WM5G Transport Programme

Summary & Closure Report

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SECTION 1: Executive Summary of the WM5G Transport Programme

The Outline Business Case was approved in December '19 which released funds to deliver the short term trials (early demonstrators), complete the market engagement, define a detailed programme plan and scope the full programme costs.

The Full Business Case (FBC) was approved in August 2020 which released the full funding defined, supporting the launch of 2 competitions and delivery of the programme.

a. Targets of programme overall

i. Demos (short term trials) x1 to showcase 5G enabled products in Transport to stimulate interest in subsequent programme.
ii. Deliver 12-14 projects through x2 competitions & Road Sensor Network project.
iii. Explore macro challenges in Transport…congestion, services inefficiencies, passenger experience improvements and support Autonomy, Electrification and Digital technology.
iv. Focus investments on products and services in Transport across Road, Rail and Trams in an urban environment addressing:
    1. Operational efficiency.
    2. Integrated travel network.
    3. Passenger experience.
v. 2 year Transport programme with demonstratable BCR of 3.7
vi. Financial contributions to include 33% commercial match overall (50% for use cases).

b. Transport programme delivered

i. Demos (short term trials) x4 delivered
    1. x3 proof of concepts using 5G connected sensors enabling services.
    2. x1 advanced technology demonstrator with Ericsson, which used the mobile comms infrastructure with no additional sensors required.
ii. 13 use case grant projects awarded and 12 completed (from x2 competitions).
iii. Road Sensor network project delivered, collaboration with TfWM, across 7x LA's.
iv. Grant Projects covered 3 main areas:
    1. Road infra-structure - 4 projects with 6 products.
    2. Rail infrastructure – 3 projects with 3 products.
    3. Passenger experience - 6 projects with 6 products.
v. 2 year programme finished in March '22 on time with overall BCR of 2.9
    1. BCR 7.2 for use case projects (£3.49m fund).
    2. BCR of 0.4 for the Road Sensor Network project (£4.67m fund).
vi. Financial contributions of 39% commercial match overall (51% use cases).

Highlights of the Transport programme delivery

- The targets have been achieved, with a high success rate of products achieving commercial success and products being at or near "market ready" at project completion…reflected in the high BCR score of 7.2 achieved for the competition "Use Case" projects.
- The Road Sensor project deployed the sensors across the 7 Local authorities and is operational. It shows a lot of promise in wider benefits but many are not quantifiable in money terms at this stage showing only a 0.4 BCR. There is high confidence the benefits will be quantified in the near term.
- A wide portfolio of products was developed with the 13 grant funded projects. The products have generated significant interest and commitment from Transport Operators.
- A robust grant monitoring process was implemented and maintained by the WM5G Transport team. This reflects best practice as defined in the Cabinet Office grant monitoring guidelines.
- Delivery of 2 extra project initiatives for TfWM, **and** a study for continuation through the Urban Road and Rail development Ecosystem…. delivered using use case project underspends.
- The programme was delivered despite COVID and cost ~£1.2m less than the programme budget as defined in the FBC mainly due to reduced competition #2 funding allocation.

SECTION 2: Introduction

The key challenges and approach as described in the business case are included in this section to set the context of the transport programme.

West Midlands challenges to be addressed

- Congestion and CO_2 on roads is leading to lost travel time, pollution, customer dissatisfaction and lost time. Insufficient live, road traffic flow data and control mechanisms.
- Poor rail service & customer dissatisfaction with stations, information and connectivity are major concerns.
- Trams and bus services are being expanded to meet demand with a focus on Commonwealth Games.
- Increase in population and impact on road congestion and changing transport.
- Time is lost when searching for parking and revenue lost for councils and businesses
- Support for new technologies including Autonomy, Electrification and Digital in Automotive is required.

How 5G/digital innovation can help address these challenges:

- Implementation of sensors at a selection of main junctions on the West Midlands Key Route road Network (KRN) providing live data of road users, which if aligned to traffic lights, road signs or Sat Nav, will enable effective traffic and congestion control by the Local Authorities and TfWM Regional Traffic Coordination Centre (RTCC).
- Improve the operational efficiency and quality of service with live data from high data rate sensors and IOT sensors, making public transport & roads more attractive for travel and to reduce pollution by enabling traffic to flow more freely.
- 5G enables new products and services which otherwise would not be possible which includes robust live and continuous monitoring of service.
- 5G offers the ability to locate and share changing roadside rules and location of space on the kerbside as well as the ability to scan and upload live situation and infra structure information.

Transport programme objectives and benefits of further intervention:

- Operational efficiency - improvement for local authority and private sector transport operators and reduce pollution and provide environmental benefits.
- Integrated network – development of an integrated and connected transport service
- Customer user experience – improvement of journey experience through enhanced travel information and environment information with services aimed at personal productivity or leisure activities.
- Benefits demonstration – showcase of transport benefits from the deployment of new 5G.

Projects scope and benefits

1. Road Sensor Network

- Install high definition sensor cameras and IOT sensors with approximately 320 road sites in the region. These form a network of monitoring, capable of collecting, processing and sharing real-time traffic data, emissions and weather data. These will be installed in phases:
  - Phase 1 (6 months, to Jan ‘21): 40 sensor sites.
  - Phase 2 (14 months, to Mar ‘22): 280 sensor sites (detailed scoping will be developed upon the outcome and lessons learned from Phase 1).
- Access to this rich data source will improve the Local Authorities ability to manage traffic locally with existing control interactions. The Regional Traffic Coordination Centre will also benefit providing the ability to manage incidents and congestion across the region.
- **“Benefits” include** - fuel savings, lost time reduction, reduced accidents and lower emissions.

2. Use Case projects

It was assumed that at least the 12 projects would be developed

- 1st competition run 7 projects with durations from 9-18 months.
- 2nd competition run with 4-7 projects over 12 months duration.

Approach to sourcing & commercial investment:

- Sensor network project:
    - Phase 1 (July ’20 – February ’21) sourced through the Midlands Future Transport (MFM) project, extending the collaboration and funding, enabling a faster deployment of sensors and early results to prove the concept.
    - Phase 2 (February ’21 - March ’22) procurement through negotiated competitive tender led by WMCA to deliver a partnership appropriate to support an R&D project investigating 5G connection and stimulating the development of new 5G enabled sensors.
- Use case projects:
    - Competitions supported by Innovate UK on behalf of WM5G Ltd with the launch supported by the Knowledge Transfer Network (KTN). Two major competitions planned in 2021. 12 use case projects to be sourced and awarded with 7 in the first competition with 4-7 in the second competition.

State aid approach:

- Road camera/sensor/ infrastructure project - no state aid (private sector not benefiting).
- Use Cases comply with General Block Exemption Regulation (GBER) as research and development projects. (Based on Innovate UK approach).

Governance:

- Monthly Transport stakeholder reviews to review progress, plans and risks. The stakeholders include TfWM, DCMS and WM5G.
- A clear change management matrix defines financial, delivery and programme variations that require approval from DCMS and the WM5G Board for any deviation from baselined metrics.

SECTION 3 - Description of what the programme did

1. Short Term trials (early demonstrators).

These were procured Jan-Mar '20 and delivered April-July'20. They were implemented in Birmingham and on the WM Metro tram service running between Birmingham and Wolverhampton.

Each of these projects were shared on social media and on the WM5G website which started to build a rapport around 5G connectivity and products and services that could result. Relationships were created in both Local Authorities and the SME/supply base which provided a launching pad for the main phase of work and gave credence to the competitions.

A summary of the short term trials are listed below:

i. Roadside vehicle detection (Appyway) – using images from a camera in a passing to assess cars parked on the kerbside an initial indication of the time to process the image and update an app was achieved (~25 seconds) using 5G.

ii. CCTV statically located at a road junction (Vivacity) – a camera was located at a road junction and gave initial indications of the capability of the AI analytics and the quality of the image required to satisfy a range of use cases. In turn this gave an indication of the data flow requirements for this type of sensor.

iii. CCTV located on a moving Tram (Go Media/Icomera) – using a HD camera on a Tram the use cases and streaming that on 5G an assessment of the use cases that could be considered came to life. Passenger counting, safety and social distancing were obvious contenders.

iv. Telecoms mast as a sensor (Ericsson) – using 4G and some software deployed in the telecoms system the mast was used as a sensor to detect the number of road users. This correlated well with independent in road loop sensors. The benefits to road operators of not having to deploy sensors was an exciting prospect. This was a very early proof of concept and needed a lot of work to develop further. Ericsson were planning to progress this technology.

2. Competitions run and projects selected

In order to select projects to fund, two competitions were defined and run during 2020, as defined in the programme plan. These competitions provided a highly visible and fair application process with state aid and collaboration criteria clearly stated.

1st competition - closed June 2020 with projects starting after setup in September 2020

2nd competition - closed November 2020 with projects starting after setup in April 2021

Time between the competitions allowed the due diligence and setup to complete from Competition #1, prior to repeating the process for Competition #2 projects. This enabled learning to transfer, time to develop the scope for the 2nd competition and avoided a peak in resources required to support the process from WM5G.

Competition #1 scope – covered 3 challenge areas with examples of applicable use case projects shared in the briefing events hosted by the Knowledge Transfer Network (KTN).

The time available for the development of new products and services was up to 18 months.
This first competition briefing scope included:

i. Rail and Tram use cases: big data, passenger management, CCTV and personal protection, station management and new or extended service provision.

ii. Road use cases (V2I / I2V but not V2V use cases): road traffic monitoring and emissions monitoring, kerbside monitoring, connected and autonomous vehicles and V2X safety messaging
iii. Traveller experience use cases: employee or passenger protection, passenger information, personal wellbeing, urban cultural tourist services.

Competition #2 scope - covered 3 challenge areas with examples of applicable use case projects shared in the briefing events hosted by the Knowledge Transfer Network (KTN). The scope of the second competition was more constrained and targeted than the first competition.

The time available for projects was a maximum of 12 months development time.

This second competition briefing scope included:

i. Improve road management (no V2V projects) : localised emissions hotspots, incident management on the road network, congestion management.
ii. Transport recovery post COVID: traveller confidence and travel options, covid guidelines and rules for operators, new product business resulting in extra revenue for operators.
iii. Logistics: interface for pickup or drop off and goods validation, dynamic journey planning, interaction between freight and logistics operators, reduce empty load operation.

Selection process for use case projects from the competitions - Following each competition, a selection process was utilised to select consortium projects from those submitted against the competition brief. The process steps are outlined below:

I. Projects assessed by independent assessors sourced by Innovate UK.
II. Independent assessor scores reviewed, any outliers removed from scoring and projects ranked based on resulting scores and comments. Any ineligible projects against the competition scope were identified and removed.
III. Projects were then assessed by a WM5G led assessment panel comprising TfWM, DCMS, InnovateUK and WM5G. Projects were selected for interview based on agreed selection criteria. The Innovate UK lead ensured consistency from the competition brief to selection also ensuring the competition rules were observed and impartiality was maintained. Funding partners (DCMS and TfWM) joined providing programme goals and Transport focus in the assessment process.
IV. Interviews were held for the shortlisted project consortiums, using the same assessment panel as in previous step. Projects were assessed for suitability against benefits, alignment to competition and deliverability by consortium.
V. A recommended list of projects was presented and agreed by the WM5G Board.
VI. Projects were notified on the outcome of the assessment.
VII. Successful projects went through a setup and due diligence process prior to project start.

The projects assessment process and approvals prior to consortium notification of competition outcome took 2 months.

The setup and due diligence process for each consortium project from notification of success to project start took ~3 months overall with the second competition projects being slightly quicker overall.

Projects were set up with a lead partner being the contracted party with WM5G and a consortium agreement bound partners to the project overall and the lead partner, which was organised by the lead partner.

Due diligence and setup for each consortium project

- Financial reviews for each partner (review using ENDOLE plus Cooper Parry independent accountancy audit) was conducted to confirm commercial viability and try and ensure payments were being made to viable entities. As a result, some consortia project partners were requested to provide regular financial statements through the life of the funding to reconfirm on going viability. Where a partner viability risk was identified, a targeted approach was agreed. This included WM5G making payments directly to individual partners instead of all flowing through the lead partner to minimise delay times for payments received. Guarantee was also required as additional protection via Parent Company Guarantees where necessary and appropriate to minimise risk.
- Collaboration agreements were required to be in place for each grant funded project - between partners to clarify key points around IP and liabilities. These were confirmed to be in place at point of issuing the grant offer letter. A template collaboration agreement from InnovateUK was provided as a good starting point.
- State aid compliance evidence and assurance was required from the consortium partners.
- Grant offer letter (GOL) was issued to the lead partner at the end of the setup and due diligence process – this contracted between the lead partner and WM5G and included details of the plan, milestones & assessment criteria, grant funding including partner split and commercial match plus general legal terms flowing from the DCMS legal requirements.

13 Use Case Projects selected from the x2 competitions:

i.	CURBS	road infra structure monitoring with sensors on public vehicles
ii.	PREDIKT	kerbside car parking detection and availability share
iii.	Tram Safety	left luggage and train station platform safety
iv.	Capacity Manager	road incident modelling and management advice
v.	Transport Accessibility	guide at station and on board a vehicle for partially sighted
vi.	Passenger management	continuous customer feedback gather and incident alert
vii.	Urban Tourism	venue crowding, travel guidance & immersive experience
viii.	5GER	train station guidance via concierge robot
ix.	TravelXR	station crowding detection and user guidance
x.	HPOMS	pantograph and overhead line damage detection
xi.	Occupancy	crowding and passenger counting on vehicle using CCTV
xii.	Polytrack	rail track monitoring using low cost sensors
xiii.	5GCat	autonomous vehicle remote monitoring and door safe

Road Sensor Network project

The Road Sensor Network project (RSN) was a funding collaboration between WM5G and TfWM. TfWM led the project management and delivery as the sensors ownership, maintenance and benefit were ultimately targeted at the local authorities which TfWM support.

The sensor project objective was to deploy 5G traffic and emissions sensors on the regions Key Route Network (KRN). The locations were agreed with the x7 local authorities and targeted at providing intelligence in feedback as well as offering CCTV streaming if necessary where cameras were to be deployed.

The project was split in to two phases:

Phase 1 – deploy ~60 sensors of various types covering traffic and emissions sensing to establish the capabilities of the sensors and the data storage and API for the traffic managers and feed in to the RTCC (Regional Traffic Coordination Centre).

Phase 2 – deploy a large number of sensors across the region and establish the use cases and benefits associated with the data available and fine tune the operational requirements from storage of data to cyber security assurance.

Other projects work undertaken by WM5G Transport

Project #1: Freight and logistics (TfWM funded) – a study to determine use cases that would benefit the freight and logistics sector and make a difference to the towns and cities in the region. A market engagement was undertaken with inputs from various couriers and operational companies which resulted in a "long list of use cases".

Twenty three use cases were defined at a high level with a description of the use case, the benefit, what data would be required to support its function and indicatively how difficult the use case would be to develop and implement.

Two use cases were selected for more detailed analysis of the functionality and data requirements. Possible approaches to promote these short listed use cases was provided to enable TfWM to support.

Project #2: EV Rapid Charging Hubs Business Case (TfWM funded) – various EV charging initiatives have been studied with "on street" parking and "park and ride" services being developed by the region's local authorities and TfWM. National Highways also have project RAPID to create ultra-fast EV charge points at service stations across the motorways network. A gap exists to support ultra-rapid charging to provide a petrol station style experience across the region. Rapid vehicle recharge can be achieved in a few minutes instead of the hours required using lower powered stations. This is designed to support business users, travellers and courier services operating from or through the W Midlands region. A business case was developed in cooperation with WMCA and TfWM to detail the proposal and firm up how this could be achieved.

Project #3: URDE (Urban Rail and Road Development Ecosystem) DCMS and TfWM funded ….renamed the UTDE (Urban Transport Development Ecosystem) **–** This project was ambitious in content with only 6 months to develop several significant work studies simultaneously. The objective was to explore how to migrate from this successful Transport programme to a sustainable future using the live operational services available as a sandpit for large scale testing and trials of new products and services. The feasibility project contained 6 workstreams:

- WS1: Project management and benefits realisation tracking for this feasibility study.
- WS2: Tram Routers installation to provide more comms routers on the W Midlands service to provide the scale to support future Rail based innovations. Only having one tram with a router was found to be very restrictive in the main programme due to servicing and tram availability. A market survey of suppliers was undertaken following a detailed requirements spec being produced. A procurement is underway to secure 2 routers on the Tram service for the next 2 years.
- WS3: Data Proof of Concept to investigate how the Tram service vehicles could be better supported using data already collected on board the operational trams. Using downloaded data a PoC was developed which showed an implementation which would offer significant benefits to operational efficiency.
- WS4: trackside connectivity on the Tram looked at how to utilise the trackside fibre to provide better operational services and support R&D services of the future.
- WS5: through market engagement with Bus, Tram and Train operators, OEM's, Local authorities' and SME's evidence was gathered across sectors to explore what challenges they are facing. This found duplication in Innovation initiatives with inefficient funding but also many challenge areas that are yet to find solutions to operational and passenger issues. Following discussion on the ecosystem concept, many organisations have provided verbal support or letters of support. These have come from a range of organisations big and small and have provided confidence that this initiative has a benefit and enthusiastic support. These findings have been summarised in a report and provide the substance behind the business case for further investment below.
- WS6: URDE business case explored how to setup and run a core service pulling together the transport sectors to create a cooperative ecosystem to rapidly develop and share new services across transport modes. This business case has defined the need and how to create this ecosystem and has defined funding required and the economic benefit of creating this ecosystem.

Cyber Security and Data Management applied to RSN and the Use Case projects

Any product or service that transfers data over a mobile communications network is inherently vulnerable and therefore at risk of being hacked or subject to service interruption. This can render the product to be unusable through to GDPR or personal information leaks which could lead to litigation. It is key that early and maturing products have cyber security designed in as early as possible. Growing risks with cyber security threats caused us some concern. Therefore, at the beginning of the programme, we decided to provide an independent review of each product to help to review the Cyber Security and Data Management details and processes being used on each project.

The approach to cyber security for the WM5G projects we grant funded is explained below:

> **Objective:** to add value by providing an independent review of cyber security for the products and services being developed
>
> **Method:** we engaged expert support to explain the importance of Cyber security for digitally enabled products and services. A review was held with each of the consortiums which looked in detail at the products and services being developed, which focused on the product as a whole, plus each organisation involved and their approach to operational cyber security. The resolution of any deficiencies or vulnerabilities was then left with the partners to resolve.

The 1st competition projects were assessed by **Thales using the ISO 27001** controls-based assessment. Each project and consortium was subject to an audit over a day. A report was generated which was provided to each partner following this audit. An assessment was given against 6 key categories with a RAG status against each which was supported by a detailed assessment and recommendations for how to improve:

- Risk management
- Change management
- Technical vulnerabilities and security testing
- Security incident management
- Secure development
- Third part management

The 2nd competition projects were **assessed by Equilibrium** as Thales were not able to support the second wave of projects in the time frame required. This assessment used the same principle of assessment but used the **IASME controls assessment for cyber security** (Information Assurance for Small and Medium Enterprises). This assessment is similar to the ISO accredited approach but is geared up to review SME's. A similar list of assessment criteria was used with a RAG status provided following assessment. A detailed report was issued to each partner as with the 1st competition projects approach.

All of the detailed reports generated were treated as confidential and were not shared more widely.

As a result of the product and project reviews most partners went on to mitigate the risks identified. Many organisations also went on to gain cyber essentials accreditation, with many securing the more stringent ISO270001 certification. The onus to make improvements was left with the individual organisations to pursue. Despite initial resistance to the audits the organisations audited were overall very complimentary afterwards and thankful that the audits had been done, driving them towards more robust and market ready products and services and better cyber security awareness in the organisations themselves at an operational level.

State Aid Compliance

The procurements for the Road Sensor project followed the state aid process defined in the business case with TfWM acting as procurement body for the sensors which are only being used for government purposes.

The use case competition projects procurement compliance has been logged through Innovate UK who are an accredited body.

All projects were assessed at project completion to confirm that any capital investments were for R&D purposes only.

SECTION 4: Projects Delivered and Benefits Realised

Projects delivery performance

Having selected the projects and completed the setup and due diligence process the projects were then monitored. A monthly review was held by the lead WM5G project manager to track plans and progress against the plan. In addition, a formal quarterly review was held with the consortium lead partner, WM5G Project Manager and WM5G Programme Director. Generally all project partners would attend.

Monthly dashboards were requested from each consortium to illustrate progress vs the plan and the milestones in the quarter. This provided insight in to progress and enabled interaction and help where difficulties were shared. A quarterly review and dashboard were also requested with the formal review held with the lead consortia partners and the WM5G PM and Project Director. The dashboards were part of the project management pack provided as evidence at quarter end. These packs including milestone evidence and reports plus the financial claims were reviewed and approved by WM5G, with DCMS and TfWM spot checking as part of the audit process.

A summary table of performance of the projects across the Transport programme was kept up to date and shared monthly with the WM5G Transport programme stakeholders (DCMS and TfWM). Mitigation actions and approach to any RED projects was agreed as part of this monthly stakeholder review.

One of the projects failed within the first 6 months due to capacity constraints in the lead partner organisation.

Benefits Realised

The benefits realisation summarises the outcomes of the investment made focussing on the government investment but also capturing the commercial match associated with each project. This section is split in to 4 sections to capture the products developed and market readiness overall, the economic return of each project at a local and wider economic level which reflects the business case rationale and finally the lists the individual Benefits realisation spreadsheets for each project. We have also included reference to the dissemination events that WM5G Transport have led or supported during this funded period to “spread the word” on projects supported and benefits of the products and to highlight the impact of better digital connectivity through 5G.

A high-level summary of the exploitation status across the projects is listed below:

8 products have commercial orders/market commitment or have enhanced existing products

- **“Transport Accessibility”** helping partially sighted people navigate stations and vehicles (Go media) - final trialling at Euston prior to ***Network Rail deployment.***
- **“Passenger Management”** gathers customer verbal feedback and interprets to provide continuous monitoring of service (Wordnerds) - ***multiple businesses in Transport and outside of Transport (retail)*** are in advanced contract negotiations to adopt.
- **“HPOMS”** a Train/Tram Pantograph monitoring system (JR Dynamics) - contracts with ***Angel Trains*** has already been signed at the end of the project for initial implementation on 21 trains.
- **“Road Sensor Network”**, a series of traffic detection and emissions monitoring sensors - >260 traffic and emissions sensors deployed across the busiest roads in the W Midlands and are already integrated in to ***some of the Local Authorities*** traffic centres helping to manage traffic and emissions & provide insights for future road investments. This is being led by ***TfWM.***
- **“CURBS”** a road infra structure monitoring service e.g. potholes, white lines, kerbs, lamp posts, traffic lights etc (Vortex IoT, now merged with Marston Holdings) – ***Marston*** aim to commercialise within 6 months. ***TfL*** are interested in this.

- **"Urban Tourism"** event (getting to) venue travel assistant (You Smart Thing) - enhanced features for the travel assistant used by venues and events organisers. This has been commissioned for the ***Commonwealth games by TfWM and is embedded in the BBC R1 big weekend event in Coventry.***
- **"Capacity Manager"**, the road maintenance planning tool from one.network has enhanced capability with the ability to interface with simulation tools and is being offered as part of its upgraded platform. TfWM RTCC is interested in this product.
- **"Predikt"** parking availability and booking app (Appyway) – the product has been modified to enable the ingestion of multiple data sources, **enhancing the value of the product**.

5 further products have developed existing or new products and need more development before deployment.

- **"Polytrack"**, a rail track infra structure monitoring system (ESR) – has very encouraging product results and strong interest from ***Network Rail & WM Metro.***
- **"Occupancy"**, passenger counting and vehicle service-use monitoring developed by Hack Partners is ready for integration, with strong interest from ***TfL and TfWM .***
- **"TravelXR"** bus and train station people crowding assessment helping individuals navigate safely in constrained environments (Briteyellow) – ***Network Rail*** has expressed strong interest.
- **"Capacity Manager"** has two complementary road traffic simulation tools developed to ingest large amounts of real time traffic data (#1 Warwick Manufacturing Group – real time analysis for incidents, & #2 Immense – planned interventions simulation). ***TfWM and the RTCC are interested.***

2 products require more PoC development to confirm viability

- **"5GCat",** a PoC for VLR to support Autonomous operation with remote vehicle and system monitoring & door safe to prevent trapping (Westfield) - pilot testing undertaken on a pod at the Dudley Rail innovation centre due to delays in the ***Coventry VLR*** availability.
- **"Tram Safety",** baggage detection linking an owner to luggage and bags (Digirail) – developed AI algorithms but had limited test time.

Overall, a high number of the funded projects have realised significant operational and commercial interest. Possible reasons for this could include:

a. Competitions were scoped to attract commercially focussed and closer to market products.
b. Pre competition market engagement developed a range of use cases and interest with many organisations, which resulted in pre studies and discussions taking place prior to the competitions being run. TfWM strongly supported this process and definition stage which added value and was attractive to SME's.
c. Project selection process robustness through the submissions and interviews held and the panel selected to review.
d. Active management of the projects by WM5G was led by a group of experienced commercial and product development professionals who provided a lot of advice and support to each project where necessary. Commercial exploitation and the "go to market" propositions were key focuses of the WM5G PM team.

All projects were led by SMEs.

The tables below provide a summary of the products developed by each consortium and their approach to generating evidence of functionality via trialling and the proof point targets.

Project	Problem / Issue	Root Cause of problem	What is product or use case being assessed and what is proof point
Curbs (Lead = Vortex IoT)	Road potholes damage costs car owners £1.25bn pa (Kwik fit Mar '20). Autonomous cars require better road assets.	Road assets such as road surface, white lines and kerbs can deteriorate rapidly or be damaged. White lines and kerb and other roadside assets assessment is infrequent.	Product = Easy/cheap system to deploy located on public service vehicles …Scanning of road surface, kerb height, lamp posts, white lines… daily ….uses camera and Lidar. Proof point = 2x National Express bus routes in Birmingham in 2nd half of 2021
Predikt (Lead = Appyway)	Time spent looking for limited parking in urban areas ~6-8 mins/day. Traffic congestion and tailpipe emissions caused by traffic movements locating parking.	Limited/inaccurate parking space availability (particularly in congested urban areas)	Product #1 = Kerbside scanning using cameras in passing utility vehicles with GPS location tagging. Product #2 = Predictive parking app ingesting real-time data from various sources. Proof point = Coventry city centre multi street kerbside scanning trials.
Tram Safety (Lead = Digirail)	Improvements to Public Transport operation possible: • Passenger safety against door trapping and proximity to moving train while boarding / on platform • Revenue - Passenger counting • Confidence / busyness of service • Security - Suspicious packages • Accessibility supporting wider range of travellers/scenarios - disabled, cyclists, heavy luggage, prams etc.	Current CCTV platform does not provide live, targetted, pro-active information to the tram / train operator.	Product = on board/off board analysis of CCTV and provide real time alerts for operators using existing CCTV and on board connectivity (requires GPU/Control module) Proof points = assessment of detection software and processing/identification algorithms in lab and on WM Metro.
Capacity Manager (Lead = BLACC)	Time lost in traffic ~£400m pa in W Midlands (pre COVID)	Congestion on key road networks is extensive. Disruption caused by planned roadworks & incidents. Traffic management is "operator" experience based.	Product = Traffic simulation using historical and live data to predict best options to manage planned roadworks and traffic incidents with user friendly interface. Proof points = A45 2x roads assess

Transport Accessibility (Lead = Go Media)	2m partially sighted in UK (24m in Europe), of which many don't use transport.	Partially sighted people not confident on station platforms and in transit to get on and off correct vehicles, safely and at right time.	Product = App based phone guidance system using voice, haptics and large displays to guide users around station and vehicle Proof point = WM Metro Tram and user groups assessing UI and % partially sighted who benefit

Project	Problem / Issue	Root Cause of problem	What is product or use case being assessed and what is proof point
Passenger Manager (Lead = Word Nerds)	Public transport companies don't know what's happening on their services & don't have a regular feedback mechanism. Therefore issues can persist undetected resulting in customer complaints, costing money/trust.	Poor customer feedback platforms and data collected annually. Issues are dealt with historically, with resolution harder and more costly to resolve.	Product = AI based real time micro-surveying tool which interprets customer feedback using context sentence & sentiment model. Trends and key issues will be logged and grouped with records of severity of feedback. Alerts for customers distress situations. Proof point = WM Metro with dashboard info using social media/on board feedback to assess
Urban Tourism (Lead = You Smart Thing)	Congestion of people and traffic around events and venues can be significant leading to negative travel experience of customers in urban locations.	Customer's lack of prior knowledge of routing/travel options which best serve their needs and enhance the travel experience. Limited environment Points of Interest (POI) available in towns and cities to enhance experience.	Product = Web-based "Travel Assistant" embedded into event management websites, integrating with booking systems. Delivers customer analytics and 'live assistance' booking options. Based on an existing product which has no 'real-time' feedback. IoT sensor deployment provides live people density feedback at venues. Rich media content improves traveller experience Proof Point = Coventry City of Culture events. 7 locations developed POI experiences in Coventry. 3 venues instrumented Train Station, Bus Station & Park and Ride at Memorial Park.
5GER (Lead = TrainFX)	Dispersed / Inadequate train service & station information available to passengers in stations. Some passengers find stations daunting places to go (vulnerable, old, young) due to size / complexity / busyness, resulting in more private travel.	Limited staff at stations for supporting passengers in a busy station environment. Travel information hampered by low speed, out of date information, often displayed on static screens that are poorly maintained.	Product = An autonomous dynamic robot "Rover" with voice communication to provide passenger information & wayfinding service across station. Proof Point = Birmingham New Street station to assess the human – machine interaction and effectiveness & acceptance of service. Assess ability of robot to operate safely in a geofenced station environment.
Travel XR (Lead = Briteyellow)	Post COVID-19, the public need reassuring that using transport is safe. Able bodied vulnerable PLUS medically vulnerable avoid public transport hubs. 70% of customers are not travelling compared to the start of lockdown.	Currently operators can provide general guidance on routes around stations but lack congestion and optimal passenger flow data. Travellers need help with pre-planning their journeys in advance and better negotiate access through a station. need re-assurance that they can navigate safely through stations in the most appropriate/efficient way.	Product = A connected passenger guidance system via App to help passengers to avoid points of conflict and social distancing hotspots. Monitors health and safety for the vulnerable or disabled passengers. Allows operators to anticipate over-crowding & mitigate by rerouting passengers dynamically. Proof Point = Deployment of sensors at 4 key locations: 5prinG, Smethwick Galten Bridge, University and Wolverhampton stations. Assessment of precise crowd flow modelling and real-time user experience.

Project	Problem / Issue	Root Cause of problem	What is product or use case being assessed and what is proof point
HPOMS (lead = JR Dynamics)	Excessive impacts of pantograph on power line due to incorrect height / deployment of the pantograph causes wire and Pantograph wear/failure. The longer the issues go undetected, the more catastrophic the damage and the more costly to repair.	Current Pantograph Damage Assessment System (PANDAS) wirelessly monitors impacts in real-time but doesn't have a camera for measurement of height/stagger/wear The rail sector want a single installation to cover all condition monitoring requirements.	Product = Affordable camera monitoring system that provides visual footage which can stream high definition footage for image processing to: - Detect impacts - Measures pantograph height / wire stagger / carbon wear Proof Point = 6-Month Trial on North-Western Railway Line (between Wolverhampton and Birmingham). Images streamed at 60fps which will be processed offboard. Alerts to be tested.
Occupancy (Lead = Hack Partners)	Transport company (Bus) lays on too many or too few vehicles to a particular service during the day/week Dissatisfied customers due to overcrowding or poor bus availability.	Inaccurate passenger count on passenger transport vehicles. Lack of live data from vehicles advising vehicle occupancy %. Bus company operation lack of flexibility.	Product = CCTV with AI to analyse passenger occupancy via live feed, data then transmitted to customer via mobile App Proof Point = x10 First Group buses equipped with CCTV and routers on B'ham to Worcester route. Passenger detection ~95% object detection accuracy.
Polytrack (Lead = ESR)	Stuck junction points, missing track brackets and deflection of track leads to safety issues and either service downtime (train or tram) or speed restrictions imposed on track (train) leading to delayed services.	Tracks monitoring is through scheduled asset condition days during the year by specialist vehicles (e.g. measurement train on mainline Rail) and manual inspection. People on track is dangerous and time intensive. The extent of Train track means manual inspection not possible.	Product = Rail track dynamic performance and health assessment tool, built from relatively inexpensive, robust, vehicle-mounted sensors for everyday use. Proof Point = Sensors fitted to operational WM Metro Tram Chassis & assessed in various ambient conditions. Link the data from sensors on the tram (shock, accelerations, displacement) to date/ time /position/ local weather to establish data signatures for track degradation and performance.
5G CAT (Lead = Westfield)	Many cities and communities would like access to a rail-based transit system to improve urban transport. Cities like Coventry can't afford a conventional tram system due to infra structure (track and vehicles) costs and operating costs.	Very Light Rail (VLR) reduces implementation cost due to lighter vehicles and less road infra structure changes required. Operation costs are then a blocker, with crew being the biggest cost. Autonomous Tram operation will enable operating viability. Autonomous trams must operate safely in motion and the doors must be free from trapping objects and people.	Product = The VLR Tram is being developed separately. The autonomous control system is also a separate development. The products being developed are: - The Tram's autonomous control system "remote supervisor". - Object/person trapped in door detection. Proof Point = Westfield is trialling its control system on the Coventry VLR at Dudley test centre. The Autonomous vehicle will be connected remotely via 5G and its control system monitored. If system operating limits are exceeded the tram will stop. Door trapping and near misses will be assessed.

Project	Problem / Issue	Root Cause of problem	What is product or use case being assessed and what is proof point
Road Sensor Network	Difficult to manage traffic with little live traffic information from the major road networks.	Current traffic information mostly from mobile phones which is averaged data with time lag. Some limited camera monitoring of hot spots to control centres is available.	Deployment of ~250 road traffic monitoring sensors across a number of junctions & locations in W Midlands. Proof Point = Sensor data flow reliability establish through 5G across a range of locations geographically. Locations across various urban environments (with surrounding buildings) and distances from 5G masts
	Cities prone to fines due to breaking emissions limits	Very little emissions data across urban conurbations	IoT based emissions measurement devices deployed at ~50 locations across W Midlands. Proof Point = Establish IoT suitability. Sensor data flow reliability was monitored
	Yearly census required to assess traffic flow and volumes which is limited time and locations	Census is a manual process of counting traffic or uses specific traffic counting m/c for	Sensors located at junctions which accurately count and classify road users Proof Point = Vehicle counting accuracy >95% for range of weather and lighting conditions

A more comprehensive Benefits review was undertaken by KPMG and is included in the appendix of this report for reference.

Individual project benefits realization spreadsheets were submitted as part of the ongoing project development which were updated quarterly and finally submitted at project closure. These were all shared with the funding partners. DCMS remained as audit partner for all of the projects throughout the programme.

The BCR values as a result of the evaluation are:

- New products and services developed as a result of the 2 competitions (12 projects) against the ~£3.6m of public spending was **7.2**
- Road Sensor Network against the £5m public funding was **0.4** as the evidence of wider benefits was not realised during the project despite great demand seen from the Local Authorities in the last few weeks of the project delivery and sensor deployments.
- Overall BCR for the programme against the £9.93m spend was **2.9**

All of this was delivered in a period when multiple isolations were required by Government due to COVID and the High Risk Vendor strategy precluded the market leader from supplying modems and routers. An amazing result still being able to deliver robustly in a more constrained environment.

Influence of 5G

Each project captured data on 5G performance and its impact on the products being developed. An overall view of 5G and what key benefits seen by projects are illustrated below. Most of the products except, those that relied on the added security and reliability, could function on 4G. However, in general it was recognised that full service with thousands of connections and products operating would limit the capability and availability of service in tomorrow's world.

There were a number of 5G performance characteristics that enable new Transport products and services, based on the use cases experienced in this programme:

- **Capacity for data and device connections**: large number of high data rate sensors which require rapid UPLOAD data rates. There are an increasing number of applications in transport which need to upload data to inform a service which is different from entertainment services which typically download information. The telecoms industry currently is biased towards download speed rather than upload speed due to applications supported to date. 5G and transport services require a better balance of the data speeds.

- **Robustness of data connection**: thousands of IoT sensors are being deployed in urban environments these all require robust connections for the low data rate outputs as well as providing robust software updates over the air to keep the products up to date. Higher capacity sensors also require the assurance to know that data is not being lost for example for live traffic monitoring the live data needs to be assured to support the controls to robustly control the traffic floes through intelligent traffic lights, signage etc.

- **Safe and cyber secure**: data transfer must not provide vulnerabilities to providers or consumers of the products and data. 5G has enhanced capabilities for protection. This applies to all of the products developed and applies to any digital connected service.

- **Low latency and positional accuracy**: speed of data transfer in 10's of milliseconds is important where safety critical functions are concerned e.g. autonomous vehicles.

SECTION 5: Process approach and key lessons learned

Transport programme grant funding process.

Prior to the programme start the grant funding cabinet office guidelines were reviewed and a baseline process established.

A set of guidelines defining evidence required at each quarter and timelines for submission and review was communicated to all the consortium projects as part of the setup process.

The grant and project review procedure was updated at the end of each quarter throughout the 18 months of live project delivery and grant monitoring. This procedure was shared with DCMS when it was updated. It was also kept centrally as a reference for all of the programme team to use as the reference document.

DCMS spot audited the consortium evidence submitted to WM5G at the end of each quarter and provided feedback if any issues were observed in the review and signoff process. This provided the audit process required of WM5G, to achieve a robust and highly rated grant oversight process.

Key project lessons learned which have significance for future programmes:

i. **Projects set up and due diligence -** following competition completion and projects selection the setup and due diligence process took between 2-3 months. Key factors that affected this timescale:
    1. Clear guidance to the consortia immediately after award on documentation and advice required was shared with guidance notes shared with all projects. This helped to reduce timescales and set expectations.
    2. Longer setup times were experienced on a couple of projects due to low capacity/late resources applied by the lead partner.
    3. An error in application of competition rules to the financials by InnovateUK resulted in a delay on one project
    4. The WM5G consortia projects were contracted through lead partners. Where a lead partner solvency was assessed to be a risk (which can often be the case for start-ups or small organisations) then payments were made direct to consortia partners.

ii. **Project delivery**
    1. Projects that had part time project management and /or inexperienced PM's especially in the lead partner tended to struggle to deliver. 4 projects exhibited this error state. It is recommended that the setup and due diligence process should assess the capacity and competence and share potential pitfalls to avoid repeating.
    2. When projects were in distress more regular reviews were held by the WM5G PM to assess the risks for viability of the project delivery and support where possible. WM5G provided more than Grant oversight on these projects and in many cases provided insight and guidance for the project delivery.

iii. **Quarterly evidence submission** - each quarter was sometimes difficult to conclude within 1 month of the end of the previous quarter. This target completion time was put in place to focus resolving any reporting and making payment as quickly as possible to try and help consortia partner cashflow. Payments were only made after successful agreement of milestones and financial submissions. Learnings on this process include:
    1. A clear timeline and guidance notes with the documentation that needed to be filled in. The quarterly reviews were timed to be in the 2nd full week on the month after quarter end. This meeting reviewed milestones completion and evidence including financials and drove the pace of completion…a positive process. No change required.
    2. Milestone report quality was variable across projects. Guidance was shared at the start of the projects. Often new consortia did not appreciate that the reports constituted the main evidence of progress being made against the grant being spent. Explanation of this helped.
    3. Finance grant claims was time consuming for consortia and for WM5G.

a. Invoices availability and mistakes by consortia across individual items occurred many times. Where a numbering of invoices and aligned input to the grant claim was made this significantly reduced errors.
b. Feedback from the WM5G PM's and consortia was that multiple data input across Milestones and partners contribution caused confusion, simplifying the data input and providing training would be an improvement.
c. Universities have a specific claims process using a JES form where often the universities struggled to transfer data to the grant claim form. It is recommended a more transparent process and guidance is provided to link these two processes.

iv. **Benefits realisation** - as an important process for tracking the return on investment of the grant proved to be cumbersome and was not well understood.
1. The WM5G Transport team worked collaboratively with DCMS to review individual projects from the very start. A first cut BR document was completed by each consortium project as part of the setup process before a grant was issued. Continuous review at quarterly review points was carried out to mature the BR spreadsheets.
2. DCMS requested towards the end of the programme a retro look of the BCR against the original programme business case, causing a lot of extra unplanned work.
3. It is recommended that a simplified Benefits capture process is deployed and a clear set of project closure criteria are clearly laid out at the start of any programme.

v. **Access to 5G routers and modems** - procurement of modems and routers was a significant issue in 2020 due 5G still being in its infancy. The supply of hardware was made worse by the market leader, Huawei, declared as a high-risk vendor by DCMS in 2020, effectively meaning that any new modems could not be purchased from them. In addition, the microchip supply issue as a result of COVID hit in 2021. Supply of modems and routers appeared to be more readily available as the programme closed in 2022.

vi. **Commercial organisations engaged with grant programmes** – there were 3 instances where organisations gained commercial contracts which led to resources on the grant projects being reduced or withdrawn. This caused the failure of one project and the need to outsource on another two. Grant projects which only pay a % of costs are less attractive than "normal contracts". This issue will remain unless there is a penalty introduced for failure to meet commitments. This may have the effect of putting companies off engaging with the process.

vii. **Availability of 5G for trialling** – for many of the projects detailed information about the connectivity available was provided by the WM5G Infra-structure team. Connectivity maps were a great asset providing very valuable input to assess the viability of locations being considered for location of sensors or access to services.

viii. **MNO involvement and support** - either as partner or sub-contractor proved difficult across many projects with actual support by the MNOs lower than expected by individual projects. MNO's being partners in the projects may have helped with engagement and commitment.

ix. **Collaborations with large Transport operators** - generally good with National Express, WM Metro and Angel trains providing key supported projects. The support from First group waned during the project it was involved in due to focus on business imperatives.

x. **Deployment of sensors and access to Transport assets** - including vehicles and stations was a challenge.
1. Stations access –The progress to install at stations was protracted due to procedure obstacles, costs incurred and a lack of knowledge by the SME on the project to implement hardware in a live Rail station environment.
2. Trams – access to vehicles to install new hardware took a lot and regular effort to progress. In the 6 months Octt 21-Mar 22 operational issues with the Trams precluded active involvement in the projects which curtailed some testing.
3. Sensors deployment on public infra-structure – projects had significant delays caused by PFI and local authority permissions delays. Having the Digital lead in the council supporting was a big help.

APPENDIX – Benefits realisation assessment (from KPMG)

WM5G Project Benefit Summaries

Overview

West Midlands 5G Limited awarded a share of a £8.1 million investment pool to UK-based consortiums in September 2020 to trial innovative and pioneering projects exploring the benefits and applications of 5G technology in the transport sector. The trials developed new products or services across the West Midlands to prove a use case that will improve road and rail operational efficiency, provide better-connected transport, or improve passenger experience.

The 14 projects included:

1. Holistic Pantograph Monitoring System (HPOMS)
2. Occupancy
3. Passenger Management
4. Polytrack
5. Predikt
6. Road Sensors Network
7. Transport Accessibility
8. Travel XR
9. CURBS
10. Capacity Manager
11. Urban Tourism 5.0 (UT5.0)
12. 5G CAT
13. 5GER
14. Tram Safety

Future financial data has been provided where product owners have been able to accurately project their growth trajectory.

Methodology

WM5G has provided match funding for 14 different product development projects over the past 3 years. All of which have been subjected to a high-level review in this document using information provided by product owners and widely available data points. This high-level information was then applied to Green Book guidance methodology, leveraging ONS multipliers and WebTAG indicator statistics to calculate the Present Value benefits and costs for each project and indicate Value for Money (VfM).

The BCR calculations have been calculated by summing the observed benefits from the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost savings) minus the total private investment over the next 5 years. It must be noted that the benefits being calculated are the total projected benefits of each project over the next 5 years and have not had any sensitivities applied to indicate the benefits that should be attributed to WM5G solely.

A number of additional impacts were considered for inclusion within the BCR calculation; however, product owners were unable to provide quantifiable projections of the future effects of these benefits due to the infancy of the projects and, therefore, we have included them within the non-monetised benefits.

The consolidated BCR across all 13 projects not including the Road Sensor Network (RSN) programme is 7.22 placing it in the **extremely high value for money category**.

The RSN has received a large amount of public and private funding in its implementation and has shown some exciting early results delivering time savings for commuters and reduced emissions and direct cost reductions for traffic data collection. The RSN has achieved a 0.44 BCR but there are significant benefits anticipated from the RSN over the coming years and these opportunities are discussed in more detail in the project summary.

The overall total public spending of the programme was £9.93m up to September 2022 as this includes the Project management and expert support services, RSN, Use Cases and early demonstrators. The use case projects have delivered a BCR of 7.22 and the RSN has delivered a BCR of just over 0.44. As described throughout this paper, the RSN and the use cases are expected to deliver exponential additional benefits in the future with the RSN showing exciting promise, but without the substantive evidence to forecast from due to the infancy of the programme. When applying the tangible benefits projected across the next 5 years for all the programmes, using the methodology outlined above, and applying them against the total public funding cost of £9.93m, the BCR for the programme is 2.90 and sits within the **high value for money category.**

Our original business case indicated a BCR of 3.7 over the 5-year period of measurement. We believe our calculations within this project summary takes a very conservative approach on the benefits that we can expect within the next 5 years, due to the early stage of many of the projects that are to be evaluated. However, even so we are still within the high value for money category and close to the benchmark set by the original business case.

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1 Holistic Pantograph Monitoring System (HPOMS)

1.1 Overall programme aims and benefits

Pantographs are special devices mounted on the roofs of electric trains, collecting power from contact with the overhead wires. Maintaining proper contact allows for a safe, cost effective and reliable train service. Excess of impact can cause damage to overhead wires, pantograph wear and failure, deteriorated wire stagger, carbon wear and possibly even extensive damage causing breakages and safety concerns. The longer the issues go undetected, the more catastrophic the damage and the more costly to repair.

Current Pantograph Damage Assessment Systems (PANDAS) wirelessly monitor impacts in real-time, however they do not have cameras to detect measurements required to assess any damage or proactively detect incorrect pantograph installation, height and wear. The rail sector requires a single installation to cover all condition monitoring requirements. Holistic Pantograph Monitoring Systems (HPOMS) offers an affordable camera monitoring system that provides visual footage to detect impacts and measure pantograph height, wire stagger and carbon wear and can send automatic alerts to train operators. This will allow proactive maintenance work to take place, with significant benefits arising from cost and time savings for train operators and reliable services for customers.

This project was led by JR Dynamics Ltd with a total investment of £450,000 (£225,000 from public grant funding and an additional £225,000 from private investment).

Expected 5 Year Sales: £180m

Expected ROI: £179.5m

1.1.1 Monetary benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	2 new permanent jobs created through JR Dynamics who are currently scaling up and commercialising their product. ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£922,466
		Use case benefits
Cost savings	Train operator cost savings occurring from reduced maintenance due to early identification of issues and less staff patrols needed to evaluate overhead wires. £2,000,000 per annum	£9,556,543
Present Value of Benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost savings) minus the total private investment.	**£10,264,009**
		Benefit Cost Ratio 22.81

		VfM = extremely high

1.1.2 Non-monetary benefits

1.1.2.1 Environmental benefits

Two fifths of the railway are already electrified, allowing people to travel and goods to be transported without the train's operation creating any greenhouse gases. HPOMS can offer a dynamic interaction between pantograph and contact lines which influence the operational performance and safety of electric trains, as well as the operational lifetime of the pantograph and overhead contact line system.

1.1.2.2 Social benefits

Damage caused by excessive impact could cause overhead wires to break, resulting in train delays, safety concerns and dissatisfied customers. It can range from approximately 3-8 hours to replace overhead wires in some circumstances. HPOMS offers the opportunity to quickly identify and rectify safety-impacting issues and reduce delays of customer services when catastrophic damage occurs.

1.1.2.3 Productivity benefits

During the first installation of HPOMS between November 2021 and January 2022, 35 automated impact alerts were generated highlighting potential areas of damage. Live alerts enabled activation of Automatic Drop Device (ADD) to reduce damage to the pantograph and power line reducing repair bills, estimated to be £1 million per year on Class 350 trains alone. Overall, for the rail industry overhead line and pantograph damage costs more than £100 million a year. Early identification of issues and proactive maintenance offered through HPOMS technology can prevent significant costs associated with damage and wear and well as resolving knock-on impacts such as derailment caused by this damage.

2 OCCUPANCY

2.1 OVERALL PROGRAMME AIMS AND BENEFITS

Bus companies and service operators can often lack access to live data from vehicles advising occupancy at any given time, making it difficult to determine how many vehicles should be deployed for particular services during the day or week. This often results in dissatisfied customers due to overcrowding or poor bus availability. Occupancy offers a CCTV product with incorporated artificial intelligence to analyse passenger occupancy via a live feed, with the data transmitted to customers via a mobile app. This can improve existing services giving bus operators the information needed to provide an efficient and cost-effective service, encourage uptake in public transport, reduce emissions and improve customer satisfaction through reduced waiting times.

This project was led by Hack Partners with a total investment of £101,000 (£51,000 from public grant funding and an additional £50,000 from private investment).

2.1.1 Monetary Benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	2 new permanent jobs created ONS composite employee multiplier 0.88 multiplied by the total PV expenditure on employee's salaries	£922,466
Present Value of Benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£872,466**
		Benefit Cost Ratio 8.64 **VfM = extremely high**

2.1.2 Non-monetary Benefits

2.1.2.1 Environmental benefits

Transport is the largest contributor to UK domestic greenhouse gas emissions, responsible for 27% in 2019. Encouraging public transport use is a measure that can immediately cut transport's carbon emissions, help tackle chronic road congestion and free up road space. The Occupancy project can harness the power of 5G and video data learning to reduce overcrowding on public transport services, boost the traveller's experience and increase utilisation of bus services. This technology could drive a shift onto public transport and reduce utilisation of single occupancy vehicles, ultimately contributing to reducing transport emissions.

2.1.2.2 Social benefits

In a post-pandemic world, it is even more important to grow passenger confidence in public transport through managing occupancy numbers. The Occupancy technology offers the opportunity to align with passenger expectations of health and safety measures on public transport through enhanced accuracy of occupancy assessment, which provides better information to travellers and operators.

2.1.2.3 Productive benefits

During the project, 12 computer vision systems were designed, sourced, built and installed on FirstGroup buses operating in West Midlands. This trial provided evidence of approximately >94% object detection accuracy in real time of this technology, with the exception of some edge cases such as small children. While the project was initially delivered on buses, this technology is ready to be scaled up and extended to other services, such as tram and rail. Following this trial, the product has become more robust and ready for scaling and its TRL (technology readiness level) has gone up to TRL 7.

If service operators such as FirstGroup decide to go ahead with the further scaling of the product, some of the key opportunities would include providing different analytics that can be derived from passenger counting and location data. Not only does this technology support public transport utilisation and improve customer experiences, but can also improve operational costs for service providers through identification of the number of stops required, adjusting vehicle timing, deploying the right sized vehicles based on required capacity and where accessibility requirements are needed.

3 Passenger Management

3.1 Overall programme aims and benefits

The Passenger Management product is an artificial intelligence (AI) based real-time, micro-surveying tool which interprets customer feedback using a model that tags and detects context and sentiment. It identifies trends and key issues to be logged and then groups inputs into severity of feedback – generating alerts for situations where a customer may be in distress. Currently, public transport companies struggle to stay abreast with what is happening on their services and do not receive regular feedback. This means issues can often stay undetected, resulting in more customer complaints which compromise both trust among passengers and costs transport companies' money. The tool can be applied to tram, train and bus operators.

This project was led by Word Nerds with a total investment of £392,000 (£212,000 from public grant funding and an additional £180,000 from private investment).

Expected 5 Year Sales: £0.55m

Expected ROI: £0.34m

3.1.1 Monetary benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Use case benefits
Time saved for staff	6000 hours x 5 years = 30 000 hours saved for train operators from staff no longer having to monitor chat forums Value of time £11.73 per hour	£328,891
		Business benefits
Employee multiplier	20 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£9,224,658
Present value of benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£9,373, 550**
		Benefit Cost Ratio 23.91 VfM = extremely high

3.1.2 Non-monetary benefits

3.1.2.1 Environmental benefits

By improving the customer experience on public transport systems by being more attentive to customer feedback, there is likely to be an uptake in public transport use. Greater public transport use will help reduce emissions in the region as it shifts transport use away from high-carbon emitting vehicles. Reduced emissions help improve air quality by removing polluting emissions from the environment while providing additional health benefits to the population.

3.1.2.2 Social benefits

Many individuals and communities within given populations face barriers and constraints to using public transport that are often overlooked. For example, women often report feeling unsafe on public transport - a 2019 YouGov survey of London commuters found that 49% of women surveyed had been sexually assaulted on public transport - and people with disabilities often cite accessibility issues as a barrier to using more public transport. By ensuring transport user feedback is received and considered, transport operators are better able to listen to these concerns and act on them. This will enable users who may be hesitant to use more public transport to have their voices heard in a timely and constructive manner and feel more confident using public transport in the future.

This project found that 91% of test responses that should have triggered an alert were correctly identified by the AI and the average time between response submissions and alert receipt was 2 minutes. The use of 5G increased the average speed of upload by 35%.

3.1.2.3 Productivity benefits

By acting quickly on service disruption, maintenance issues and other problems happening in real-time on transport networks, delays and future maintenance problems can be reduced. Reduced delays give passengers productive hours of their day back and ensures transport operators can maximise efficiency. Staying ahead of maintenance issues by responding to technical problems when they arise can reduce the cost of future maintenance as it avoids problems developing further.

In addition, transport companies can save employee hours by automating part of the customer feedback process through its tagging and sorting ability – enabling a more productive use of staff time.

While responding to safety concerns is principally a benefit to potential victims of crime, it also benefits the transport operators by saving costs associated with regulator fines where customer complaints about safety have not been dealt with appropriately.

4 POLYTRACK

4.1 OVERALL PROGRAMME AIM AND BENEFITS

Delayed rail services often arise from difficulty with regular and swift maintenance - stuck junction points, missing track brackets and deflection of track leads can often lead to safety issues, reduced train speeds or service downtime. Railtrack monitoring is normally carried out through scheduled asset condition days during the year, undertaken by specialist vehicles and manual inspection. It requires workers to be on the track and is often dangerous and time intensive. Manual inspection is also difficult due to the sheer scale of train tracks across the region and country more broadly.

Polytrack aims to address these issues by providing insights for better informed track maintenance and renewals, leading to lower rail infrastructure costs. The sensors are fitted to trains or trams providing data signatures related to track degradation and performance using movements such as shock, accelerations and displacement. These data points alongside time, position and weather information enable train operators and maintenance to identify maintenance concerns and respond efficiently and swiftly to minimise service delays.

This project was led by ESR with a total investment of £269,000 (£139,000 from public grant funding and an additional £130,000 from private investment).

Expected 5 Year Sales: £0.57m

Expected ROI: £0.44m

4.1.1 Monetary Benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Use case benefits
Maintenance cost savings	£95 000 per year saved from early indications of problems on train lines.	£454,411
Time saved from reduced delays	5000 hours per year saved for train operators and passengers through early rectification of track issues Value of time £11.73 (TAG data) per hour over 5 years	£274,076
		Business benefits
Employee multiplier	5 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£2,306,165
Present Value of Benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£2,904, 651**
		Benefit Cost Ratio 10.80 VfM = extremely high

4.1.2 Non-monetary Benefits

4.1.2.1 Environmental benefits

Rail users often report frustration with delayed rail services – often without notice and with severe disruption to critical travel routes such as the commuter belt. By reducing service delays, the overall rail service delivered to passengers can be greatly improved with minimal disruption. This in turn will likely encourage more travellers to take up rail travel. By shifting to low-carbon emitting travel options such as rail service and away from private vehicle use, the region is likely to see a reduction in carbon emissions and traffic congestion. This provides an overall environmental benefit through a reduction in pollution and an increase in air quality.

4.1.2.2 Social benefits

Improvements in customer satisfaction arising from reduced rail service delays provides significant social benefits as it impacts quality of life and daily travel experiences. Additionally, lower fuel costs associated with a modal shift from private vehicle use to rail service use will provide cost savings to travellers – a particularly important issue as the energy crisis continues and hits low-income households the hardest. In addition, there are significant social and health benefits from more rail use including better air quality for all, particularly those with health conditions or who are pregnant, and it can help ensure safer streets for cyclists and pedestrians by reducing vehicles on the road.

4.1.2.3 Productivity benefits

Reduced maintenance costs arising from earlier track problem detection could provide significant financial savings to train operators. The sensors are relatively low cost – built from inexpensive, robust materials that can be used every day mounted on vehicles. By using the sensors, rail operators can detect problems earlier and avoid significant staff time being used on maintenance detection. This will lead to an overall reduction in operating costs – potentially saving train operators significant money.

There are also productivity benefits to be gained by rail users and their employers – rail service delays have significant knock-on effects when they impact commuters. By reducing overall service delays, the region is likely to see economic and productivity gains as people can reach places of employment and other local services on time and without disruption.

Following this trial, PolyTack has become more robust and its TRL (technology readiness level) has gone up to TRL6-7 from TRL 2-4.

5 PREDIKT

5.1 OVERALL PROGRAMME AIMS AND BENEFITS

Struggling urban centres and high streets cite parking as a significant challenge, with the stress associated with finding and paying for parking often linked to people avoiding local shops. Similarly, concentrated periods of peak commuter rush can mean that employees struggle to locate available on-street parking which in some cases could extend commute times by up to 20 minutes. On average, the time spent looking for limited parking in urban areas is approximately 6-8 minutes per day, adding to increasing congestion and tailpipe emissions. Predikt offered two potential technologies to detect available on street parking spaces. Both approaches used 5G services to relay data on available parking spaces to a central, aggregated service. The first of these technologies offered kerbside scanning using cameras in passing utility vehicles with GPS location tagging and the second was a predictive parking app ingesting real-time data from various sources. These technologies can save users fuel and money as well as reduce congestion and tailpipe emissions, particularly in urban areas.

This project was led by AppyWay with a total investment of £970,000 (£485,000 from public grant funding and an additional £485,000 from private investment).

Expected 5 Year Sales: £2.25m

Expected ROI: £1.67m

5.1.1 Monetary benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	2 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£922,466
		Use case benefits
Time saved from reduced delays	6,500 hours per year saved for individuals navigating peak times of travel Value of time £11.73 (TAG data) per hour over 5 years	£356,299
Present Value of Benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£793,765**
		Benefit Cost Ratio 0.82 VfM = low

5.1.2 Non-monetary benefits

5.1.2.1 Environmental benefits

The environmental consequences of parking manifest themselves in emissions of greenhouse gases and air pollutants occurring while cars are cruising for parking. Economic consequences are reflected in the time costs incurred while cruising for parking, and in time losses from traffic congestion caused by

cruising. Through reducing the time it takes to find appropriate parking spaces, there have been significant opportunities to reduce tailpipe emissions in the short term while car fleets transition to zero emission vehicles. Reducing our carbon emissions will improve overall air quality and benefit society as a whole.

5.1.2.2 Productivity benefits

Any increase in drivers on the road and increase in kerbside demand comes with an increase in congestion. The cars may be zero emissions but they still risk being stuck in traffic and increasing congestion as they cruise to find parking. The findings from the pre-pandemic 2019 Inrix Global Traffic Scorecard showed that on average, Brits waste 115 hours in congestion, costing the country £6.9 billion, an average of £894 per driver. Additionally, parking fines amount to approximately £1.2 billion per year.

This project provided evidence that this technology could reach between 86-92% on customer facing accuracy, looking at whether the AI can detect full bays where there are clearly spaces, just one space or whether the driver could have parked in a preferable bay. 85% of the time the prediction was also proven to be within an acceptable tolerance for the driver in real-world scenarios.

The ability to optimise parking data and provide drivers with accurate parking locations will save time and fuel. This will also benefit fleet operators and local authorities, allowing higher productivity and reduced enforcement infringement. Following this trial, the camera hardware's TRL (technology readiness level) has gone up to TRL 6 from TRL 3 and the AI solutions TRL has gone up to TRL 7 from TRL 1. The Predictive Availability is also now ready for active deployment at TRL 7, later in the year.

6 Road Sensors Network

6.1 Overall programme aims and benefits

The Road Sensors Network project began in January 2020 with clear objectives – to harness the benefits of 5G to generate better data collection of road users. By implementing sensors at key junctions on the West Midlands Key Route Road Network (KRN), Local Authorities and TfWM Regional Traffic Coordination Centre (RTCC) could better control traffic and congestion – a significant problem in the area. Deployment of road traffic monitoring sensors across junctions and locations in the West Midlands as well as Internet of Things (IoT) based emission measurement devices at locations in the region has provided new and critical data collection to significantly improve road management and emission control.

This project was led by Transport for West Midlands with a total investment of £9,748,814 (£4,670,000 from public grant funding and an additional £5,076,814 from private investment, which also includes reinvestment of £2,333,814 worth funding into further improving the computer software behind the Road Sensor network system by the company Vivacity as a result of the funding presented by WM5G).

6.1.1 Monetary benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee expenditure multiplier	2 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£922,466
		Use case benefits
Time saved for staff	3,600 hours per year saved for TfWM staff taking surveys of road traffic Value of time £11.73 (TAG data) per hour over 5 years	£197,335
Time saved from reduced congestion	29,576 hours per year saved for commuters due to improved traffic management Value of time £11.73 (TAG data) per hour over 5 years	£1,621,236
R&D expenditure multiplier	BEIS R&D multiplier 2.03 multiplied by the total PV expenditure on R&D[1] from Vivacity's reinvestment of funding provided by WM5G for the RSN cameras and software £2,333,814	£4,745,414
Operating cost savings	£300,000 per year saved from data analytics undertaken	£1,434,981
Carbon emission reduction	155,572 kg CO2e per year in carbon reduction from idle traffic 205.76 £/tonnes CO2e over 5 years	£348,349
Fuel savings	59,153 litres per year of saved fuel sitting idle Value of litre of fuel £1.02 (TAG data)	£105,305

[1]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/897462/macroeconomic-modelling-of-2-4-r-and-d-target.pdf

Present Value of Benefits	The sum of the value of environmental impacts (carbon savings), productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£4,298,272**
		Benefit Cost Ratio 0.44 VfM = low

A number of the congestion time savings, fuel cost savings, and environmental impacts are still yet to be realised and projections are difficult to predict until further data can be gathered to provide this analysis, however these are expected to be significant going into the future. Proof points have been provided to show how time can be saved from congestion and delays due to quicker identification of traffic build ups and a faster response from navigational systems to reroute traffic, however only 10% of the cameras had been installed at this point and hence more data needs to be consolidated before the full extent of this benefit can be determined.

There are also some proof points around data collection and savings that can be generated from the collection and leveraging of this data, but again it is restricted by the number of cameras that had been installed at the point of evaluation.

6.1.2 Non-monetary benefits

6.1.2.1 Environmental benefits

The data collected from the sensors will enable better road traffic management and ultimately, reductions in delays and congestion. As a result, fuel costs will be reduced as less fuel is used as motorists can avoid driving in start-stop traffic conditions. This is beneficial to the environment as it reduces carbon-emissions and improves air quality while being economically beneficial to people's cost of living - particularly those on lower-incomes.

In addition, road air quality sensors currently only send updates once a day with minimal coverage across the network. However, with 5G sensors, air quality data can be monitored on a real-time basis and utilised to construct a public health exposure model. Advanced navigation routines can then be deployed to direct high-carbon emitting vehicles to alternative low-polluting routes if limits in a certain area have been exceeded. An environmental benefit by improving air quality, and a health benefit to those in the region who can enjoy greater air quality – particularly those with health conditions and during pregnancy.

6.1.2.2 Social benefits

5G-enabled traffic management sends alerts to journey apps, traffic signs and V2X-equipped vehicles on upcoming traffic conditions. The high bandwidth speed of 5G means this information is fed to road users in real-time, as the conditions worsen, enabling them to act upon information surrounding adverse weather conditions or other poor traffic conditions quickly to avoid potential harm. Approximately 3% of traffic accidents in the West Midlands region are caused by weather conditions and a reduction in these types of accidents through this data will save road users from serious and sometimes fatal accidents.

In addition, pedestrian accidents can be avoided as data collected from live, video streams can identify vulnerable road user movements and behaviours– sending information to road traffic management about best options for spatial planning. Live stream of videos allows local authorities to pinpoint the

causes of accidents and mitigate them in a more targeted fashion. A benefit to pedestrians who can now travel more safely – particularly those who are most vulnerable and those travelling in vehicles who will experience fewer accidents with pedestrians.

The sensors also provide a significant benefit to police and emergency services and those who require their services. 5G live streaming enables traffic controllers to assess incidents in real-time by severity and allocate appropriate resources efficiently. Routing for emergency service vehicles can be then determined based on live road conditions. This reduces the response time of emergency services and enables those in need to be treated faster.

6.1.2.3 Productivity benefits

Improved road traffic management provides significant productivity benefit to the drivers themselves and their employers. Time spent sitting in delays and congestion can be avoided – giving motorists and public transport users time back in their day and reducing time spent in commutes, a benefit to employers and overall economic productivity.

Productivity benefits are expected to ramp up considerably in the coming years with the installation of the remaining road sensor network cameras. In addition, the increase in transport levels across the region back to pre-pandemic levels, and the utilisation of the sensors for the management of the increased traffic flow during the Birmingham Commonwealth Games in 2022. Traffic levels saw an increase in traffic flow of 22% when the Gold Coast held the Games in 2018.[2]

[2]https%3A%2F%2Fwww.goldcoastbulletin.com.au%2Fnews%2Ftraffic-reports%2Fnew-report-finds-gold-coast-traffic-will-increase-by-22-per-cent-during-commonwealth-games%2Fnews-story%2F225351b37fcf37d85fcd7f3b560c5165&memtype=anonymous&mode=premium

7 Transport Accessibility

7.1 Overall programme aims and benefits

Accessibility on public transport networks has long been a barrier for persons with impairments and disabilities. There are 2 million people in the UK with a visual impairment, many of whom do not use transport given the existing barriers to full accessibility and inclusion. Partially sighted people in the UK report a lack of confidence along station platforms as well as confidence concerns getting on and off the right vehicles, safely and at the right time. To help improve transport accessibility for people with visual impairments, GoMedia's App based phone guidance uses voice, haptics and large displays to enable users to better navigate stations and vehicles. By doing so, partially sighted transport users can achieve a greater level of independence and empowerment using public transport networks.

This project was led by Go Media with a total investment of £406,000 (£203,000 from public grant funding and an additional £203,000 from private investment).

Expected 5 Year Sales: £1.58m

Expected ROI: £1.37m

7.1.1 Monetary benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	3 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£1,383,699
Present value of benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£1,180,699**
		Benefit Cost Ratio 2.91 **VfM = very high**

7.1.2 Non-monetary benefits

7.1.2.1 Environmental benefits

By empowering partially sighted travellers to use public transport with more confidence and improved feelings of safety, the region can achieve an uptake in public transport from this segment of the population. By doing so, the overall region will benefit from a reduction in carbon emissions as more travellers switch to using public transport networks rather than high-carbon emitting vehicles. The reduction in private car usage will benefit the wider community with fewer cars on the road, less congestion and reduced air pollution.

7.1.2.2 Social benefits

This project has 50 test users including, 20 visually impaired users from TMB, 8 visually impaired users on WM5G trial and 18 non visually impaired users on WM5G trial. A survey of found that 94% of respondents were able to locate elements they couldn't locate before and 88% found the tool to be a 'completely useful tool for guidance within transportation'. 86% felt more positive about the transport operator because of the app. The individual benefits of the app to partially sighted users are clear – it provides them with a greater feeling of inclusion, positivity and accessibility when using public transport. As a result, 100% of users reported being in favour of extending this app on the full public transport network.

By enabling partially sighted transport users to better navigate existing public transport networks, commuter time can be reduced for those who may currently take longer to get between home and work due to accessibility obstacles. This benefits not only the individual commuter – giving them back time in their day – but also their employer.

7.1.2.3 Productivity benefits

By improving traveller independence for visually impaired passengers, there should be a reduction in time spent by transport staff responding to queries about navigating the network. While the trial found that visually impaired passengers are already confident, independent travellers, when rolled out to a much wider range of travellers, it's likely that staff on transport networks may be approached less for queries. Estimates suggest this could save 17% of queries - freeing up 3.4 hours a week for a full-time employee – equating to 163.2 hours a year.

8 Travel XR

8.1 Overall programme aims and benefits

The COVID-19 pandemic has had a significant impact on public transport – 70% of passengers who used public transport before the lockdown are no longer doing so. As the pandemic continues, the public needs reassuring that public transport is safe – however as it stands, some able-bodied people and medically vulnerable passengers are avoiding busy public transport hubs. To avoid these busy times and places, passengers need better information ahead of time to pre-plan journeys knowing where and when these hotspots of congestion may be. While operators are currently able to provide general guidance on routes around stations, they lack access to congestion and optimal passenger flow data. The Travel XR product helps tackle this issue by providing operators with accurate, real-time data enabling them to anticipate over-crowding and re-route passengers dynamically and efficiently.

This project was led by Briteyellow with a total investment of £964,000 (£482,000 from public grant funding and an additional £482,000 from private investment).

8.1.1 Monetary benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	10 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£4,612,329
Present value of benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£4,130,329**
		Benefit Cost Ratio 4.28 **VfM = very high**

8.1.2 Non-monetary benefits

8.1.2.1 Environmental benefits

By improving the passenger experience at busy transport hubs, Travel XR can improve uptake in public transport use. As more passengers feel safe and comfortable travelling through busy transport networks and hubs, they are likely to continue to use public transport, reducing emissions from private car usage. This reduction in emissions will improve air quality for all residents of the region and help drive progress in reaching net zero targets for the region and wider UK.

8.1.2.2 Social benefits

The COVID-19 pandemic has been difficult for everyone, but it has been particularly worrisome for those who are medically vulnerable. The risks of catching COVID-19 and other infections in busy transport networks can deter people from using public transport and for those with vulnerabilities, the

risks are even greater. Ensuring that public transport is safe is essential for moving forward out of the pandemic and can provide reassurance to all passengers that the risks of catching infections are low on public transport networks and in busy transport hubs.

Travel XR gives confidence to passengers to use public transport services as they can actively avoid congested hotspots through re-routing by transport staff. The data provided to operators will enable those feeling anxious about congestion to avoid points of conflict and find areas with better social distancing. This is critical to ensure full accessibility and inclusion for all passengers using public transport networks – particularly those with medical vulnerabilities or disabilities.

8.1.2.3 Productivity benefits

Travel XR can provide operational efficiency improvements for station operators by reducing congestion and ensuring passenger flow is optimised. The data received will enable operators to re-route passengers and ensure bottlenecks of congestion can be avoided. This will reduce delays caused by congestion and queues and keep people moving around transport hubs more efficiently. This also benefits passengers as it gives them time back in their day that they would have otherwise spent in delays and congestion. In addition, the data collected can better provide insights from passengers about how and when they travel – improving the information available to operators to make efficiency and productivity changes.

9 CURBS

9.1 Overall programme aims and benefits

Currently roads are monitored periodically, often using specialised vehicles to scan and assess road condition. Road assets can deteriorate rapidly or be damaged, which will be heightened through increasing levels of urbanisation and population growth. There are therefore benefits to increasingly regular assessments of road asset condition, which include proactive detection of potholes, identification of obstacles or obstructions and other damage. In addition, autonomous vehicles require good road assets, and so good detection of repair and maintenance needs is an enabler for any future adoption.

Vortex IoT introduced a Continuous Urban Scanner (CURBS), which is a specialist camera that can be retrofitted to existing vehicles and enables effective road management through utilising data to create a real-time 3D mapping and dynamic monitoring system. The trial involved attaching the camera to a fleet of 8 buses.

Data that can be monitored includes potholes, road markings, road signs, bus stops, lamp posts, traffic lights, rubbish, pavement degradation, kerbs, pedestrian spillage, detection of near-miss traffic incidents and safety assessments at crossings.

This project was led by Vortex IoT with a total investment of £618,000 (£309,000 from public grant funding and an additional £309,000 from private investment).

9.1.1 Monetary benefits

There is an expected reduction in operating costs for maintenance teams, and this proactive method of maintenance also expects to reduce maintenance related litigations which will further reduce costs.

Vortex IoT have recently been acquired and, as a result, are investing in significant employee growth.

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	38 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£17,526,851
Present value of benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£17,217,851**
		Benefit Cost Ratio **27.86** **VfM = extremely high**

9.1.2 Non-monetary benefits

9.1.2.1 Environmental benefits

Surface condition of roads is currently measured through specialised vehicles, which scan and survey the roads. They operate slowly, which can sometimes increase congestion around the vehicle. CURBS' cameras are retrofitted to existing vehicles which run at standard speeds, and therefore there may be less scanner-related incremental greenhouse gas emissions in the road monitoring process.

In March 2020 Kwikfit noted that road pothole damage costs car owners £1.25bn per annum and any replacement parts are likely to have embodied carbon impacts. The regular scanning of roads and proactive detection of potholes will likely reduce the car damage caused, and therefore the carbon impact of subsequent replacement of parts.

The CURBS tool also monitors rubbish, including fly tipping, and therefore waste that has been inappropriately disposed of can be identified and dealt with in an environmentally responsible manner. This is also a social benefit, as pedestrian experience may be improved.

Higher quality roads are required to ease any transition to autonomous vehicles and shared autonomous vehicles. Shared vehicles should reduce the number of cars on the road, reducing emissions and increasing efficiency of the vehicles being used.

Well maintained roads and visible road markings are likely to encourage road users to cycle, which would reduce emissions attributable to road users.

9.1.2.2 Social benefits

Birmingham City Council received 3,916 pothole enquiries in 2020 (2019: 3,967), demonstrating that road maintenance is an issue causing public discontent to the extent of engaging with the council. Proactive maintenance could mean a reduce in public enquiries, and also a more pleasant and comfortable experience for users of the roads, for example cyclists, cars, and some public transport.

CURBS can contribute towards increased safety for road users due to less unexpected pothole shocks, increased visibility of signs and white lines, and any ineffective traffic lights being promptly detected.

Pedestrians may experience a faster detection of broken streetlamps, improving safety at night, and also the monitoring of near-misses and pedestrian spillage onto roads could result in an increase in safety. Faster detection of kerb issues could also make pavements a better place for wheelchairs and prams, improving the accessibility of our road and pavement infrastructure.

As noted above, road users pay c.£1.25bn per annum in damage costs. A reduction in damage costs could result in many households having an increased amount of discretionary spend.

9.1.2.3 Productivity benefits

Better maintained roads may result in more efficient road usage, as cars will not need to vary speeds due to potholes or cracks. Ultimately this may lead to shorter journey times, and a more efficient usage of fuel.

If autonomous vehicles were a downstream impact of more proactively maintained roads, this could result in less time behind the wheel and therefore an increased amount of usable time in the day.

As noted above, wider monitoring of road issues could enable the effective and efficient allocation of Road Investment Strategy funds.

10 Capacity Manager

10.1 Overall programme aims and benefits

Congestion of the West Midlands road network is an extensive issue, with the root-cause identified as planned roadworks and incidents. While the root-cause is sometimes outside of control, the outcome in terms of traffic management and congestion is variable dependent on the operator experience and the tools available to them.

Capacity Manager is a Blacc product which uses 5G traffic sensing data for traffic management, providing an almost real-time view of the road capacity available and also the impact of roadworks, incidents and events. This data can inform operators and support their traffic management decisions. Data collation will enable modelling and scenario testing of congestion impacts of events, for example planned roadworks, and therefore more informed future traffic planning.

This project was led by Blacc with a total investment of £890,000 (£445,000 from public grant funding and an additional £445,000 from private investment).

10.1.1 Monetary benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	2 new permanent jobs created for Blacc ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£922,466
Present value of benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£477,466**
		Benefit Cost Ratio 0.54 VfM = very low

Motorists in Birmingham spend 9% of total journey time in traffic at an estimated cost to the economy of £407m per annum. Reducing this idle time could therefore be an economic benefit attributable to the project.

10.1.2 Non-monetary benefits

10.1.2.1 Environmental benefits

Capacity manager may enable better traffic management, and therefore ultimately reduce the amount of time spent by vehicles on the roads. This results in lower vehicle fuel consumption, particularly that driven by idle time and starting and stopping. This should reduce carbon-emissions due to road users, and also improve air quality for those in the impacted areas.

10.1.2.2 Social benefits

Motorists in Birmingham spend 9% of total journey time in traffic, and therefore reducing congestion on the roads could significantly reduce motorist journey times. This could drive an increase in leisure time, and therefore greater quality of life for those in the area.

As noted above better traffic management may result in a decrease in fuel consumption, and therefore lower fuel costs and more discretionary spend for motorists and businesses passing through the impacted areas.

Understanding road network capacity and the impact of traffic events is a driver behind more reliable estimates of journey time. This will therefore provide the social benefit of road user satisfaction, and also the productivity benefit of less time wasted as a result of allowing margins for increase journey time.

10.1.2.3 Productivity benefits

Capacity Manager enables the internal productivity benefit of local authorities and regional traffic centres achieving any goals in terms of effective and efficient traffic management.

Reducing the congestion is likely to be able to increase road capacity, and therefore if required, more users could access the roads at any given time. This increases the productivity of the road as an asset.

The artificial intelligence involved in Capacity Manager uses a continuous learning model, and therefore if the technology was to be rolled out beyond West Midlands, the learnings from the programme would result in more effective road congestion modelling from the outset of the rollout.

11 URBAN TOURISM 5.0 (UT5.0)

11.1 OVERALL PROGRAMME AIMS AND BENEFITS

Congestion and traffic around events and venues in urban locations can result in negative travel experiences for customers. Urban Tourism uses 5G technologies to deliver a 'Travel Assistant' service which is embedded into event management websites, integrating with booking systems. Using 5G-enabled sensors at stations and major venues combined with booking and travel information, it enables personalised integrated multi-modal door-to-door travel planning by merging identity governance technology with a unique, easily integrated 'Travel Assistant' user experience. In the post-pandemic world, this also supports and incentivises advance journey planning to and from venues and live events supporting the recovery of these industries.

The project ran for 18 months starting in September 2020 until February 2022, with the focus and test bed of the project being Coventry UK City of Culture 2021 events that started in April 2021. Urban Tourism have supported a BBC R1 event in March 2022 and has also been commissioned to support the Commonwealth Games this year.

This project was led by You Smart Thing (YST) with a total investment of £1,080,000 (£540,000 from public grant funding and an additional £540,000 from private investment).

11.1.1 Monetary Benefits

Type of benefit	PV Benefit calculation	Total PV benefit
		Business benefits
Employee multiplier	7 new permanent jobs created ONS composite employee multiplier 1.88 multiplied by the total PV expenditure on employee's salaries	£8,163,630
Present value of benefits	The sum of the value of productive impacts (time saved and employee expenditure multiplier) and financial impacts (cost and fuel savings) minus the total private investment.	**£7,623,630**
		Benefit Cost Ratio 7.06 **VfM = extremely high**

11.1.2 Non-monetary Benefits

11.1.2.1 Environmental benefits

This project identified that customers currently lack prior knowledge of routing or travel options which best serve their needs and enhance the travel experience, when travelling back and forth from venues and live events. Through integrating event management websites with travel booking systems, Urban Tourism can encourage uptake of public transport and in turn reduce harmful carbon emissions from single occupancy vehicles. The solution has shown the ability reduce journeys made to destinations by passenger cars

by over 30%. As a result, UT5.0 will contribute to reducing road network congestion and lowering the cultural sector's GHG and noise emissions. Analysing congestion and car park usage against CCC

github, City Metrics (System Spec.3.5) and DfT NTS data 2019, the YST travel assistant was also able to reduce road use and car park usage by ~84.3% by offering alternative sustainable options where users can register for updates and route details.

Additionally, in efforts to improve air quality and active travel, TfWM has been able to motivate 27% journey's to cycling and walking, indicating that there is still room for improvement. Using a date range covering the beta-trial periods September – December 2021 Urban Tourism calculated of all those who registered on the UT5.0 YST Travel Assistant, 26.3% chose to cycle, while 7.4% chose to walk. Increasing the TfWM's figure to 33.7%.

11.1.2.2 Social benefits

Through advance travelling planning and booking, customers can save time from choosing route or mode options through less congested areas. This technology was instrumented in three venues across Coventry including a train station, bus station and a park and ride. The live data could also be beneficial to transport operators who provide for 'last mile' routes to destinations and event organisers, as they can derive how travel behaviours may be influenced in order to drive a shift onto public transport and improve the overall visitor experience for event attendees.

During the alpha trial, 477 trips were made to Coventry regions using the Urban Tourism enabled travel assistant from August to September 2021. In the beta-test, UT5.0 hotspot content was made available on a number of YST client travel assistant deployments to drive visibility across multiple domains, including Coventry BID, Visit Coventry, Coventry City Council and Coventry City of Culture and a short survey was created and distributed to end-users to demonstrate the effectiveness and user buy-in of the product. The results of the usability questions concluded that 96% of users we able to access the hotspot material, while 78% of those sessions roughly loaded within 0 – 5 seconds, and no recorded failures. Additional findings showed that 35% of users show a significant buy-in, while 46% have a high level of interest, and only 17% are opposed to the concept.

11.1.2.3 Productive benefits

Through the provision of demand data, Urban Tourism could also support transport operators in identifying suitable transport demand models and aligning service timings with anticipated peak periods during live events. This could also provide venues with opportunities to improve car park utilisation and maximise revenue.

The YST platform has been able to offer extended capabilities as a result of this project, resulting in an increase in software as a service (SaaS) sales and the need for additional resources to deliver the product. YST has since hired seven more team members, and the commissioning of the YST product to supply travel planning capabilities to the Commonwealth Games has resulted in an additional 50 open vacancies to support the Travel Assistant's planning, testing, and delivery over the games time.

12 5G CAT

12.1 Overall programme aims and benefits

There are a number of cities and communities that do not have the funds to improve their urban transport with a rail-based transit system such as a tram. These costs are driven by high initial infrastructure costs and operating costs. The autonomous control system on Very Light Rail (VLR) Trams is a way to reduce not only the infrastructure cost but also the operating cost as the crew is the largest cost for operation.

The products being developed are a tram's autonomous control system "remote supervisor" and a door detection system that will be connected remotely via 5G and its control system monitored. The benefit being that there will be no need for drivers on the vehicle creating a large cost saving and a more efficient operation of the line.

This project was led by Westfield with a total investment of £530,000 (£215,000 from public grant funding and an additional £215,000 from private investment).

12.1.1 Monetary Benefits

This product requires additional funding which has not been fulfilled. Due to this lack of funding, there are no monetisable benefits to be realised over the next 5 years.

12.1.2 Non-monetary Benefits

20 UK cities have registered their interest with over 400 vehicles projected over the next 8-10 years, however the product still requires further maturity before tangible sales plans can be evaluated and as we are only measuring 5 years into the future the benefits are non-monetisable for the moment.

12.1.2.1 Environmental benefits

The improved accessibility to public transport will increase its use across regions, reducing the use of private vehicles and leading to a fall in carbon and poor air quality emissions. With over 20 UK cities interested in this product there could be substantial uptakes in public transport use and therefore large improvements in air quality across those regions.

The less evasive construction of VLRs will also produce environmental benefits, with less concrete needed and machinery leading to reduced carbon emissions and harmful pollutants in the construction process.

12.1.2.2 Social benefits

Improved transport accessibility from regions not able to previously be serviced by frequent public transport services that could be provided by the VLR technology in the future could improve opportunities for those that aren't able to afford private vehicles or for disabled individuals who wouldn't have previously been able to travel. This will level up communities as it will provide increased opportunities to those disadvantaged in society.

12.1.2.3 Productive benefits

The autonomous control system can improve the efficient deployment of tram and train operating staff, leading to savings in staff time and also the operating costs of transport operators as the autonomous vehicle will be connected remotely via 5G and its control system monitored.

13 5GER

13.1 Overall programme aims and benefits

The 5G Enabled Smart Train Station Rover (5GER) project aimed to develop the first UK 5G-enabled smart train station robot/rover through the state-of-the-art 5G technology and mobile robotics for the applications in large and complex railway stations like Birmingham New Street.

This product was to provide an intelligent, 5G connected, and highly secured robotics solution for station operators to improve their operational efficiency for cost savings, enhance passenger's experience and health protection, and disseminate real-time passenger information.

The aim was to integrate the 5G-enabled smart train station rover with the TrainFX well-developed next-generation Passenger Information System (PIS) through the 5G network. The data would then have been available before or during journeys and provide a feasibility demonstration of robotics in a real train station environment. The services would have included guidance to travelers for options of services available, tailored to individuals' needs.

This project was led by TrainFX with a total investment of £63,743 (£43,056 from public grant funding and an additional £20,687 from private investment).

13.1.1 Benefits

The 5GER project failed after the first quarter due to resource constraints by the lead consortium partner, TrainFX. This was caused by additional commercial projects awarded diverting the resources in TrainFX away from the grant funded project, effectively stopping overall progress despite the universities involved making good progress.

Due to this project failing so early into its inception no benefits were felt from this project and hence we have not included any benefits within this project summary.

14 Tram Safety

14.1 Overall programme aims and benefits

The current CCTV platform on trams does not provide live, targeted, pro-active information to the tram / train operator. Leading to security and accessibility issues on the transport network and revenue loss from inaccurate passenger counting.

The use of 5G data fed AI detects people and objects and provides safety and security improvements along with business information that is all delivered in real time. This allows for on board/off board analysis of CCTV and provide real time alerts for operators using existing CCTV and on-board connectivity (requires GPU/Control module).

This project was led by Digirail with a total investment of £184,000 (£92,000 from public grant funding and an additional £92,000 from private investment).

14.1.1 Monetary Benefits

This product requires additional funding which has not been fulfilled. Due to this lack of funding, there are no monetisable benefits to be realised over the next 5 years.

14.1.2 Non-monetary Benefits

If further funding was supplied to continue this product the following non-monetisable benefits could come to fruition.

14.1.2.1 Environmental benefits

Improved passenger counting on trams and trains could improve the planning and frequency of train and tram deployment, reducing the power needed and increasing the uptake of passengers on the service as it is a more enjoyable and convenient service. The uptake in public transport will reduce cars on the road, lowering air emissions from vehicles and the potential to reduce the frequency of trains and trams will also reduce emissions from the grid from a lower power requirement to run services.

14.1.2.2 Social benefits

Improved safety on trains and trams through reduced accidents and monitoring of the platforms, doors and sides of the carriage will reduce the number of accidents. An alert is sent to the driver when the tram is in motion to signal if an individual is within a certain vicinity of the tram that could cause them damage and is accurate 95% of the time, this will prevent accidents and improve the safety of travel.

The Passenger Assist system is designed to provide real time alerts to operational staff when passengers with additional needs (in this case wheelchairs) are alighting/disembarking the Tram. This increased monitoring will improve the service offering to those with a disability when travelling and level up society by providing these individuals with greater opportunities. This was accurate up to 78% of the time.

The FAST system is designed to alert staff when someone has left intentionally/accidentally their bag on the Tram. This system was accurate 75% of the time and would be used for security threats, improving the safety perception for all those using the transport system.

14.1.2.3 Productive benefits

The people counting technology was accurate 92% of the time, this will allow for improved route monitoring and journey and route planning. This will then improve the frequency accuracy of train and tram scheduling, saving commuters time and also time savings for staff operating lines that are no longer needed.

Improved accessibility from the Passenger Assist system will also provide time savings for all those using and operating the train and tram, as there will be less delays as individuals with disabilities are assisted onto the train as staff will ne notified in advance through external cameras to detect wheelchairs, prams, bikes, and suitcases using a trained CNN model and alerts sent to the mobile app for said detections to help with real time assistance.