

PURPOSE OF DOCUMENT

This document forms part of the project close-out for the MK5G Create Project.

VERSION CONTROL

Version	Date	Author	Comments
1.0	07/09/22	Paul Flowers	Published following internal review
2.0	16/10/22	Paul Flowers	Up-issue to include DCMS feedback

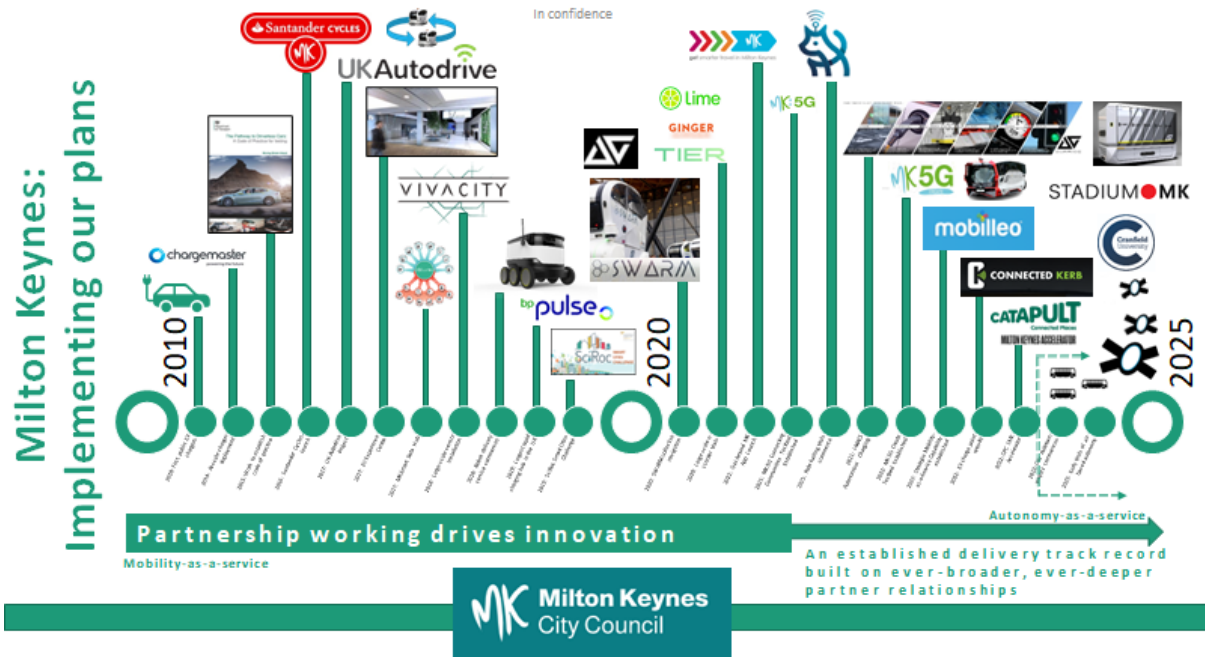
EXECUTIVE SUMMARY

MK5G Create was a complex, multi-year project, involving a large number of partners. Our intent was to validate new 5G and related technologies within a hospitality setting, with a view to improving visitor experience and enhancing the operations in and around Stadium:MK, with a view to deploying the technology city-wide to deliver better city and citizen experiences. Our overwhelming conclusion from delivering the project was that the technologies we deployed had matured to an extent that allowed their deployment more widely across the city. This includes the 5G infrastructure, but also covers the autonomous vehicle, drone and robot capabilities we deployed. The issues identified in earlier trials in terms of network connectivity and coverage, network security, network speed and network reliability were all addressed with the 5G technology, and in terms of vehicles, the level of safety, and ability to work autonomously, albeit with an onboard safety operator or through remote tele-operation had greatly improved. We still believe more work in this area is required, since to deliver a commercially-viable city-wide autonomous shuttle service, we anticipate the need to operate without an onboard safety operator, and more work is needed to satisfy ourselves that these levels of autonomy are safe and secure in a busy city centre environment using shared public highways. Additionally, we were also able to successfully demonstrate how our concept of a ‘connected stadium’ could be realised for greater benefit, and how we could successfully link previous unconnected and rich data sets to address real-world challenges. In addition to the technology aspects, we were able to demonstrate how an innovation-led, consortium-based project can come together to solve the problems and deliver the use cases we envisioned. Through the project, we have created a sustaining legacy upon which we plan to build for the future, and are actively working to further leverage the outputs and outcomes from the project for the greater good – for example through wider deployment of autonomous vehicles, robots and drones across the city, creating new enriched services for our citizens, visitors and in terms of event and city operations. Here we share more detail on what we achieved and our approach to delivering this project.



OUR AMBITION

As an ‘urban laboratory’ Milton Keynes has a rich heritage of down-streaming new technologies into real-world environments, this includes early deployment of electric vehicle charging infrastructure, use of advanced sensor networks to monitor traffic movement, use of delivery robots across the city and use a shared data exchange platform that connects previously disparate data sets together to provide improved insights into city operations. The diagram below shows how this project forms part of our overall plan for the city, in terms of improving travel and transport, and our forward-looking plans to introduce more ground- and air-based autonomy in the years to come.



As shown in the diagram above, part of our work has been to trial and pilot deployment of connected autonomous vehicles and other micro-mobility solutions such as rental scooters and cycles. Our overall Travel and Transport Vision, Blueprint and Plan aims to encourage our growing population to move to shared mobility solutions as part of our net zero ambitions.

We started work in this area more than 5 years ago, and whilst we found that people responded positively to the use of self-driving vehicles, the limitations in terms of connectivity and coverage meant a full service would not be viable. The MK5G Create project was designed to address these challenges, and included an ambition to build out a private 5G network to support deployment of vehicles and other technologies designed to enhance the experience and operation of the stadium complex, with the specific project objective being to test how 5G technologies could improve the citizen and visitor experience in and around Milton Keynes, as well as city operations in relation to travel and transport, and also to test how these technologies could enhance citizen and visitor experience, and operations within a major events and hospitality setting.

Milton Keynes had previously trialled the use of connected, autonomous vehicles and found that the technology was not mature enough to support large-scale, city-wide deployment, so this project was designed to re-visit this work and assess the opportunity using the latest technological advances. The specific use cases were as follows:

- Kerbside management: use of innovative technologies and technological solutions in order to facilitate ease of travel around the stadium complex
- Connected Autonomous Vehicles: use of latest generation connected, autonomous vehicles operating over a private 5G network to support travel around the stadium and beyond, and to assess safety and security implications as a pre-cursor to city-wide rollout
- Use of robotics technologies in a range of hospitality settings to provide an enhanced hospitality experience and to support wider operations
- Use of unmanned aerial vehicles (drones) to support stadium operations, e.g., safety and security, and provide entertainment, e.g., through drone-racing events within the stadium complex

The diagram below summarises why we felt Stadium:MK was the right location to carry out our work, and summarises the specific use cases we were seeking to solve.

About our work at Stadium MK



STADIUM MK



Why Stadium MK?

Premier, showcase location
Fully self-contained testbed
Mixed use, high footfall
Established travel hub
Enabling infrastructure

30,400 seat stadium
5,000 seat arena
304 hotel rooms
1,300 parking spaces

Our use cases

Kerbside management

- Ease of travel within the stadium area

Connected
Autonomous Vehicles

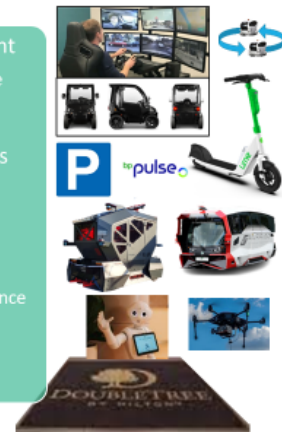
- Travelling around the stadium and beyond
- Safety and security

Robotics

- Enhanced hotel experience

Drones

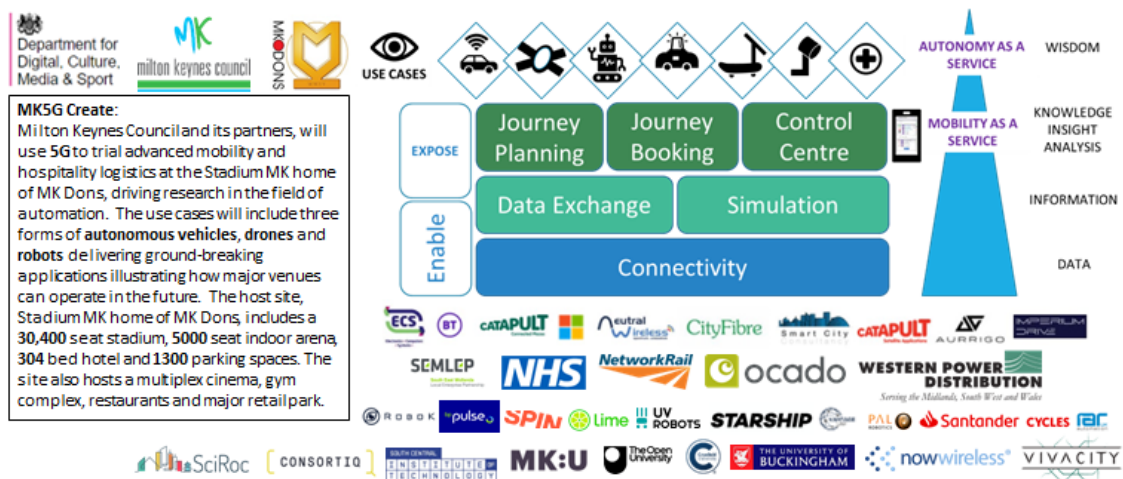
- Safety and security
- Entertainment



WHAT WE DID

To ensure success, we appointed an independent project lead, to drive the activities end-to-end, from initial bid to final delivery. Our approach was also highly collaborative, and whilst jointly led by the council and stadium teams, we worked quickly to establish a strong consortium that comprised a mix of public-sector organisations, large corporations, and small- and medium- enterprises as well as academic, governmental and other local and regional stakeholders covering both technical and business domains. Key for us was to identify win-win opportunities for all those involved, and we worked with a range of organisations to understand potential appetite, capability and fit. Through this process, we worked to design the scope, define and develop the associated use cases, that would deliver and demonstrate a compelling vision of the future, galvanising the team around a shared vision and ambition. To support the team in their delivery, we created a strategic advisory board sitting alongside DCMS, comprising a set of decision-makers from both the public- and private-sector, including representation from Network Rail, SEMLEP, the NHS, Cranfield University, Ocado's Chief Data Scientist, a visiting Professor from BT, as well as a set of professional advisors including the Satellite Applications Catapult, who could provide a wide-range of insights to support and guide the work, linking it to wider strategic initiatives at a regional or national level. The diagram below summarises the project, including the scope we defined, a breakdown of the different components of the project and an overview of the range of organisations involved in the project.

MK5G Create: project overview



Overall, the project was designed to use 5G to trial advanced mobility and hospitality logistics to drive research in the field of automation. As well as providing the base connectivity, we developed a data exchange and simulation capability, with a suite of linked applications including journey planning, journey booking and control centre applications for both the council and the stadium to support the use cases outlined earlier. Our aim was to advance our mobility-as-a-service capability, and ultimately build a full autonomy-as-a-service solution and as part of the project we were also able to show how we could connect data in a way that enabled and allowed insight into new information, exposing this to a wider community who were able to visualise and analyse this in a way that created new opportunities.

As well as the partner organisations, the team involved other organisations who supported us in an advisory capacity, supplied additional services, or helped us with our wider outreach and engagement activities. This included representation from Network Rail and Ocado on our Advisory Board, and engagement with MK:U and other educational institutions as part of our outreach work. You can find out more about the collaborative approach we took on the project in our separately published Collaboration paper.

WHAT WE DELIVERED

The project itself used 5G to trial advanced mobility and hospitality logistics, driving research in the field of automation. The use cases included three forms of autonomous vehicles, drones and robots and delivered ground-breaking applications illustrating how major venues could fundamentally change the way they operate in the future and how travel and transport could be improved for citizens and visitors. This included a number of use cases

which resulted in the deployment of robots, drones, autonomous and driverless vehicles, and other shared modes of transport, as well as AI-enhanced CCTV camera capability, and the underlying 5G connectivity. In addition, the project delivered a comprehensive ‘Data Exchange’ to manage 100’s of connected devices and other data feeds, as well as suite of software applications to enhance the visitor experience, through joined up journey planning and operational dashboards to support stadium and council operations. One of the key parts of the Milton Keynes vision is to ensure seamless integration of the different travel and transport options, and key to this was the delivery of a truly multi-modal journey planner, designed to address limitations seen with other journey planning applications, namely:

- Existing journey planning tools tend to focus on traditional modes of transport: walk, cycle, drive; *Our solution introduces new and emergent transportation options that can be added ‘on-demand’ and tailored specifically for Milton Keynes*
- For emergent modes of transport, no unified view exists and users’ needs to access individual apps; *Our solution provides a neighbourhood visualisation capability, creating a unified view in a way that encourages open navigation and exploration*
- Existing journey planning tools provide limited ability to engage the citizen in the world around them; *Our solution creates the ability to deliver a highly personalised and localised experience to better connect the citizen with Milton Keynes*
- Existing journey planning tools are focused solely on the citizen; *Our solution is to present aggregated information in a way that creates new opportunities for Milton Keynes Council and stadium and arena operations*

The diagram below shows the rich user functionality delivered in the journey planning application:

What's different: for people



Through this work, we were also able to provide enhanced operational capabilities to support the stadium in their day-to-day operations and event management and the city in their management of the overall transport system, capabilities described as “game changing” by the end users of these dashboards. Examples of the dashboards and visualisation capabilities delivered as part of the project are shown in the diagram below:

What's different: operations



Other specific deliverables included:

- Delivery of a standalone 5G network to support the new environment
- Use of drones to undertake structural surveys around the stadium
- Hospitality robots operating re-stock, refreshment delivery, and bell-boy services
- Linking CCTV and AI capabilities to show live space-by-space utilisation of car parking
- Traffic-flow monitoring via connected sensors at stadium ingress and egress points
- Launch of an autonomous 10-seater shuttle connecting rail stations and the stadium
- Use of autonomous pods and driverless cars around the stadium complex and beyond
- A showcase event for VIPs and other stakeholders to see all aspects of delivery

Some of these aspects are shown in the diagram below, which includes use of autonomous and driverless vehicles, drones and robots in and around the stadium.



Finally, the diagram below shows how we built and realised our vision for the ‘connected stadium’. As well as connecting data from buses, scooters, cycles and the autonomous and driverless vehicles, we added 30 connected cameras in and around the stadium and used sensors at each of the entry and exit points. The sensors automatically detect a range of different vehicle types into and out of the stadium, allowing us to monitor how busy each junction and the stadium as a whole is. The cameras allow us to see a 360-degree view of the stadium, but we also use the camera feeds to assess car park occupancy using AI-overlays. Collectively this, and other information is displayed as part of the stadium

dashboard, using within the operations centre to aid management of the complex both day-to-day and during matches and other events.

The connected stadium

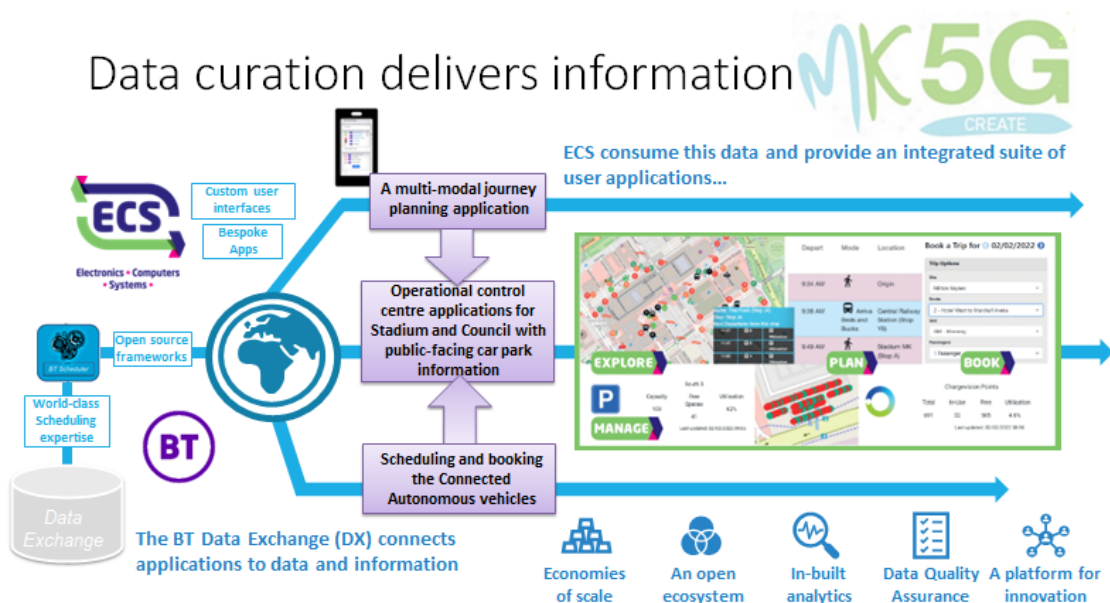


As part of the project, we developed a set of metrics to assess the benefits of the work we undertook. We worked to identify a series of measures that could both (a) reflect the degree to which we had achieved our ambitions for the project, and (b) based on measures that were available, repeatable and linked to previous trial outcomes. A separate, more detailed benefits report is available, but our aim was to agree a broad set of measures that tested the technology evolution since our earlier trials, establishing baselines and targets and then undertaking measurement within set windows to assess performance. Measures included:

- Accuracy of reporting car parking usage and utilisation using the IP-enabled camera feeds and the Artificial Intelligence overlays that were used to auto-detect space occupancy
- The safety of the autonomous and tele-operated vehicles, measuring the number of safety interventions observed against the number of miles driven
- Vehicle operability, assessed through both the levels of vehicle autonomy observed at the stadium and the vehicle reliability (as determined by fault rate)
- As assessment of the ability to use 5G connectivity to overcome issues observed previously in relation to coverage and connectivity, e.g., to support real-time vehicle communications etc.
- Ability of robots to undertake different activities within a hospitality setting

WHAT IMPACT WE HAD

Using the results we gathered, our conclusions from the project were that the 5G, vehicle and other technology had matured to the point that these could be considered for deployment more widely. The introduction of the 5G network, with its highly secure, highly available network characteristics overcame the issues with connecting autonomous vehicles observed in our earlier trials. We were also able to demonstrate far greater levels of accuracy in terms of AI-based car park space availability management than those we had seen in earlier experimentation in the city centre when technology was less mature. We found that through connecting different data sources together, we were also able to create a unique, distinctive and rich visitor and operator experience that supported the Women’s Euro Events at the stadium, and that we plan to deploy more widely across the city and beyond. The stadium operations team have an ‘on a page’ view that provides new and additional data in terms of what is happening around the stadium that is linked to existing data sources such as gate and turnstile data – together this information allows data to guide on-the-day decisions in terms of managing the inward and outward flow of people into the complex, and enabling post-event reviews to take place using the data that has been gathered. The stadium also has a single view of all camera feeds, which allows quick assessments of events as they happen on the ground to support any emergency response. For visitors, the experience included new options, e.g., for VIPs to park and travel on the autonomous pods to their seats and for hotel visitors to travel to different stops around the complex, e.g., to restaurants, shops or local rail stations. Citizens and visitors can also plan their journeys, e.g., having the ability to check on scooter or electric vehicle charger capability through a single application, and linking their overall journey planning to the availability of these services. The use of connected data sets was central to the success of the project and an example of how we approached this to deliver rich functionality to a range of users is summarised in the diagram below.



THE ISSUES WE OVERCAME

A detailed set of lessons has been developed as part of project review and closure. The key themes are summarised here for completeness. The project was undertaken at a time of the COVID-19 pandemic which did impact the way in which the project teams had to work. Whilst we did make adaptations, in part some of the issues we experienced were exacerbated by the need to work remotely or because of the wider pandemic impacts.

- Delays in equipment delivery impacted the critical path; delays arose due to the use of leading-edge technology, but supply chains were also impacted as a result of the COVID-19 pandemic; key learning is to plan these deliveries much earlier in the plan providing a degree of contingency should issues arise
- 5G License application process was complex and resulted in additional work over an extended period and delays in securing licenses; key learning is to undertake a full application process walkthrough as part of mobilisation with close working with licensing authority throughout the process
- Interworking issues: due to the leading-edge nature of the equipment and the complexity of the integration some issues arose when attempting to integrate the hardware, software and firmware components, these were overcome through close team-working, but the key learning is to consider the use of a staging environment earlier in the project to pilot the work and undertake inter-working and inter-operability testing earlier in the project in order to de-risk the overall plan
- On-the-ground logistics and design; managing the local delivery, installation and commissioning of the different components and equipment on the ground proved challenging at times, with some deployment issues identified late in the process; use of surveys, audits and development of detailed implementation packs, with

end-to-end ownership, accountability and responsibility agreed up-front would improve these aspects

- Ways of working: whilst collaboration tools were in place from the start of the project, and these did help overcome the challenges associated with COVID-19, the project would undoubtedly have benefitted from more face-to-face meetings and co-location during key delivery and deployment phases, something that was simply not possible during the height of the COVID-19 pandemic and whilst the associated public health measures, such as lockdown or ‘work from home’ guidance was in place

WHAT WE LEARNED

In terms of learning, we found our collaborative approach was able to create far greater opportunities and deliver far greater capabilities than the individual contributions alone, for example through integrating advanced onboard networking capabilities into the vehicles themselves and through connecting different and disparate data sets together. The rich partner mix we built also allowed us to deliver the core components of the project with confidence, but also to create space for innovation in new and emergent areas and we created an environment where partners worked together to overcome issues and deliver ever better outcomes, including early establishment of co-location facilities. By establishing an end-to-end lead for the work, we were able to manage the work in a way that assured success, despite the complexity of the project, in terms of its scope, scale, ambition and the challenges associated with the emergent nature of the technology and the wide partner base.

As outlined earlier, a critical enabler was the ability to connect previously disparate datasets, and as well as addressing this through technology, another factor critical to success was the early establishment of data sharing agreements with all data providers. A full set of lessons, including specific technical learning in terms of 5G and other equipment is available.

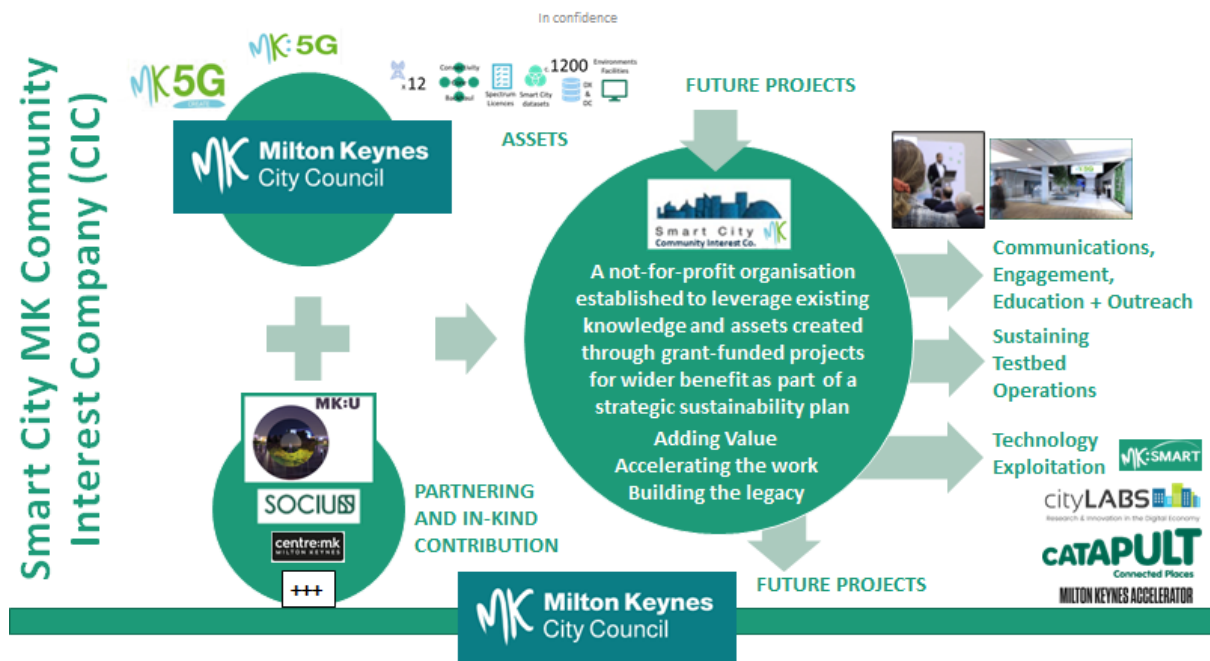
As well as the focus on the project deliverables and the wider collaboration work, we also worked to establish a strong suite of engagement, communications, outreach and sustain activities, to ensure that the value created by the project was available more broadly and beyond the life of the project itself. More information on this aspect, including detail on our strategic sustainability plan can be found in our separately published Sustainability paper, but in essence, our engagement, communications, outreach and sustain approach was as follows:

- We developed a communications and media strategy to engage as wider audience as possible using a range of channels, running a number of targeted events, locally and nationally with stakeholders, decision-makers, local education, and other interested

parties such as UEFA and the FA, culminating in a project Exposition in the Marshall Arena and around Stadium:MK to promote and showcase the project, with attendance from across Government, Education and Industry and enabling visitors to meet our partners and experience the new capabilities we had delivered first-hand

- In terms of sustainability, our strategic plan for sustainability is centred on the creation of a not-for-profit Community Interest Company – Smart City MK CIC – that will maintain the 5G and other testbed infrastructure on behalf of Milton Keynes Council both for the benefit of both future projects, and the wider community and enabling access to other resources, including a new Smart City Experience Centre in centre:mk, to showcase the work and an operational presence within MK:U’s campus facility at Bouverie House in Central Milton Keynes that provides a state-of-the-art demonstration and showcase environment
- We are also facilitating SME access to the testbed and wider city infrastructure through the establishment of a council-funded ‘Milton Keynes Accelerator’ programme delivered in conjunction with the Connected Places catapult and other industry partners. This is a significant council investment and the accelerator is intended to support SMEs in speeding up the launch of new and innovative technologies in the areas such as data analytics, 5G and artificial intelligence

The diagram below summarises the different components of the sustain plan:



In conclusion, we have seen our approach to sustaining the project and embedding communications, engagement, outreach and sustain into the project from the start as well

as our work to develop a more strategic sustainability approach as the project itself concludes has enabled the work from the project to continue for the ongoing benefit of the city, citizens and partners, supporting the plans we have for the future, and leveraging the investment we have collectively made in the project. We would certainly adopt and embed these approaches on future projects of this nature and would commend the model we have adopted to other innovation-led projects.

Through the work of the project, we have been able to develop a blueprint for future success and wider deployment for the benefit not only of Milton Keynes, but for other cities and organisations seeking to deploy 5G and related technologies into travel, transport and other sectors, and we are actively pursuing these opportunities as a result, developing and building on the work we have undertaken (see the diagram below for more detail). The work we have undertaken has shaped and informed our strategic vision and approach, and presented us and our partners with new opportunities which we will also pursue.



In terms of ongoing application of the work, we continue to work with the stadium to enhance the operational dashboard, and plan to incorporate new features, such as cameras and sensors to monitor queue length, integration of aggregated mobile handset data to understand 'busyness' around the complex, and linking the real-time data back to the simulation tools to support the creation of a true digital twin capability. We also intend to extend the stadium capabilities to other hospitality venues within Milton Keynes, for example, the National Bowl.

In terms of the car parking applications, we intend to deploy the solution in and around Milton Keynes, and are looking at how we could deploy both centrally in the public car parks and also at park and ride sites, again linking this to the overall mobility-as-a-service platform the city has built.

Our plan is also to extend the use of connected, autonomous vehicles in the city centre and across the city, and our vision is for passenger shuttles to operate in and around the city centre, connecting key locations and integrating with other travel and transport hubs in order to provide a differentiated passenger experience, reduce carbon emissions and ease congestion.

In terms of robotics, we intend to establish a central robotics operations capability that will enable a range of venues to offer robot-based delivery or service capabilities, but without the need to undertake significant up-front investment.

As we extend out from the stadium complex and across the city, the scale of the network and associated services will cover a much greater area, introduce many more users to the systems and require a step-change in the number of sensors we have deployed. It is our view that we can scale the work undertaken at the stadium to support this wider vision and plan.

THE IMPORTANCE OF COLLABORATION

A key part of our approach on this project was to embed collaboration from the start, going far beyond the core set of partners and collaborating with a wide range of other project contributors, with the local community, with other local organisations and stakeholders and with other projects within the 5G programme. A full report on our approach to collaboration is also available, but we summarise our key insights and learning here also.

Our learning is that there are many rich opportunities to collaborate on innovation-led projects such as this – both at a local level and beyond, and that networks exist to facilitate these collaborations which can prove beneficial to all. By taking an open approach to collaboration, and seeking out potential opportunities to collaborate can enrich the experience for not only the project and the overall programme, but also for our partners and stakeholders, with many positive benefits for all involved. By way of example, our cross-consortia collaboration with 5G VISTA meant that the team were able to complete their trials, in line with their project plans in a real-world stadium environment. For the MK5G Create project, we were able to enrich our events through inclusion of drone racing and wider 5G VISTA engagement and for Stadium:MK, the 5G VISTA engagement opened up the potential for new and different ways for fans to engage in matches and events, leading to new use cases for our 5G testbed and our connected stadium. The joint outcomes underscored our approach and commitment to collaborating, one which we plan to take

forward as part of our future project work. Beyond the 5G VISTA work, we have also been able to build enriched capabilities and developed sustaining relationships with many of the other organisations we collaborated with as part of the MK5G Create project.

DISCUSSION ON FINDINGS

This project was part of a wider strategic drive within Milton Keynes to transform travel and transport city-wide, and builds on a long-standing programme of work which is progressively delivering the cities vision for shared, sustainable mobility, designed to address the forward-looking transportation challenges as the city continues to grow on an unprecedented scale, and aligned to the cities Net Zero ambitions (Carbon Neutral by 2030, Carbon Negative by 2050). Given the growth anticipated, we know that that congestion (and therefore) carbon levels would increase to a point where they would become unacceptable, so it is our intention to commence deployment of fully-autonomous, fully-electric, connected, autonomous shuttle services into the city to provide alternative transport solutions for our citizens and visitors. This project was an important step on that journey, since it proved that the technology had matured to the point that such a service would be viable, both operationally and commercially, a much-improved position over the earlier trials we had run. To this end, as part of our 2050 Strategy, we have incorporated the proposed shuttle service – the City Autotram - into our wider strategic planning, identified the lines we would operate, the sequence in which we would deploy, and developed a commercial and business model that would sustainably support the ongoing operation of the service using a range of business and technology partners. As part of our strategy, we are adopting a Transit-oriented Development model, a design approach that is widely recognised in Europe and the US, but that is less familiar as a development concept within the UK. Transit-oriented development is typically defined as more compact development within easy walking distance of public transport stations or stops that contains a mix of activity generating uses – housing, jobs, shops, restaurants, community and housing facilities. Crucially, Transit-oriented Development is not just development near public transport, it is also development that increases ‘location efficiency’ so people can walk, bike and take public transport, that boosts public transport patronage and minimised the impact of traffic and provides a rich mix of housing, jobs, shopping and recreational choices that provides value for the public- and private-sectors, and for both new and existing residents creates a sense of community and place. Although part of our strategic vision, this project helped us to validate the approach and provided confidence that this approach was right for us as part of our strategic planning for 2050. As we commence the new services, we will continue to learn, adapt and evolve our findings in order that we can tune and optimise the technological, operational, business and commercial models to support its growth and evolution both within Milton Keynes and across the UK. Our vision for the service is encapsulated in the design drawing below, and we would be happy to share our learning from the work as we move forward. Whilst subject to funding, we plan to commence the work on the central loop – the first phase of the City Autotram network - in January 2023.



In terms of the other use cases, we deployed as part of the project, we are exploring how we might introduce robotic and drone services into the city to compliment those that already exist. Potential robotics use cases include the operation of a robot delivery service that incorporates multiple robotics and service providers with robotic operations undertaken at a number of hospitality sites around the city, but under the central control of a robotics operations centre. This could, for example, enable individual hotels, restaurants, coffee shops, or retail and leisure centres to offer robotics services without the need to establish their own operations instead commissioning 'robots-as-a-service'. In terms of unmanned aerial vehicles (drones), we are actively exploring how we could create a testbed to demonstrate how drones could be safely operated within a smart city environment, connecting ground and air to provide enhanced and highly differentiated services. As part of this, we are also planning to work collaboratively with the Civil Aviation Authority and other regulatory bodies and user groups to develop a legislative framework that would support such innovation, and clarify the role of local authorities in such regulatory approval. Ultimately, we see drones as providing a range of services, both for the public- and private-sector, including express delivery services, but also in terms of rapid emergency response or efficient and effective movement of medical supplies between hospitals. Our vision is one that encompasses not only a fully integrated, shared transport strategy, creating a connected city that offers a range of multi-model transport options and linking traditional modes of transport like cars, buses and trains with new and emergent transport options such as rental scooters, cycles, autonomous and self-driving vehicles hailed like taxi cabs today and with all types of transport linked seamlessly through a single journey planning application, localised to meet the needs of our citizens and businesses, but one that also anticipates drone and robot deployments undertaking activities as diverse as health and safety, security, delivery, hospitality etc. As we move from a mobility-as-a-service offering to a true autonomy-as-a-service offering within the city, it is our view that as well as transforming the citizen experience, such a revolution will change the way we plan, build and operate our transport connections, services and infrastructure across the city, creating a more efficient, more effective, more productive and more connected city environment than ever before. We hope our vision, ambition and model for deployment can be adopted more

widely by cities and towns across the UK and we would be happy to share our learning and approach with other places interested in developing a similar approach or using the range of technologies we have deployed to deliver new services.