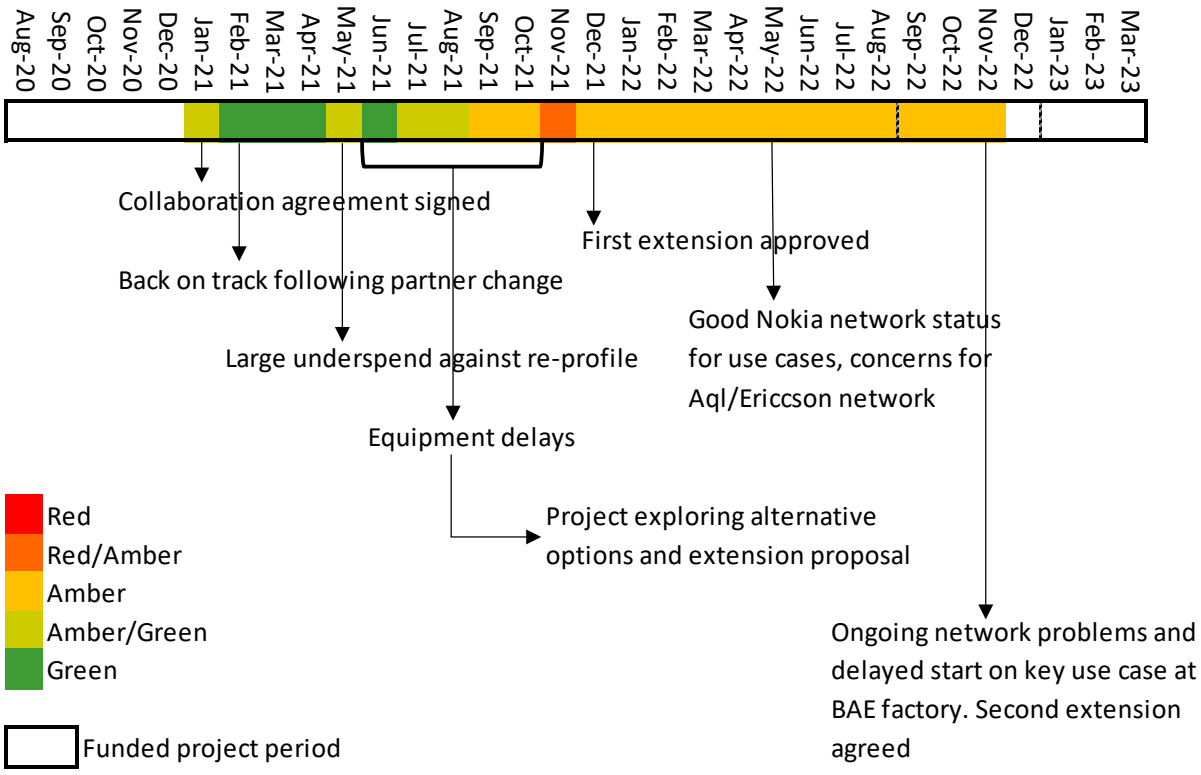
15.1.3 External factors affecting delivery

Three was initially named as a partner, but were replaced by Aql before the first collaboration agreement was signed, although this change did cause some delays to the overall project. The onset of COVID-19 at an early stage of the project meant that working patterns had to be changed. This initially presented some challenges from people adapting to new ways of working but this was an issue that many project members had to adapt to. This impact was difficult to directly quantify but it certainly had an impact. The UK exit from the EU also presented challenges as it resulted in chip shortages which again had an impact on equipment being supplied. Overall despite these challenges the project was successful in showing how 5G could be used within the manufacturing sector.

15.1.4 Timeline

The initial timeline was for this to be a two year project running from August 2020 to August 2022. Delays caused by the shortage of smart chips meant that one of the partners was not able to install and resulted in the project not being officially completed until March 2023.

Figure 18: Project timeline and delivery RAG rating



Source: 5GTT Delivery Dashboard

15.2 Consortium Partners

The project was delivered by a consortium of seven organisations led by the University of Sheffield/ Advanced Manufacturing Research Centre (AMRC). As noted above with Huawei having to be replaced, it meant that the project needed to find a new 5G supplier. The consortium did not change over the course of the project.

Table 90: Consortium members, 5G Factory of the Future

Organisation	Type	Role/responsibilities on project	Staff allocated to project
AMRC Northwest / University of Sheffield	Research	Project Lead, Use case R&D, Open access demonstration, Dissemination, Business sustainability	2 departments
BAE Systems (operations) Limited	Manufacture of air and spacecraft and related machinery, Defence activities	End user, Use case development, Dissemination, Business sustainability	3 FTE (with supporting shared service staff)
IBM United Kingdom Limited	Manufacture of computers and peripheral equipment	AI platform supplier, Use case development	8

Organisation	Type	Role/responsibilities on project	Staff allocated to project
(AQ) Limited	Other telecommunications activities	Network supplier	10 (working across multiple projects) 3 FTE
Machine Tool Technologies Limited	Manufacture of other general-purpose machinery not elsewhere classified, Wholesale of machine tools	Use case development	8
Miralis Data Limited	Business and domestic software development, Data processing, hosting and related activities, Management consultancy activities other than financial management	Use case development	11 (working across multiple projects) 2 FTE
Digital Catapult	Other professional, scientific, and technical activities not elsewhere classified	Network Integration, Design Authority, Dissemination	16

15.2.1 Working with consortium partners

Interviewees noted that consortium members worked very well over the course of the project. Despite the challenges caused at the outset, all the members were able to work well together. Communication overall was efficient and encouraging, given the fact that the consortium members had never worked together previously.

15.2.2 Personnel

Over the course of the project there were more than 50 people involved in varying capacities. Some of the personnel were involved in multiple 5GTT projects so were not exclusively assigned to Factory of the Future.

15.3 5G Deployment

15.3.1 Approach to deployment

The project looked to deploy private 5G networks to help support the five use cases being tested as a result of this project. Whilst the project did not look to deploy Open RAN, it did look to deploy a private network which remained in place after the noted project completion date.

As the table below demonstrates, the key elements assessed as part of this project were latency, data processing speed and the ability to connect a significant number of devices to the same network without suffering a loss of quality.

Table 91: Network indicators

Indicator	Measure	Baseline	Target	Achieved at end of project
End to End Latency	Milliseconds	4G (60ms)	RTM: 10ms	15ms; Best achieved (end-to-end / return trip) on Nokia SA network (AMRC site) 50ms; device (BAE Site) to device (AMRC site) 33ms; device to device (BAE & AMRC site)
Peak Data Rate	Bytes per second	5G NSA (80mbps downlink / 40mbps uplink)	5G NSA (80mbps downlink / 40mbps uplink) RTM: 43mbps uplink HRS: 100mbps downlink CCS: N/A DT: N/A FEM: 40mbps uplink	(AMRC to BAE site) Max upload: 79.4 Mbit/s and (AMRC to BAE site) Max Download: 78.9 Mbit/s (AMRC) Max upload: 59mbps (AMRC) Max download: 689mbps (AMRC device to device): 40mbps
Number of IoT Connected Devices	Number of Devices	NB-IoT	AMRC: 50 (5G enabled) BAE FoF: 20	3-4 currently AMRC Kitting cell 1-2 (4G) CCS BAE FoF: 5 (non-5G)

Source: Benefits Realisation

15.3.2 Use cases

Use cases and benefits included:

Real Time Monitoring and Closed Loop Control. This use case looked to reduce the cost and time associated with defects and quality issues. It targeted challenges such as addressing uncertainty in manufacturing processes, reactive vs adaptive controls and the latency challenges of high frequency data. This was linked to creating a no-fault forward manufacturing system. This use case aimed to generate a 15% reduction in the number of defects helping to improve the amount of machine downtime. Monitoring information shows this use case achieved its target with an estimated 15-25% reduction realised in the number of defects, amount of waste generated and machine downtime.

Factory Ecosystem Monitoring. This use case looked to reduce the amount of infrastructure and through life operational costs via real-time agile monitoring of critical production environments. Several were looking to be addressed via this use case such as gaining the ability to monitor the environment around manufacturing facilities that could influence operations and create a flexible manufacturing capability with minimal fixed infrastructure. The use case had a target of generating a 30% reduction in overall tooling. The result was an estimated 5-10% improvement in machine utilisation, a 10-15% reduction in energy use and a 20% improvement in maintenance time, according to project reporting.

Chain of Custody System. This use case looked to reduce wasted material, increase visibility across the supply chain network and guarantee operational efficiency and delivery to customers. The use case looked to address a number of challenges such as developing a solution agnostic to sensors and hardware, optimising packing based on layouts and 3D nesting, plus creating centralised tracking of a product through the supply chain. There was a target of a 15% reduction of manufacturing time, an estimated 30% reduction in lost and damaged assets, and also recorded improved schedule accuracy and supply chain transparency with real time condition monitoring for assets, based on project reporting.

Distributed and Shared Hybrid Reality Spaces. This project looked to enable real time rich information and reduce time to print drawings. This allowed experts to work off-site and inspection, supervision, and approvals could take place remotely. Monitoring information records a target of 15% reduction in manufacturing time and 10% reduction in printing drawings. The final results of other measures included a 15% reduction in maintenance time and a 65% reduction in travel costs.

15.3.3 Security impacts

The project aimed to identify whether the 5G technology would have an impact on improving security. The project team therefore included a security expert who was hired to address the resilience impacts of the network being put in place. Interviewees remarked that this project helped consortium members to gain more understanding of the potential security benefits that 5G could have within the manufacturing industry specifically. Tests also showed some vulnerabilities. For example, radio jamming successfully collapsed the network. The final report for the project highlighted a need for further security testing such as unauthorised access/DDoS attack and data poisoning.

15.3.4 Technology Readiness Levels

The use cases did not progress from their starting TRL remaining constant over the lifespan of the project.

Table 92: TRL Summary

	Starting TRL	Target TRL	Current/ End TRL	Target met?
Real-time Monitoring and Adaptive Closed-Loop Control (RTM)	5	7	6	No
Digital Twin Track and Trace (DTT)	6	8	6	No
Factory Ecosystem Monitoring (FEM)	7	9	7	No
Chain of Custody System (CCS)	7	9	7	No
Distributed and Shared Hybrid Reality Spaces (HRS)	4	7	4	No

Source: Benefits Realisation

Although the TRL of the use cases did not progress beyond their starting TRL, each of the use cases still did achieve some level of success helping to improve understanding of manufacturing use cases.

15.4 Collaboration knowledge sharing and overcoming barriers

15.4.1 Sharing Learning and best practice

Interviewees were very positive about how this project allowed for sharing and best practice to be shared not just across the consortium members but throughout the wider 5G ecosystem. They remarked on how marketing and communication around the 5GTT programme more widely was effective and was at the appropriate level ensuring that members were not bombarded with information. Interviewees were also very positive about how consortium members carried out a lot of dissemination activities during the lifecycle of the project through conferences and articles. DCMS were also noted as being very helpful in facilitating the development of new relationships both through assistance with project management of the Factory of the Future project but also through linking consortium members to the UK5G network. In general the sharing of learning and best practices was one of the best features of the project with consortium members working well together and looking to take these relationships forward into new ventures.

Table 93: Publication and events summary

Dissemination Activities	Number of articles/events
Telecoms/communication technology industry press or events	31

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

15.4.2 Interaction with wider ecosystem

As alluded to above, one of the main benefits arising from this project was how it helped to foster collaboration from consortium members to the wider 5G network. DCMS helped to facilitate these relationships and during the project through working groups and conferences members from the Factory of the Future were able to collaborate and work closely with several other 5G projects. It helped that some of the consortium members were already involved in other projects and this was valuable in sharing knowledge across the 5G ecosystem and bringing learning from other 5GTT projects into this one.

15.4.3 Business and industry generation

This project specifically looked to increase awareness of 5G solutions within the manufacturing space. The use cases specified above highlight the various applications of this technology and how they offer the chance for manufacturing firms to operate in new and more efficient ways. Interviewees noted that this project was not just focused on increasing revenues and profits, but also in finding ways to generate greater productivity and efficiency of 5G solutions. They remarked how the new solutions developed allowed consortium members to enter new markets and have interactions with new potential partners and customers. All of these elements point to interviewees feeling confident that this project developed new business opportunities and showed how the manufacturing industry can operate more effectively.

Table 94: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	£2,300,000	£200,000
Number of partners that received funding / contributed R&D	2	2

Source: Benefits Realisation

The testbed and expertise developed over the course of the project has secured follow on follow on projects at AMRC NW including

- for the YO-RAN project which was awarded funding through FORNC;
- 5GAMMEx – a £100,000 grant awarded by BEIS/DSIT to expand the ultra-low latency real-time machining use case. The grant was awarded under the UK-Turley Tactical programmes and is supported by Nokia UK and Nokia Turkey
- The AMRC Low Carbon Smart Factory Demonstrator. This £2.5million project funded by the Lancashire LEP aims to reduce the carbon footprint of old and new buildings and help manufacturing companies reduce carbon emissions.

15.5 Programme processes and DCMS Support

Interviewees noted that DCMS were very supportive in terms of organising project consortium members and helping collaboration across these organisations. The consortium members did note that Benefit Realisation reporting was difficult to carry out and that consortium members were often unaware of what DCMS wanted them to carry out.

15.6 Overall summary of contribution to success measures

The Factory of the Future project resulted in strong evidence of added value of 5G technology against 7 of the 11 5GTT success measures:

- It was effective in demonstrating the reduction and removal of barriers helping to accelerate the deployment of 5G in the UK.
- The project was successful in demonstrating how information and knowledge can be transferred more readily within the 5G ecosystem.
- The project through its use cases helped to demonstrate how 5G networks are more secure than previous generation technology.
- The project demonstrated numerous examples of additional welfare and environmental benefits the 5G technology generated for the manufacturing sector.
- The project was valuable in showing how 5G can help in the development of industry 5G expertise and increasing the ability for 5G to be used in commercial ventures.
- The project was able to demonstrate the generation of 5G activities beyond the scope of the programme.
- Finally, the programme was able to show how new business models requiring 5G could be facilitated.

15.6.1 Additionality

Interviewees noted that the programme helped to accelerate a project which might not have happened for a further two years without project funding. They noted that whilst in theory all of the use cases could have been carried out on previous generation technologies, in practice this would have been very difficult. The 5G technology definitely helped to ensure the use cases were carried out more effectively than they would have been on previous generation technology.

15.6.2 Sustainability

Interviewees did note that new job roles were created due to this programme. The use cases addressed a number of elements from reduction in lost and damaged assets, to reducing the number of defects and amount of waste generated. Lessons learned during this project can be shared more widely across the manufacturing sector. The network developed as a result of the project remained in place after the project was completed.

16. WM5G INFRASTRUCTURE ACCELERATOR

16.1 Overview of the project

The 5G Infrastructure Accelerator (5G IA) workstream sits within the wider 'West Midlands 5G' (WM5G) project which aimed to stimulate the growth and development of a thriving 5G ecosystem in the West Midlands region. The primary objective of the 5G IA workstream was to accelerate the deployment of 5G networks in the West Midlands by overcoming existing barriers and acting as a mediator between the Local Authorities (LA) and Infrastructure Providers (IP). While the workstream itself did not involve the deployment of a 5G network, it undertook several activities such as mapping public assets and developing a commercial and technical solution for mass outdoor small cell deployment.

Table 95: Overall project summary

Project	WM5G Infrastructure Accelerator
5GTT Competition	Urban Connected Communities (UCC)
Sector	Digital Infrastructure
Location	West Midlands
Timeline	September 2019 – March 2022
Lead consortium partner	WM5G
Other consortium partners	Birmingham City University, Farrpoint, P3 (Umlaut), Gately Hamer, Gately Hamer, Gately Plc, KPMG, Built Environment Networking Limited, Sitenna UK Limited.
Type of network/technology deployed	5G networks
Total project costs	£2 million
Funding awarded by DCMS for 5GTT	£4 million

16.1.1 Overall summary of contribution to success measures

The WM5G Infrastructure Accelerator resulted in strong evidence of added value of 5G technology against 7 of the 11 5GTT success measures.

Table 96 Summary of impact of WM5G Infrastructure Accelerator

Success measure	Evidence	Contribution Score
The reputation of the UK as a leading 5G nation has improved	The WM5G IA workstream was mainly focused on improving the speed of deploying mobile networks in the West Midlands. However, the workstream participated in several knowledge exchange events which were publicised worldwide. As well as this, its outputs which include the digital connected map, standardised documents, and barrier busting activities have the scope to be used throughout the EU.	2
Programme activities have attracted further funding within the area of 5G/5G R&D	The workstream's activities have resulted in the continuation of its barrier busting activities which is being provided by WM5G on a commercial basis. Besides, DCMS is supporting the further development of the barrier busting activities and the connected map through the DCIA and ARI-5G programmes.	3

Success measure	Evidence	Contribution Score
Reduction/removal of barriers has accelerated deployment of 5G in the UK	The workstream's activities has resulted in a 4.5 month reduction in the time to deployment of small cell 5G network in the West Midlands. Apart from this, it has conducted best practice for negotiations between the LAs and the MNOs by developing standardised lease agreements and wayleaves.	3
Information and knowledge is more readily transferred within the 5G ecosystem	The workstream widely participated in knowledge sharing activities and events both within and outside the 5G ecosystem. Apart from participating in events, it shared blog posts, had an active social media presence on Twitter and LinkedIn, and shared a quarterly update report to a wide range of LAs.	3
5G networks are more secure than the 5G networks they replace	The workstream did not deploy a 5G network.	0
Additional welfare and environmental benefits	Apart from the reduction in time to deployment and costs avoided to MNOs and LAs, it is estimated that the workstream delivered approximately £100 million in benefits to the regional economy.	2
Public services cost avoidance	By reducing the time to deployment, the workstream has generated estimated savings of £33 million to LAs and £7 million to MNOs and IPs over the next 5 years (2022 – 2027).	3
Development of industry 5G expertise and increased ability to use 5G for commercial activities	The workstream educated over 100 employees from LAs on topics ranging from a general overview of 5G, Town and Country Planning, and the Electronic Communications Code (ECC). It employed at least 2 full time and 2 part time staff during its course.	3
Generation of 5G activities beyond the scope of the programme	The workstream is providing barrier busting activities commercially to LAs and MNOs. Furthermore, DCMS has announced the DCIA and ARI-5G which will further develop the connected map.	3
Programme activities have generated demand/ supply certainty and or new viable business models requiring 5G and or related telecoms technologies	The activities of the workstream has increased the speed at which 5G mobile networks can be deployed in the West Midlands region. This has been widely accepted by LAs and MNOs and during the course of the workstream. The WM5G IA team have received Expressions of Interest to adopt their process improvements by several LAs outside the West Midlands.	3
Projects generated viable networks that fulfilled the specifications to support the 5G applications required	The main focus of the workstream was to bridge communication gaps between MNOs and LAs to facilitate faster 5G network deployment. However, the workstream was not involved in deploying 5G network.	0

16.1.2 Project aims and activities

The 5G Infrastructure Accelerator was one of the key workstreams of the WM5G project. Its primary objective was to speed up the deployment of 5G networks in the West Midlands region by working in partnership with LAs and Mobile Network Operators (MNO). To achieve its objectives, the 5G IA undertook several activities including:

- Exploring neutral host solutions – a single shared network used by multiple MNOs on an open access basis;
- Hosting a small cell design competition and supporting three pilot deployments of 5G networks;
- Mapping public assets and standardising the process to access public assets to build smart infrastructure;
- Barrier busting by educating the LAs and the IPs, and acting as a mediator between them. This was aimed at facilitating the wayleaves and lease agreement processes and reducing time to deployment; and
- Supporting the deployment for Fibre networks for neutral hosts and other networks.

Although not all the benefits of the workstream have been realised, 5G IA's activities have resulted in notable outputs and emerging outcomes, including:

- A reduction of 4.5 months in time to deployment of 5G networks in the West Midlands;
- Cost savings worth £7 million to MNOs and £33 million to LAs over the next 5 years (2022 to 2027);
- A faster process for MNOs and LAs to access public assets and approve 5G network deployments through asset map.
- Wider benefits to the regional economy of £100 million due to earlier deployments of 5G networks.

16.1.3 External factors affecting delivery

Consultation revealed that trade regulations against High Risk Vendors (HRV) impacted the speed at which MNOs were deploying the networks they had initially planned. The lead stakeholder mentioned that MNOs were sceptical of investing in high risk equipment from Huawei which resulted in a diversion of resources from network deployment to changing of equipment and finding alternate vendors. This situation was exacerbated by COVID-19, however the stakeholder also mentioned that online meetings resulted in 5G IA having a greater number of interactions with LAs which was an unintended positive outcome of COVID-19.

16.1.4 Timeline

The project lasted from September 2019 to March 2022. Despite the disruptions mentioned above, it was successful in delivering its aims. This is confirmed by the lead stakeholder, who mentioned that 5G IA delivered its aims in a timely manner.

There is no timeline for this specific project, as it belongs to the wider WM5G programme.

16.2 Consortium Partners

Table 97: Consortium members, WM5G Infrastructure Accelerator

Organisation	Type	Role/responsibilities on project	Staff allocated to project
Birmingham City University (BCU)	Academic	Expertise/support	1 department

Organisation	Type	Role/responsibilities on project	Staff allocated to project
University of Bristol	Academic	N/A	N/A
Midlands Engine	Investment in Midlands businesses	Support for expansion of the connected map across the midlands	0
Pickstock group	Modular buildings manufacturers and Fibre providers	Interest in deploying fibre in the UK. WM5G stimulating discussion with Birmingham CC. Plus possible opportunity with new smart factory in WM.	0
Farrpoint	Consultancy	Building business case for full fibre	2
P3 (Umlaut)	Consultancy	Providing mobile coverage and capacity data for WM	2
Gately Hamer	Legal and Surveying practice	Expertise in surveying and legal around the ECC. Plus local council connections	4
Vodafone	Mobile Network Operator	Information sharing around 5G network progress and working with WM5G Barrier busting to resolve issues with Local councils	0
BT/EE	Mobile Network Operator	Information sharing around 5G network progress and working with WM5G Barrier busting to resolve issues with Local councils	0
Three	Mobile Network Operator	Information sharing around 5G network progress and working with WM5G Barrier busting to resolve issues with Local councils	0
O2	Mobile Network Operator	Information sharing around 5G network progress and working with WM5G Barrier busting to resolve issues with Local councils	0
Cornerstone	Mobile Network Operator Joint Venture Infrastructure company (TEF/Vodafone)	Information sharing around 5G network progress and working with WM5G Barrier busting to resolve issues with Local councils	0
MBNL	Mobile Network Operator Joint Venture Infrastructure company (TEF/Vodafone)	Information sharing around 5G network progress and working with WM5G Barrier busting to resolve issues with Local councils	0
BT Openreach	Fibre Operator	Information sharing around fibre networks and stimulating discussions between Local Councils around anchor tenancy models	0
Virgin Media	Fibre Operator	Information sharing around fibre networks and stimulating discussions between Local Councils around anchor tenancy models. Plus sharing of mobile network coverage and hot spot data.	0

Organisation	Type	Role/responsibilities on project	Staff allocated to project
CityFibre	Fibre Operator	Information sharing around fibre networks and stimulating discussions between Local Councils around anchor tenancy models. Plus sharing of mobile network coverage and hot spot data.	0
VX Fibre	Fibre Operator	Information sharing around fibre networks and stimulating discussions between Local Councils around anchor tenancy models. Plus sharing of mobile network coverage and hot spot data.	0
Zayo	Fibre Operator	Information sharing around fibre networks and stimulating discussions between Local Councils around anchor tenancy models. Plus sharing of mobile network coverage and hot spot data.	0
SSE Telecoms	Fibre Operator	Information sharing around fibre networks and stimulating discussions between Local Councils around anchor tenancy models. Plus sharing of mobile network coverage and hot spot data.	0
WIG	Infrastructure provider	WM5G Sharing of connected map to encourage investment in small cell networks. Facilitating discussions with local councils to ensure easy installation of small cells.	0
Arqiva	Infrastructure provider	WM5G Sharing of connected map to encourage investment in small cell networks. Facilitating discussions with local councils to ensure easy installation of small cells.	0
Freshwave group - Freshwave group is registered in Jersey (iwireless - subsidary)	Infrastructure provider	WM5G Sharing of connected map to encourage investment in small cell networks. Facilitating discussions with local councils to ensure easy installation of small cells.	0
Ontix	Infrastructure provider	WM5G Sharing of connected map to encourage investment in small cell networks. Facilitating discussions with local councils to ensure easy installation of small cells.	0
Mavenir	open RAN software and private networks	WM5G Sharing of connected map to encourage investment in small cell networks. Understanding future private and public networks options and costs.	0
BAI Communications	Infrastructure providers and transport specialists	WM5G Sharing of connected map to encourage investment in small cell networks. Understanding future private and public networks options and costs, plus potential use case alignment.	0
TIP	Telecoms convening body in Infrastructure development and trials	Initial discussions around future collaborations	0

Organisation	Type	Role/responsibilities on project	Staff allocated to project
Bruntwood Scitech	Property developers and science park owner	Initial discussions around future collaborations	0
Atlas Towers Group Limited	Passive infrastructure provider	Initial discussions around future collaborations	0
Cellnex UK limited	Passive infrastructure provider	Discussions around 5G network progress and working with WM5G Barrier busting to resolve issues with Local councils	0
Gately Plc	Legal practice	Providing legal support for a 'legal trial' to shorten the timescales of legal completion from LA's	1
KPMG	Consultancy practice	Business Case creation for Urban Rail development ecosystem	2
BUILT ENVIRONMENT NETWORKING LIMITED	Professional, scientific, and technical activities	Preparation and roll out of Webinars supporting WM5G	4
SITENNA UK LIMITED	Management consultancy activities other than financial management	Digital platform provider	1

16.2.1 Working with consortium partners

5G IA was a workstream which was a part of and operated through the wider established vehicle of ‘WM5G’. During its course it worked in partnership with 5pring – a 5G application accelerator within WM5G and several organisations such as BCU, FarrPoint, Umlaut, and KPMG, among other partners. However, these partnerships were not generated through a collective involvement in the 5GTT Programme and so do not constitute a 5GTT consortium. This was confirmed by the lead stakeholder who mentioned that people who furthered the 5G IA workstream were teams within WM5G.

16.2.2 Personnel

We know from 5G IA’s Benefits Realisation Report (BR) that two full time employees were hired by WM5G to aid with its connected map use case. The BR also tells us that two part time employees from UCC and DCMS supported 5G IA. During its course, 5G IA has also been responsible for training 99 staff members from LAs within the West Midlands Region and 66 staff members from LAs outside the region. This training was in various aspects ranging from a general overview of 5G, to Town and Country Planning, and the Electronic Communications Code (ECC).

Apart from this, the lead stakeholder mentioned that a few employees were hired early on, especially with industry and network deployment backgrounds on the back of the project. They further mentioned that it was difficult to persuade people to join the team from an already well paying sector. So, recruitment was mostly limited to employees who were already looking for a change.

16.3 5G Deployment

16.3.1 Activities

As mentioned earlier, the primary objective of 5G IA was to reduce the time to deployment of 5G networks in the West Midlands region. It identified several challenges to timely deployment of 5G networks such as obstructive landlords (LAs), lengthy lease negotiations involving the EEC, and an inconsistent approach to town and country planning by LAs resulting in an increased volume of failed applications, amongst others. There was also a lack of understanding of the standards put in place by the government in the EEC by both the LAs and MNOs (IPS).

To reduce the barriers identified, the activities of 5G IA focused on four main themes:

- **Exploring neutral hosting and passive sharing solutions:** Neutral hosting is the use of a single network by several MNOs to provide their services.
  - 5G IA prepared a Neutral and passive sharing report in 2019 which found that a move towards neutral hosting on a small cell 5G network had potential to reduce capital and operational costs.
  - Thereafter in 2020, 5G IA conducted a workshop and invited a small number of stakeholders that were involved in small cell network deployment to further learn its difficulties.
  - Apart from this, 5G IA supported three pilot network deployment programmes in the West Midlands by helping them with multiple legal agreements.
- **Barrier busting:** 5G IA worked towards educating the LAs and the MNOs on various fronts ranging from a general overview of 5G, to Town and Country Planning, and the Electronic Communications Code (ECC). Stakeholder consultation revealed that one of the main reasons for delays in terms of agreements between LAs and IPs was a lack of understanding of the EEC. To reduce this, the project undertook several activities including:
  - Providing guidance to LAs and MNOs regarding the EEC and Town and Country Planning.
  - Mediating lease agreements and wayleaves between LAs and MNOs by explaining MNO activity to LAs, and by providing cost calculations.
  - 5G IA also worked on standardizing wayleaves and lease agreements.
- **Mapping of public sector assets:** 5G IA mapped 950 public assets through various sources which allowed better planning by MNOs of their deployment requirements and activities.
- **Studying the feasibility of deploying Fibre in the West Midlands:** 5G IA worked in partnership with Farrpoint, a fibre and business case consultancy to study the feasibility of deploying fibre in the West Midlands.

Table 98: Overview of targets achieved against objectives

Indicator	Measure	Baseline	Target	Achieved at end of project
5G availability across the WM/Cities	5G Coverage	Zero 5G at the March 2019	80% Coverage by Mar 22	21.92% coverage in December 2021

Source: Benefits Realisation and Closure report

16.3.2 Outputs and Outcomes

The main outputs of 5G IA and the outcomes that resulted from the workstream are detailed below:

- **Digital 'Connected Map':** 5G IA identified and mapped over 400,000 public assets in its digital mapping tool, it was identified that 950 out of these could be used to host part of a mobile network. This 'Connected Map' was aimed at enabling MNOs and IPs to identify public assets with ease, allowing them to better plan the deployment of networks. 5G IA's closure report informs us that IPs attributed a saving of anywhere between three to six months in network deployment to the Connected Map.

- **Standardisation of wayleaves and lease agreements:** WM5G IA worked with the Greater London Authority (GLA) to draft standardised templates of the lease agreements and wayleaves. These were in line with the EEC, which regulates the agreements. These standardised documents were then adopted by a majority of LAs in the West Midlands region as a precedent for neutral starting point for discussions between the LAs, the MNOs, and IPs.

- **Code Valuation Tool:** The WM5G IA also developed a tool calculate the compensation to LAs for a ten year period for the use of public assets. This was deemed necessary as a significant delay in network deployment previously occurred due to LAs and MNOs not being able to agree on the compensation for the use of public assets for network deployment. The basis of the tool was the valuation process as described in the ECC. The tool can be found on the WM5G website.

- **Barrier Busting process improvements:** The high-level procedures and process improvements that have resulted from the activities and outputs of 5G IA have been shared widely across the 5G ecosystem (UK5G) and wider LAs and IPs. This high-level process/procedure is aiding public parties within the UK to calculate a minimum value of their assets. However, to provide a full Barrier busting service to Councils will require some funding, either from central government, local government, or the MNO's. WM5G have created a Case Study on Barrier Busting that can be shared with all LAs.

16.3.3 Security impacts

The 5G IA workstream was focused on reducing time required to deploy 5G network by busting barriers, increasing awareness, and standardising the deployment processes. As such, it did not focus on network deployment and network security impacts.

16.3.4 Technology Readiness Levels

Table 99 enumerates the TRL levels of 5G IA's outputs. As can be seen, 5G IA has met its target TRL in 3 of the 4 outputs generated during its course. Work is continuing on the one output, 'Connected Maps' that did not meet its target TRL, with DCMS support through DCIA programmes.

Table 99: TRL Summary

	Starting TRL	Target TRL	Current/End TRL	Target met?
Digital 'Connected Map'	Level 3 - experimental proof of concept	Level 9 – actual system proven in operational environment	TRL 8 – system complete and qualified	No
Code 'Valuation' process and calculation method.	Level 1 - basic principles observed	Level 9 – actual system proven in operational environment	Level 9 – actual system proven in operational environment	Yes
Barrier Busting	Level 2 – technology concept formulated.	Level 9 – actual system proven in operational environment. A standard approach for all councils	Level 9 – actual system proven in operational environment. A standard approach for all councils (Across LAs in WM)	Yes
Standardised commercial and	Level 2 – technology	Level 9 – actual system proven in operational	Level 9 – actual system proven in operational	Yes

	Starting TRL	Target TRL	Current/End TRL	Target met?
technical approach to small cell network deployment across the UK Councils	concept formulated.	environment. A standard approach for all councils	environment. A standard approach for all councils. (Noting that it sometimes needs to be adapted in different ways depending on the specific LA scenario)	

Source: Benefits Realisation

16.4 Collaboration knowledge sharing and overcoming barriers

16.4.1 Sharing Learning and best practice

As can be seen from Table 100, the learnings from 5G IA were shared widely both within and outside the 5G ecosystem. Within the 5G ecosystem. The workstream actively participated and shared its findings, thought papers, and research outputs at several events including the DCMS Better Connected events and Connected Britain. Apart from this, 5G IA regularly shared its learnings through its BRs with DCMS. These learnings were around difficulties faced during the course of the project's activities from the MNOs and the LAs, and the measures adopted by 5G IA to overcome these difficulties.

Table 100: Publication and events summary

Dissemination Activities	Number of articles/events
Research outputs (Case studies and reports)	28
Knowledge dissemination events (attended and hosted)	27
Other communication activities (Social media and blog posts, among others)	7

Source: Benefits Realisation

As with all the projects, there is a summary page on the UK5G/UKTIN website, which provides an overview of the project.

16.4.2 Interaction with wider ecosystem

Consultation has revealed that the 5G IA team worked with the GLA, Manchester Combined Authority, and Glasgow at the start of the workstream to discuss learnings and find ways for standardisation. There was a four-way discussion about the objectives of the workstream and the outputs. This eventually expanded into nine different areas including Belfast, Dublin, and Aberdeen, among others. The team distributed a quarterly knowledge sharing piece. The team was quite often approached by wider local authorities, requesting a presentation of the workstream's outputs and process improvements.

16.4.3 Business and industry generation

During its course, 5G IA worked as an 'honest middleman' facilitating commercial agreements between MNOs and LAs for faster 5G network deployments. Apart from this, it also worked on building commercial models for faster deployment of small cell 5G networks in the West Midlands regions. Although the exact extent of business generated on the back of 5G IA is unclear, the lead stakeholder mentioned that WM5G is providing its services in the regard to wider infrastructure providers on a commercial basis.

This is confirmed by the workstream's closure report sent to DCMS which states that barrier busting and lease completion activities are being offered on a commercial basis to LAs and MNOs. Apart from this, we also know that several LAs from outside of the West Midlands have approached WM5G for help in standardising

network deployment procedures. The outputs of 5G IA, such as the 'Connected Map' are being further developed through DCIA. This has significant business generation potential from both LAs and MNOs.

Table 101: Funding received for project

	Public funding received for this project	Additional spent on R&D to progress this project
Total £	No data	£1,975,000
Number of partners that received funding / contributed R&D	No data	8

Source: Benefits Realisation

Apart from the funding awarded by DCMS to WM5G, Table 101 enumerates additional investment that were made by wider private partners and LAs into the development of 5G IA's outputs. As can be seen, this was mostly done in the form of support in kind and amounted to £1,975,000.

16.5 Programme processes and DCMS Support

Overall DCMS' involvement in aiding WM5G through the processes of the workstream is viewed in a positive light. This is evident from 5G IA's closure report which mentions that DCMS, has effectively accelerated the deployment of digital infrastructure in urban areas. Stakeholders had a positive opinion of DCMS' support throughout the workstream, although there were comments that several of DCMS staff were very rigid in following procedures including the filing of the BRs. However, they also suggested that the process got a lot simpler as the workstream progressed.

16.6 Key outcomes and successes

16.6.1 Additionality

In line with its objectives, the 5G IA workstream did not involve developing or testing 5G use cases, its outputs were focused on enabling a better understanding of the regulations that governed the 5G network deployment landscape; and enabling standardised processes and clearer communication between the LAs and IPs for faster deployment of 5G networks.

This meant that 5G connectivity was not the only goal in 5G IA. However, consultation with the lead stakeholder revealed that the 5GTT programme funding added significant value to the workstream. The stakeholder mentioned that the programme would not have happened if not for the funding received by the programme.

16.6.2 Sustainability

The 5G IA workstream was highly successful in reducing time to deployment of 5G networks in the West Midlands by 4.5 months. Its barrier busting activities have garnered significant interest by Local Authorities, NHS, and MNOs throughout the country. 5G IA, through WM5G is involved with DCMS' new Digital Connectivity Infrastructure Accelerator (DCIA) and Accelerating RAN intelligence in 5G (ARI-5G) programme, which are linked to the barrier busting activities undertaken by 5G IA. Apart from this, we learnt from the lead stakeholder that WM5G are providing their services to other infrastructure providers on a commercial basis.

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